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Translating User Needs into Product Design for Disabled People: a Study of Wheelchairs

by

Marcelo Márcio Soares

A DOCTORAL THESIS

Submitted in partial fulfilment of the requirements for the award of Doctor in Philosophy of the Loughborough University

September, 1998

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CONTAINS PULLOUTS
"There is as much difference between us and ourselves as between us and others."

Michel de Montaigne
(1533-1592)
This thesis is dedicated to:

Teresa and Julia,
who guided me in the past, who taught me to respect others as I would myself, and the meaning of the word "dignity".

Nalva,
who guides me in the present, who is by my side through everything, who teaches me the real meaning of the word "love".

Gabriel,
who I am guiding for the future and hopefully teaching the meaning of "dignity" and "love" in the same way that I was taught.
I express my gratitude for

The side by side,
hand in hand,

encouragement,
support,
cooperation,
solidarity,
and assistance.

To:

God, who inspired me, guided me and gave me His practical support even when I was unaware of His presence.

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To all, I am indeed thankful.
Abstract

The challenge in design is to provide users of products with what they really want. Thus, matching customer needs with product characteristics is crucial. Customers are those best able to express their own needs. However, disabled people may find it difficult to articulate what their needs are. The aim of this thesis is to produce a design method in which the "voice of the disabled customer" can be translated into product requirements in a form which designers and manufacturers can use. Wheelchairs were chosen as the product for study.

A review of the literature on ergonomics and product design, potentially and actually, applicable to mobility for the disabled is given. There is a discussion of issues including consumer needs, product requirements, consumer satisfaction and products for the disabled.

A major part of the thesis is concerned with surveys of wheelchair designers, prescribers (physiotherapists and occupational therapists), rehabilitation engineers, users, and carers on their views on wheelchair design, assessment, prescription and use. It was found that most designers in the survey carried out all phases of the design process based on their assumptions about users' expectations and needs, and not including the users', carers' or prescribers' requirements in the design process. Deficiencies in wheelchair design were recognised by all stakeholders involved in the processes of prescription, supply and use.

In addition, many prescribers, rehabilitation engineers, users and carers reported weaknesses in the processes of assessment and prescription. Prescribers and rehabilitation engineers agreed unanimously that such weaknesses have implications for wheelchair design. A surprisingly high number of users and carers rated their own wheelchairs, or the wheelchair belonging to the person whom they assisted, as less than good for certain vital characteristics such as safety, reliability, suitability, manoeuvrability and comfort. Almost all prescribers, rehabilitation engineers, users and carers reported that they had never been involved in wheelchair design with a company that produces wheelchairs for a large market.

A user-centred design method for wheelchair design, based on the findings of the literature review and the survey, is presented and the suitability of the method is investigated using the opinions of several wheelchair designers. The thesis concludes with lessons which have been learned and suggestions made for further research.
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Part 1:
BACKGROUND

- Introduction
- A review of the literature on ergonomics and product design for the disabled
Chapter 1: Introduction

1.1 Importance of the study

The brief fictitious story below allows this introductory chapter to highlight some aspects of the relationship between products and their use that will be covered in the rest of this thesis.

Mrs. Waters is in her late twenties. Although she has a moderate disability, she has used a wheelchair since her childhood. She looks after her home and husband, and brings up her young son. Mrs. Waters lives in a very comfortable house, but has a number of complaints concerning her wheelchair, the objects and environments surrounding her:

"... In a typical morning of my daily life, she says, I wake up at about half past six in the morning. I make breakfast using a fancy new microwave oven that my husband gave me as a present a couple of weeks ago. It was meant to do everything you could ever want to do with a microwave, but it is too complicated to use. My husband (who's a doctor) said he wouldn't to go near it. Fortunately I've memorised some settings and just ignore the rest. After doing a bit of housework, like doing some washing, playing with my son and sometimes doing some gardening, I go out in my car to the playground, shopping or visit some friends or relatives. It is quite hard to manage get my son in the back seat, fasten his seat belt while I am using my wheelchair. I also have problems transferring myself from my wheelchair to the driving seat. The wheelchair is quite large and heavy, and doesn't give me enough mobility. I store the wheelchair using a special lift to accommodate it on the roof of the car.

I have fifteen-hours of assistance a week to help me with shopping and housework, but I am absolutely convinced that this weekly cost could be avoided if I could manage most of domestic activities myself using appropriate equipment and user-friendly products. Unfortunately I live in a very unfriendly environment. My district is very hilly and has virtually no dropped kerbs. The shops, local Leisure Centre and other public places where I used to go on a daily/weekly basis have restricted spaces, steep slopes and cambers or steps which block the way. Neither of the two...
manuals or the powered wheelchair that I've got can overcome these problems easily. I usually need the help of somebody else.

None of my wheelchairs have the height of the seat adjustable. So, I have difficulty seeing and reaching things at most levels when I am shopping, doing housework and playing with my toddler son. I can't get my powered wheelchair into my car because it is very heavy and cumbersome. So, it is also difficult to carry and control my son and shopping from the manual wheelchair because I have to use both my hands for propulsion. My husband complains of pain in his back when pushing my chair because he is very tall and the wheelchair push-handles are not adjustable. So, the chair forces him to bend forward when pushing me.

I am definitely not very happy with my chairs. I would like a fashionable chair. A chair that represents my personality with a nice design, including bright colours. One that when people see me will make them think 'there's a lady who can do things herself and if she needs help she'll ask for it'. With my grey, ugly, cumbersome chairs I find people are always saying 'do you need help with this or do you need help with that'. I find this so frustrating. If I need help I'll ask for it. I need a powerful wheelchair that should be lightweight, highly manoeuvrable, reliable and which permits me to cope with lifts, corridors, crowded places, and the boot of my car. These are not the characteristics of the wheelchairs that I actually own".

This fictitious story has all the ingredients of reality and corresponds with the experiences of many, if not most, disabled people. Unfortunately it also corresponds with the experiences of non-disabled people using ordinary consumer products. Whether products are designed for the non-disabled or disabled, or both, they should be able to be used in a functional, pleasurable and safe way. This is not what is happening in an extremely vast number of cases.

If we consider the products used in our daily activities it is not hard to find ones which fail to satisfy our needs, e.g. the correct programming of a microwave oven or a video cassette recorder; the use of the remote control of a new and sophisticated TV set; the adjustment of self-service photocopier machines and so forth. Dealing with such products may often result in error and frustration. Additionally, design failures in everyday products make a considerable contribution to the number of accidents at home. According to data from The Department of Trade and Industry's Home Accident Surveillance Systems (Home Accident Surveillance Systems - HASS, 1998) accidents in the home are associated with over 4000 deaths per year in the United Kingdom. It is estimated that almost three million people seek medical attention annually as a result of non-fatal home accidents.
Nowadays, a vast number of consumer products have reached a level of complexity and difficulty which is usually not well accepted by users. Although the degree of technological sophistication has produced a strong appeal from the point of view of market strategy, it can produce serious frustration for the user. These products lack maturity and the functional content that the user really needs. Customers are no longer satisfied with products that meet only technological criteria, they desire products that they can use in a safe, efficient, comfortable and pleasurable way.

It is broadly known that designers usually design products with some presumptions about the consumers' expectations, and how they will behave with the products. The designers usually believe that the products suitable for themselves will be equally suitable for others. Consequently, such presumptions usually consider that the users of everyday objects are healthy adults, in very good perceptual, cognitive, emotional and physical condition.

Designers who use the above mentioned approach (and the quality of the products in the market place indicates that the majority of them design in such a way) will probably fail twice. Firstly, they will fail because they are expert in the use of the products that they themselves design, forgetting to consider the needs, abilities and requirements of a representative sample of consumers. Secondly, they will fail because they also forget that in addition to an extremely diverse population of consumers - in terms of physical and mental capabilities - there are a considerable number of people whose physical and mental capabilities are below (and sometimes well below) the level of the majority of the population. Not considering the largest range of users' requirements in the design of the product is to condemn the users with limited capabilities to have difficulties which can lead to failure, misuse and accidents. In fact, if consumer products - which are almost exclusively designed to be used by a population with full physical and mental capabilities - are responsible for a large number of home accidents, what happens when these products are used by those with lower levels of physical and/or mental skills?

Products can be designed to meet the needs of a broader spectrum of users without diminishing their value. In fact, the design of products suitable for the great majority, irrespective of age, sex or physical ability, is a question of respect for human dignity. In a society with a truly human dimension, the man-machine interface must be such that first and foremost, it will not damage the user's health, but will also respect diversities in the same way that correct town-planning eliminates structural barriers (Dahlin et al., 1994).

Although disabled users may have diminished sensory or motor capabilities, limited cognitive ability, or emotional difficulties, their needs are, in general, similar to those of the able-bodied
population. So, apart from the needs related to their own disabilities, disabled users have needs in terms of aspirations, uniqueness, values and status which should be reflected in the products that they use. Dissatisfactions in using the product will occur if the products do not fully meet their needs (e.g. Mrs. Waters' new microwave oven in the fictional story in the beginning of this chapter). This applies to both kinds of products: those products for general use of the entire population and those designed to meet the needs of disabled people in particular.

The freedom to choose, one of the most precious - and fragile - human freedoms, is responsible for the sense of independence. Independence depends on choice. The quality of lives that people experience as they perform daily activities relates directly to the number and types of choices available. This, of course, depends critically on economic, social, and political conditions. When people, especially disabled people, are faced with a hostile physical environmental conditions and unfriendly products and furniture in their homes that limit choices, there will be frustrations, and a reduction in pleasure, independence and quality of life.

Disabled people have difficulties using those consumer products designed for the general use of the majority of the population. As previously mentioned, a significant number of those products do not perform their functions, as expected, when in use by able-bodied users. They are not also designed considering the part of the population which has limited physical and/or mental abilities. To overcome these difficulties, disabled people sometimes carry out adaptations to enable these products to meet their needs. So, the everyday products used by the disabled population have been designed following two approaches: a) by adaptation of existing products and the development of special aids and b) by taking into account the limitations and capabilities of the disabled in the design of new products.

Products designed specifically for disabled people, as will be discussed in detail in the next chapter, frequently derive from a medical perspective. This limited approach does not consider a number of aspects such as people's aspirations, uniqueness, values, status and lifestyle, which are regularly considered in the design of products for the able-bodied population. Many of these products stigmatise the user and often increase the user's sense of disability and dependence. In view of this, many products designed for the disabled may be rejected and abandoned even though they are of clinical benefit.

The importance of developing products for all segments of the population that focus on customer needs should be a priority area in the product design process. So, to match customer needs with product characteristics is the first, and maybe the most important, phase during the
product development process. The customer's role involves more than simple consultation, but rather includes using the customer as a partner in the design and development process (Gardiner and Rothwell, 1985). One fundamental question arises from this point. How can customer needs be translated into specifications - particularly ergonomic specifications - in the several phases of product development?

Undoubtedly, customers are the best people to say what their needs are. But, it appears that the "voice of the disabled consumer" is not being heard by designers and not by those responsible for prescribing the products that they will use. If the assumption that the "voice of the disabled consumer" is not being heard is confirmed, there will be a need to investigate: a) the relationship between user needs and product requirements from an ergonomics point-of-view; b) the current methods that designers use to design the product; c) the process of product prescription and the involvement of prescribers in the design process; and d) the views of users and their carers on the product they use and what demands they make in design.

This project is directed to a specific product. The wheelchair was the chosen product because a) it is a product used by more than half a million persons in the United Kingdom; b) it is expected to improve users' quality of life; c) it has a strong social appeal; and c) it seems not to provide full consumer satisfaction.

Wheelchairs all too frequently, have been designed for fabrication in small quantities, made of tubular steel, bent and welded, and consequently expensive to be manufactured. The use of modern manufacturing high-volume techniques, a user-centred design and the use of marketing techniques in wheelchair distribution and sales seems to be far from current practice.

Business in the wheelchair market seems to be very attractive. In the United Kingdom the price of privately purchased wheelchairs starts at £180 (standard self-propelled wheelchairs), and increases according to their quality up to £8200 (outdoor electrical wheelchair). There are more than 500,000 people using wheelchairs in the U.K. According to the Royal College of Physicians of London (1995), the National Health Service (N.H.S.) issued 172,224 manual wheelchairs in 1991/92 at a cost of £43.7 millions. In the United States, as cited in Cooper et al. (1997), data from the National Center for Health Statistics show that there were 1,411,000 wheelchair users in 1992. Cooper (1995), states that there are over 20 million people worldwide relying on wheelchairs as their primary source of mobility. The size of such a market is sufficient to justify the use of mass-manufacturing techniques and marketing strategies in the production, sale and distribution of wheelchairs.
It is certain that designing, prescribing and providing a wheelchair for a disabled person is always a compromise. The wheelchair needs to be comfortable and safe, yet also light and manoeuvrable. A large number of wheelchair users are not only dependent upon them for moving themselves about. They are also dependent upon relatives, friends or a paid carer to take them out or to help them to transfer in and out of the wheelchair. Thus it is as important to consider the needs of the carer as well as the needs of the wheelchair user.

This complex situation seems not to have been adequately addressed by wheelchair designers. This has resulted in recognisable design problems in a number of wheelchairs currently available from the N.H.S. or the private market. According to Cooper et al. (1997), the wheelchair has, for most of its history, been a design that has segregated instead of integrated its users.

A number of questions arise from the considerations made above. They are presented below.

1.2 Main questions to be addressed

Generic questions

It was previously mentioned that mismatches occur between the design and use of products for both the able-bodied and disabled populations. It is currently accepted that usability is essential to guarantee the quality of products. Ergonomics plays an important role in guaranteeing usability and, consequently, better performance for consumer products in general and products for the disabled in particular. A number of questions need to be addressed which might be in relation to any consumer product, including wheelchair. They included the following questions (under the heading of General, Disabled, Wheelchairs and Methods. These are all addressed in the Literature Review.

General

- What can be considered an ergonomically well-designed product?
- What is the role of ergonomics and product design in product development?
- How does the product design process work?
- What is the role of users in the product design process?
- What can be defined as consumer needs and user requirements?
- What are consumer satisfaction and dissatisfaction?
Chapter 1: Introduction

**Disabled**

- How do the needs of the disabled differ from those of the whole population?
- How have the needs of the disabled been met in the design of consumer products?
- Is it possible to design products and devices so that they are usable by both able bodied and the disabled?
- What are the special characteristics of products for the disabled?

**Wheelchairs**

- What different sorts of wheelchairs are currently available?
- What are the main components of wheelchairs?
- What is involved in the design of wheelchairs?
- What sources of literature are available to help designers in the design of wheelchairs?
- What is the role of standards in the design of wheelchairs?

**Methods**

There are several methods in industrial design, engineering and manufacturing which are used to guarantee the competitiveness and acceptability of consumer products. It is important to investigate the current methods in design and manufacture of products, which are based on user needs, to answer the questions below.

- What is product quality and how does it affect the manufacturing process?
- What is the role of consumer satisfaction in product development?
- What methods, based on user needs, are available in design and manufacture?

Considering that there are some methods, based on user needs, in the design and manufacturing of products, it is important to examine if in the field of wheelchair design these methods are used effectively. This involves investigating the process of wheelchair design, prescription and use which are examined through field studies reported in this thesis.

**Specific questions**

One of the main question to be addressed in this thesis is if there is any involvement of wheelchair users, carers and prescribers in the design process. The answer to this question will reveal if the "voice of the disabled consumer" is being heard throughout the design process.
The first step in finding an answer to this question is to approach wheelchair designers. It would involve answers being sought to the following questions:

- How do they approach the design of wheelchairs?
- How do they meet both physical and ergonomics specifications?
- What kind of data do they need from users?

The answer to these questions will be vital in revealing whether what is regarded as good practice in the design process is actually implemented by wheelchair designers and manufacturers.

To check on the assumption that users are not heard in the design process, a survey with others stakeholders - prescribers, users and carers - will be carried out. Approaching the stakeholders who are or should be involved in the process of wheelchair design, prescription and use will produce answers to the following questions:

**Questions to wheelchair prescribers**

- Have they had any training to enable them to assess users and to prescribe wheelchairs for them?
- Can they identify from their experience any weaknesses in the process by which clients are assessed and wheelchairs prescribed?
- Have they ever been involved in wheelchair design?

**Questions to wheelchair users**

- Which wheelchairs do they use and how did they obtain them?
- For how long do they use their wheelchairs indoors and/or outdoors?
- Do they feel that their needs and abilities were taken into consideration during the process of assessment and prescription?
- How do they rate the importance of design characteristics of wheelchairs such as safety, robustness, stability, aesthetics, comfort, portability, adjustability?
- Is their impression that the wheelchairs provided by the N.H.S. and the private market are designed taking into account the range of needs of disabled people?
- Have they ever been involved in wheelchair design?
Questions to carers

- Can they identify any weaknesses in the prescription process for the wheelchair belonging to the wheelchair user whom they assist?
- How do they rate the importance of design characteristics of wheelchairs such as safety, robustness, stability, aesthetics, comfort, portability, adjustability?
- Is their impression that the wheelchairs provided by the N.H.S. and private market are designed taking into account the range of needs of disabled people?
- Have they ever been involved in wheelchair design?

The answer to the questions above will define if there is any involvement of the stakeholders in the design process, to what extent this occurs, or, in the case of a negative answer, if they would like to be involved in the wheelchair design process and how. This point will be the core of a user-centred method for wheelchair design.

After the production of the user-centred method for wheelchair design (if necessary), some questions will arise such as:

- How a sample of designers evaluate the new method?
- What are the weaknesses and stronger points in the new method?
- Is the method acceptable, useful and usable?

1.3 Aim and organisation of the thesis

Aim

The main objective of this thesis is to investigate how user needs can be translated into the design of products for the disabled population. This involves the study of three major points: a) the relationship between user needs and product requirements from an ergonomics point-of-view; b) the process of design, prescription and use of wheelchairs and c) the involvement of prescribers and users in the process of wheelchair design. This thesis is focused on ergonomics and product design. So, aspects related to manufacturing, costs and marketing are not discussed in depth.
Organisation

The thesis is organised into four parts:

- **Part One - Background**, includes Chapters 1 and 2. It contains the introductory section and the major review of the literature.

- **Part Two - Field Studies**, includes Chapters 3, 4 and 5. It involves examining current practice in wheelchair design, supply and prescription, and use. It is important to mention that the results of the field studies are indicative, rather than definitive.

- **Part Three - A Design Method for Wheelchair Production**, includes Chapter 6. It shows the steps involved in the user-centred design method and investigates its suitability.

- **Part Four - Outcomes**, includes Chapter 7. It brings together a number of major issues of the research in order to formulate the conclusions, recommendations, and areas for further studies.

The overall structure and contents of the thesis are described below.

**Part One - Background**

- **Chapter 1**, the Introduction, establishes the context of the work and defines the problem area which the research will address. The objectives of the research are also identified, and the scope of the work is described.

- **Chapter 2** provides a comprehensive review of the literature involving aspects related to
  a) the production of ergonomically well designed products;
  b) issues of ergonomics and product design related to product development;
  c) the product design process,
  d) the importance of considering user needs;
  e) aspects related to the design of products for the disabled person and the wheelchair use in particular; and
  f) the methods, based on user needs, currently available in the design and manufacture products.
  This chapter ends with a summary of the major findings.
Part Two - Field Studies

- Chapter 3 aims to identify the process of wheelchair design. It investigates a) the designers' views of ergonomics in the design process; b) product development in companies which produce products on a small and large scale; c) the involvement of users in the design process; d) the use of literature and standards; and e) aspects related to production, product evaluation and marketing.
Chapter 2: A review of the literature on ergonomics and product design for the disabled

2.1 Looking for ergonomically well designed products

Nowadays, consumer products, no matter how complex, are supposed to make work and leisure easier. In everyday life users have to interact with thousands of consumer products and they expect that these products will perform their activities in a quick, safe, efficient and pleasant way. However, the many frustrations and errors that usually occur in handling a product show that this is not always the case. If this fact is true for consumer products in general, it also applies to those products used by the disabled population.

In this thesis, consumer products are defined as those goods and services which are used by the general public (Cushman and Rosenberg, 1991; Hunter, 1992; Kreifeldt, 1984). Cushman and Rosenberg (1991), and Wilson (1983) state that consumer products fall into two categories: a) those used for the satisfaction of more general human wants and needs and b) those designed for specialised groups, such as children and disabled people. They are usually used in or around the home, in a residential or social setting rather than in a workplace environment. Users of these kinds of products are often untrained, unskilled, and unsupervised; may be any age, of either sex, or any physical condition; and may have widely varying educational, cultural, or economic backgrounds. Consumer products (e.g. television) may change the habits and behaviour of the society in which they are used. Consumers do not buy some consumer products just because of their inherent utility but also because of the subjective values attached to them.

Consumer products, including a number of products for the disabled population, are sometimes designed having in view just sales and profits. For this reason a lot of products with poor design are regularly introduced in the market without taking into account the real consumer's needs. Thimbleby (1991), in *The Ergonomics Society Lecture*, said that "We are all faced with poor design" (p. 1269) and Norman (1988) concluded "Alas, poor design..."
predominates" (p. 2). Some of these products have a short life in the market due to consumer rejection, weakness before competitors or litigation.

Stearn and Galer (1990) point out that it is at the consumer level that the effects of good and bad ergonomics, and consequently good and bad design, are most acutely felt.

The increase of competitiveness in modern consumer markets has stimulated companies to look for quality. Reducing losses during product manufacturing, reducing warranty claims, reducing product development cycle time and improving user satisfaction are objectives of quality. According to Griffin and Hauser (1993), quality improvements lead to greater profitability. The concept of quality adopted in this thesis is user-based and is taken from Juran and Gryna (1988). They say that "quality consists of those product features which meet the needs of customers and thereby provide product satisfaction" (p. 2.2). The number of companies in the market of products for disabled people is a clue that competitiveness in this market is also growing. So, the necessity to deliver quality to customer, either able-bodied or disabled, is no longer an optional, but a question of survival for companies. Indeed quality is based on the customer.

Ergonomics plays an important role in guaranteeing usability and, consequently, better performance for consumer products in general, and products for the disabled in particular. While ergonomics has become a widely known and respected discipline, the use of ergonomics attributes (such as ease of use, ease of learning, high productivity, comfort, safety, and adaptability) are largely used by the media as elements that will add quality to products and be perceived by users as necessary for the fulfilment of their needs. The appeal of an "ergonomic design" of the product seems to have merit in the eyes of the advertisers (Leonard and Digby, 1992).

Ergonomics is a discipline that has the human being as its principal focus. It is useful, in its practice, to collect data concerning the body's structure, functioning, behaviour and the environment where work is carried out. So, ergonomics uses data largely derived from the fields of anatomy, physiology, psychology and engineering. Consequently, ergonomics also uses methods originally concerned with the acquisition and application of these data. Ergonomics, and more specifically product ergonomics (the area of study which aims systematically to analyse artefacts and their interaction with humans), can be considered as a fundamental tool in looking for quality in product design.

Ergonomically well designed products are those which consider a wide variety of users - the everyday user, the curious, old people, children, male, female, the healthy or unhealthy -
offering safety, efficiency, comfort and aesthetic satisfaction, under normal conditions of use, and under foreseeable conditions of misuse. Although, in general, not all user satisfaction factors are necessarily ergonomic, ergonomically well designed products aim to guarantee user satisfaction.

However, it is a sad truth in design and marketing that in most cases styling of products comes first, technology second and ergonomics only third (Dirken, 1990). There is an unnecessary conflict between ergonomics and aesthetics (Andre and Segal, 1994). Norman (1988) argues that:

"If everyday design were ruled by aesthetics, life might be more pleasing to the eye but less comfortable; if ruled by usability, it might be more comfortable but uglier. If cost or ease of manufacture dominated, products might not be attractive, functional, or durable. Clearly, each consideration has its place. Trouble occurs when one dominates all the others." (p. 151)

The balance between these attributes will distinguish good and bad designs and, consequently, ergonomically well designed products. Of course, this balance might be established based on the context created by the user, the task, the environment, and the culture. And also, in the case of products for the disabled independent living (called henceforth "products for independent living"), the user's medical and therapeutic needs. Designing implies a continuous choice between several solutions. The designer, for example, deals with conflicting interests between aesthetics and usability.

Norman (op.cit.) has drawn attention to the fact that well-designed products, as opposed to poorly designed products, are easy to interpret and understand because they contain visible clues to their operation. The author refers to the principle *Form follows Function* that states products should indicate how and for what they were intended to be used. Certainly, this principle guides most product ergonomic design. Meanwhile, it is important to observe that the introduction of new technologies - particularly with the use of electronics and microelectronics components - and therefore the possibility to produce miniaturised products, requires a new form of user interface - the medium of communication between the user and the product. Bernsen (1989) says that the idea that form follows function is basic to industrial design, but this not only means that the design must fulfil the 'given' function of the product: design is also a continuous interpretation of what function is about, of setting new functional demands and meeting them.

The concept of *Form follows Function* is largely used in most of the products for independent living. The design of such products is generally initiated by the medical and
therapy professions in response to a medical and physical need. Therefore, the design is frequently guided to solve the problem within the context of the users' disability rather than design a product which take into account the users' aspirations, desires and lifestyle as well as fulfilling its functional role. According to Barber (1996), the result of this approach is that the design generally leads to a solution that is centred more towards a piece of technical apparatus than towards a complete consumer product. This is absolutely true and easily observed in those products for independent living: designers often prioritises the medical and therapeutic requirements and forget the users needs in terms of their personal aspirations such as uniqueness, values and status.

In looking for ergonomically well designed products for both able-bodied and disabled people, ergonomics and product design perform distinct, but not incompatible, roles. Both fields of activities are responsible for defining the user interface. The role of ergonomics and product design will be discussed in the next sub-chapter.

2.2 Ergonomics and Product Design: bridging the gap

Designing well is not easy. Product development is a risky business because it involves, with a high cost, many areas of the company. To have a reasonable chance of success it should meet user requirements fully. The design process can reduce the risk and/or cost of product failure (Kreifeldt, 1984). The product design process will be discussed in the next sub-chapter.

Ergonomics is a technology supported by scientific data; product design is the process of creating new and improved products for the use of people and manufacturing aims to produce valuable and marketable goods. Ergonomics has clearly strong inputs from science while Product Design is assisted by aesthetic inputs. Manufacturers, on the other side, are mainly interested in the performance of the product in the market in terms of the quantity of goods sold and the profit made.

Usually the three groups have different approaches. Ergonomists focus mainly on product usability and safety, employing empirical methodologies to achieve this purpose. Product designers endeavour to seek a balance between form, value and appearance of products, relying on experience, intuition and creativity to achieve this end. Manufacturers are more pragmatic having to fight for survival in a extremely competitive environment. According to Grandjean (1984) and Wood (1990), ergonomists have long criticised designers for producing unsafe products, failing to emphasise the importance of usability and the lack of scientific
reasoning; on the other hand, designers have said that ergonomic data are presented in a format or language unsuitable for designers. They represent an obstruction to design creativity. Finally, manufacturers, broadly speaking, prefer to consider facts realistically instead of what they regard as the idealistic approach of ergonomists and designers.

The sometimes uneasy relationship between designers and ergonomists has been mentioned by several authors (Abeni, 1988; Brown and Wier, 1982; Grandjean, 1984; Lingaard, 1989; Pheasant, 1996; Ryan, 1987b; Smith, 1987; Ward, 1990, 1992; Wood, 1990). According to Meyer (1989) and Ward (1990) one of the main areas of conflict between product designers and ergonomists arises from the emphasis that each group places on the methodology employed to reach its objectives. Designers are always expected to be innovators, always looking for a different solution to a problem, by the way they work in a creative and intuitive manner, trying out a number of solutions and evaluating them later. They usually approach the problems using what is called "lateral thinking", which means the use of creative thinking to solve problems avoiding a too logical and too constrained to conventional frames of reference approach. Ergonomists, although they sometimes use creative techniques, tend to analyse the problem and develop formulae or experiments that will deliver what they regard as the answer or best solution.

Although the previously cited authors recognise friction between ergonomics and product design, they are unanimous when they affirm that this disagreement needs to be overcome. The successful integration of ergonomics and product design will produce an aesthetically pleasing and functionally superior product (Kreifeldt and Hill, 1976). They are both directed to the same end: fulfilling user satisfaction and producing a successful product. Harris (1990) claims that because the world markets comprise a multitude of anthropomorphic, behavioural and cultural differences, ergonomics knowledge is vital in helping design to meet the challenge of product development for a global market. So, the integration of ergonomics and product design seems to be particularly relevant when designing products which claim to be used for both the able-bodied and the disabled population.

Ergonomics plays three traditional roles in product development: a) user needs identification, b) user interface design and c) test and evaluation. In fulfilment of these roles ergonomists have appropriate procedures: a) identifying user needs and preferences, and verifying how effectively these needs and preferences are met and b) measuring how effectively user needs are being met in a form that enables them to provide this feedback at various stages in the product development cycle (Fisher, 1991). In reality it is important to know what knowledge is required to meet ergonomics requirements and what knowledge is in reality used by the designer.
After having conducted interviews with four designers, Mossel and Christiaans (1991) stated that aesthetic aspects are often so important for the designer that they can overrule the constructive, managerial and ergonomic aspects. The study carried out by the authors leads to the following conclusions: a) most of the ergonomic information is taken from existing products, designers presumptions or by the clients themselves; b) no users trials are done; tests are carried out by the designers on themselves; c) ergonomic aspects have a low priority compared with aesthetic and managerial aspects. Although this study only encompassed the work of four designers, the results must be considered as a source of reflection for the role of ergonomics in design activities. With the except of the conclusion stated in the previous item (b), the remainder are similar to those found in the survey described later in Chapter 3 of this thesis (Approaching the Process of Wheelchair Design).

Pheasant (1986) argues that designers need to move from the idea that ergonomics is a matter of applying data and to develop a totally user-centered approach. A user-centered design is a method to develop products based on the needs and interests of the user, with an emphasis on making products usable and understandable. A user-centered method for wheelchair design is the major core of this thesis.

Norman (1988) defines two fundamental psychological principles of design to make products understandable and usable: a) providing a good conceptual model and b) making things visible.

Analysing the first one, it is important to observe that a good conceptual model allows us to predict the effects of our actions. A mental model can be defined as a conceptual representation of a system and/or task formed by user, based on previous experience as well as on current observation, that provides predictive and explanatory power to the user in understanding the system and guides the interaction with it (Christiaans, 1989; Norman, 1983 and Wilson and Rutherford, 1989). People form mental models through experience, training, and instruction. According to Norman (1988) the conceptual model can be seen in three perspectives: a) the design model, the designer's conceptual model; b) the user's model, the mental model developed through interaction with the system and c) the system image, the visible part of the device, results from the product itself (including documentation, instructions, and labels). Gelderblom and Christiaans (1992) have drawn attention to the fact that in operating unfamiliar consumer products the user can have great difficulties in finding the appropriate way to handle the product and that these difficulties can be of a cognitive nature. This is because Mrs. Waters, in the fictional story in the introductory chapter, had so many difficulties to operate her new microwave oven. The designer expects the user's model...
to be identical to the design model. Problems arise when designers do not interact directly with users and assume that this premise is always true. Problems are also more serious when the products are used by disabled users, mainly those suffering from cognitive impairments. Designers are not typical users. On the contrary, they become so expert in using the object they have designed that they cannot believe that anyone else might have problems handling this product. Thimbleby (1991) states, in a sarcastic way, that designers tend to design things for themselves to use and fool themselves that there is no problem with the design and suppose the fault is entirely the user's for not thinking.

The second principle introduced by Norman (1988) is based on the visibility concept: the correct parts must be visible, and they must convey the correct message. The author says that when simple things need pictures, labels, or instructions, the design has failed. A typical consequence of reduced visibility is reduced feedback. On account of modern technology interacting has also been changed. In the past controls of several products were designed to be held, turned, pulled and pushed, today they are designed to be merely touched. Consequently, a new form of feedback has been produced: information once afforded by the movements of hands and fingers, the depression of buttons and switches, or the sound of clicks and cranks is either absent or has been replaced by the ubiquitous "beep" (Andre and Segal, 1994). On one hand, this modern technology permits a greater freedom to the designer to explore a product's aesthetic and formal aspects. On the other hand the designers must pay more attention when reducing feedback. For example, a minimal tactile and kinaesthetic feedback when pressing a key of a mobile phone, or a control of an electrical wheelchair or scooter, when driving, could result in the necessity of users looking at the phone or the control and away from the road.

Eason (1984) states that usability is determined by the specific user, the specific kind of task, and the specific environment in which the interaction takes place. In this way usability is a variable that may change with time.

The principles mentioned above make the users the focal point of the design. A so-called, user-centered design approach claims to focus on users in all stages of product development. The need to focus on the customer and end user at all stages of development, obtaining relevant, meaningful and applicable feedback and accurate market research which facilitates forecasts of future customer requirements were almost universally commended by respondents of a survey carried out by Glen and Lord (1996) with 113 companies involved in the development of new products within the U.K. medical device industry.

The unique way to carry out a design process centered on the user is using ergonomics beginning early in the product development process. Such an approach has been supported by
several authors (Cushman and Rosenberg, 1991; Harris, 1990; Kreifeldt, 1984, 1992; Ward, 1990). The use of rapid prototyping and usability testing have enabled ergonomics to provide input earlier and to work iteratively, making design problems easier to identify and design recommendations easier to support. The term "usability", here, is related both to obtaining user requirements prior to initiating the product design process and in the early stage of design, as well as, to evaluating prototypes and products that have already been built (Mital and Anand, 1992). Rapid prototyping (or desktop manufacturing - DTM) is the producing of a three-dimensional prototype from a CAD model. According to Richardson and Poulson (1996), the user-centred approaches along with the use of rapid prototyping techniques for the development of assistive technology products are increasingly being reported.

Ungari (1995) states that three new waves are washing over the product designer activity in America today: CAID (computer-aided industrial design), task analysis and usability testing. An interesting point to be observed is that the latter two have been in the domain of ergonomics for several years. These tools represent a new potential for designers and ergonomists to jointly create products that have the users as a fundamental part of the process rather than a recipient of it. Ungari (op. cit.) concludes: industrial design can now become a user-centered process based on user interactivity instead of on user adaptability. The product design process and a user-centred approach will be discussed in the next section.

### 2.3 The product design process

According to Kotler (as cited in Smith, 1994):

"A product is anything that can be offered to a market for attention, acquisition, use or consumption that might satisfy a want or need. It includes physical objects, services, persons, places, organizations and ideas." (p. 57)

Additionally, product development (which comprises the product design process) is the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product (Ulrich and Eppinger, 1995). This concept is applicable for products aimed at the able-bodied and the disabled user. Smith (op.cit.) ponders that although products or services satisfy a want or a need, some market segments - car manufacturers, for example - do not sell the product itself, they sell the skills of their workforce, self-esteem, comfort, safety and style. The product is part of the medium through
which these needs and wants are satisfied. So, concludes the author, the customer is essential
to help manufacturers answer the question "what do you provide?".

According to Barber (1996), marketing strategies are used extensively to supply products and
services that appeal to varying types of people, based on an understanding of people's
aspirations, uniqueness, values and status. However, these strategies have not been applied to
products for independent living, largely because the main consumer is the N.H.S. and
government agencies and not the people who use them.

This thesis assumes that product requirements (also called "product specifications") mean the
precise description of what the product has to do. Customer needs are generally expressed in
the "language of the customer". Product requirements must specify, in an unambiguous,
precise and measurable way, what the product has to do in order to satisfy customer needs
(Ulrich and Eppinger, 1995).

The product design process is a series of compromises between several product requirements:
function, performance, reliability, usability, appearance and cost. To find the exact solution is
sometimes very difficult and a compromise has to be established between some acceptable
solutions. According to Mital and Anand (1992) product design is the first and perhaps the
most important step in the manufacturing sequence.

The level of complexity in the product development process varies according to the nature of
the product. The product design process has been studied by many researchers, for instance
Baxter (1996); Jones (1992); Löbach (1981); Maldonado (1977); Rozenburg and Eekels
(1995). Others have paid special attention to the role of ergonomics and users in the process
of designing products (e.g. Cushman and Rosenberg, 1991; Gilfoil and Mauro, 1980;
Kreifeldt, 1984, 1992; Mital and Anand, 1992; Mital and Morse, 1992; Ulrich and Eppinger,
1995; Wood, 1990). Aspects related to quality and the production process were studied by
Cross (1995); Fox (1993); Jebb, Sivaloganathan and Evbuomwan (1993); Magrab (1997) and
Pugh (1991). Only a few authors have concentrated in the design of products for independent
living including Poulson, Ashby and Richardson (1996); Vanderheiden and Vanderheiden
(1992) and Wilkoff and Abed (1994). Although the methods described by these authors have
many similarities, they also reflect differences depending on the types of products to which
they are applied.

The product design process can be defined as a method composed of a set of rational and
systematic procedures with the objective of conceiving and developing physical products to be
employed by users. Although extremely useful, the product design process itself is not
sufficient to guarantee the good quality of the design of any particular product. In fact, no one can anticipate all of the problems that will arise during the design process but the risks as well as the costs can be minimised by following good practice and using effective methods and appropriate information wisely (Poulson; Ashby and Richardson, 1996).

The design process for consumer products can be summarised as consisting of six main sequential, or sometimes concurrent, phases: a) specification; b) conceptualisation; c) modelling and prototyping; d) product evaluation; e) production and f) marketing and evaluation. These six steps are now described.

2.3.1 Design specification

The establishment of the broadest conceptual objectives that a new product will fulfil is defined in this step of the design process. Aspects such as defining the business plan for the new product, defining which needs the product will satisfy, who will use it, and what are its characteristics should be carefully analysed. This phase is traditionally defined by marketing and management teams; or from discussion between designers and clients. Ergonomics might perform an important role in the several steps which comprise this phase. It is important to say that design specifications are only one part of the total list of specifications in a product development process. Other specifications may include: marketing, engineering, manufacturing, financial and so on.

Design specification is the phase responsible for:

- Identifying needs
- Evaluating competitive products
- Establishing user profile
- Defining product performance requirements and
- Determining design constraints.

2.3.2 Conceptualisation

This phase of the design process involves the generation of ideas which fulfil the criteria previously established in the design specification. This process is usually based on designer creativity and intuition and how similar problems have been resolved by others. Various well-developed techniques such as brainstorming, synectics and others are available for such
purposes. An early objective of this phase is to produce as many solutions as possible without criticisms. From an ergonomics point-of-view, the problem with this approach is that the solutions engendered are rarely evaluated on the basis of safety or usability, resulting in the manufacture of many unsafe or inconvenient products (Meyer, 1989; Ryan, 1987b).

An evaluation and selection of the best ideas is carried out. The use of a decision matrix including the product specifications helps in the choice of the best concepts (see sub-chapter 6.2.5). Ergonomics may contribute to this process providing the designers with an understanding of the users' physical and cognitive needs in order to generate solutions sensitive to function (Wood, 1990).

The concepts produced at this point are represented in form of renderings and drawings detailed enough to form a clear idea of what the final product will be. It is important to mention two very modern techniques used to design products: computer-aided industrial design (CAID) and Kansei Engineering. Computer-aided industrial design is a computer-based design system that allows designer to create and evaluate product designs in three dimensions and to generate photorealistic images and animation from the basic geometric design (Erhorn and Stark, 1994). The physical model generated by this technique can be used for evaluation by users. Kansei Engineering is a technique developed essentially to interact with users and is more fully described in sub-chapter 2.6.3, page 68.

2.3.3 Modelling and Prototyping

Modelling is the phase of the design process responsible for the selection and development of the most promising concepts and turning them into representative static models (computer graphics, or non-working "mock-ups") and working models (Wood, 1990). The objective of this phase is to produce realistic models suitable to meet specifications and goals set out for them. It is important to observe that non-working models and "mock-ups" can be also used in the previous phase to help in the choice of the best concept. Models can then be transformed into working, full-scale prototypes.

According to Erhorn and Stark (1994) rapid prototype technology permits the production of a prototype in a few hours compared to the days or weeks of conventional prototyping, decreasing the cost and time required to create a physical model of a design.
Turning a concept into a physical reality involves the use of several numeric values: e.g. lengths, weights, diameters, balance, etc. At this point ergonomics provides helpful support to the design in the form of extensive data from its literature.

Incorporating the users, beginning with the very earliest product development process steps, contributes to reducing to a minimum users' resistance to the final design and the need for substantial modifications. The next sub-section analyses in detail aspects related to product evaluation.

2.3.4 Product evaluation

Product evaluation can be used from the design phase of product development with the evaluation of the first mock-ups, until the evaluation of advanced prototypes at field sites and the "job one" (the master copy of the product which will later be mass produced). Analysing the interaction between product performance and users (either the disabled or able-bodied) from the results of product tests may indicate that some modification to the design is necessary. The tests also provide manufacturers with knowledge of the degree to which a prototype fulfils market needs and legal requirements.

The measurement of the interaction between consumers and products can provide requirements to improve the product's ergonomic specifications and general qualities. Only by such an approach can inadequate designs be identified. Specific methods are used for this purpose including evaluating design in terms of factors such as safety, effectiveness, robustness, reliability, comfort, dimensional compatibility, easy of use, aesthetics, and, increasingly, pleasure aspects.

Broadly speaking, there are two kinds of product tests: physical or ergonomic. Physical tests are used to verify the product's technical quality such as its physical, electrical, and electronic characteristics (e.g.: potency, power consumption, impact resistance, corrosion, resistance, etc.). Physical tests are relatively more important for the components, the product's internal parts, or products that usually have few contacts with users. The human does not interact in a major way with the product (or its components) in this kind of test.

The use of ergonomic tests on products is different from physical testing, because the former involves the user directly (Kirk and Ridgway, 1970; Rennie, 1981) and relates his or her anatomy, physiology and psychology to various features of the product (Kirk and Ridgway, 1971). These kinds of tests typically apply to everyday products for able-bodied and/or...
disabled people where the products are used in the home, work and in leisure, where a major feature of product use involves extensive contact with people.

Usability tests (sometimes referred as user performance tests) are part of the ergonomic tests. Product usability is defined by the International Standards Organisation as "the degree to which specific users can achieve specific goals within a particular environment - effectively, efficiently, comfortably, and in an acceptable manner" (De Vries, Van Gelderen and Brigham, 1994, p. 120; Jordan, 1998, p. 5 and Mital and Anand, 1992, p. 169). Usability tests are an important and essential part in the product development process mainly when intuition is used to make design decisions (Cushman and Rosenberg, 1991). They are concerned both with obtaining user requirements prior to or initiating the product design process and in the early stages of design; and with evaluating products that have been built. This approach make users the focal point of the design.

The necessity to evaluate consumer products physically and ergonomically comes from the necessity of manufacturers to evaluate their new products and compare them to those already on the market, especially those of competitors.

Evaluating the ergonomic qualities of a product should be assessed at any phase in the design process. Computer-aided systems constitute excellent tools to carry out this early evaluation. Simulations with mock-ups, models and prototypes permit study of what the users' reactions will be during real product performance and identify failure or malfunctions in the product.

The use of product evaluation, in general, although sometimes very expensive, contributes: a) to keeping a company's good image (avoiding the danger of negative oral propaganda); b) to avoid negative reactions from consumer organisations and c) to avoid liability in court.

The criteria used to evaluate products for independent living are not very different from those to evaluate consumer products in general and include the following aspects:

- **Safety**, the property of being able to handle a product without risk of damage, death or injury provoked by faults, malfunctions or errors in normal use, or foreseeable misuse, of the product or its components
- **Effectiveness**, the characteristic of a product which enables it to do the job it is intended to do efficiently and effectively with a reasonable amount of human exertion to produce the intended effect
- **Suitability**, the characteristic a product has to be appropriate to the user's medical and social requirements
• Robustness, the quality of a product to be able to resist fairly hard use and occasional misuse
• Reliability, the probability that an item will perform a required function under conditions for a stated period of time
• Comfort, the quality of a product to produce physical and mental well-being during any activity associated with its use
• Dimensional compatibility, the characteristic of a product to be dimensionally suitable with the anatomical and anthropometric dimensions of users and the physical constraints of the environment in which it is to be used
• Ease of use, the attribute of a product not to demand excessive strength, over-exertion or attention in use
• Aesthetics, the virtue of a product to be pleasurable to the user in terms of its visual appearance, sound, smell and feel
• Good value, the ability a product has to offer good value for money at purchase, in maintenance and in the repairing of parts and components.

According to Galer (1983), the criteria for evaluating products for disabled people have to be specified in detail to be applicable to the testing of particular aids. This specification should include the following:

• For the product: dimensions, materials, components, controls, displays, instructions, structure, noise, vibration and any special features of the product.
• For the user: age, sex, anthropometry, senses, intelligence, functional ability, socio-economic status, product ownership and any special features of the users.
• For the task: the objective to be achieved by the use of the product and the dynamic interaction of the user, the environment and the task for which the product was designed.

2.3.5 Production

The production phase involves a variety of activities including process and material selection, production operation planning, material handling, inspection and quality control and packaging. Manufacturing, the essence of the production phase, has the goal to accomplish conversion of raw materials into finished product as easily, quickly, and economically as possible and requires that the following steps be taken: product design, manufacturing system design, and manufacturing system operation (Mital and Anand, 1992 and Mital and Morse, 1992).
According to Vanlandewijck, Spaepen and Theisen (1997), an extremely difficult problem is faced by the manufacturers of assistive technology. On the one hand the manufacturers need to produce the highest possible volume of products to reduce manufacturing costs. On the other, these products should suit the user's individual capabilities and limitations. The use of the "design for all" approach (discussed later in sub-section 2.5.3, page 43) and modular design, which permit the combination of a number of variants for each component of the product in such a way to meet individual needs, may be the solution to this problem. However, the more specific the product is in meeting individual needs, the more difficult is it to use the above mentioned approaches.

Industrial ergonomics and industrial engineers are responsible for solving production problems. This phase of the product development process does not involve directly product ergonomics and industrial design and is not discussed in depth in any of the later chapters.

### 2.3.6 Marketing and further evaluation

Marketing and evaluation of the product is responsible for assessing customer feedback before and after the product has already been launched onto the market. Using appropriate techniques, the marketing team is able to define strategies to identify customer satisfaction/dissatisfaction after purchase. Obtaining feedback will determine the image and performance of the product and allow immediate action to be taken if any problems arise.

Once introduced in the market, the new product normally goes through one or more periods of sale growth and decline. This phenomenon is called Product Life Cycle. According to Pessemier (1982) and Smith (1994) the life cycle of a product comprises five stages: introduction, growth, maturity, saturation and decline. Poor design and lack of good ergonomics can severely affect the product life cycle (Burgess, 1989). Wilson (1983) claims that, from an ergonomic point-of-view, if all stages in this cycle are carefully considered some requirements may be produced incorporating ergonomics design criteria. This procedure will limit constraints in user interaction, improve safety and facilitate recycling. In this way it will contribute to extending product life.

Although designers and ergonomist should consider the product life cycle, which includes product sales and disposable phases, the phase of Marketing and further evaluation is not directly involved with design (but it is very useful for the next generation of designs) and, in view of this, is not discussed in this thesis.
An important point that should be addressed in the product design process is related to product safety. This matter affects both the disabled or able-bodied users.

2.3.7 Product Safety

Consumer products frequently harm their users; the reasons for this are many and varied, and include misuse, faulty manufacture and even poor design. Consumer products that do not attain safety requirements may cause injury or death to users and be excluded from the market by preventive or repressive legislation. Consequently, the financial loss and negative publicity can produce catastrophic effects for the company.

Laughery (1993) states that products are frequently designed requiring some knowledge or information on the part of users which they - at least some of them - may not or do not have. This doctrine assumes that consumers will use their intelligence and experience to protect themselves against possible hazards while handling products.

Designing a consumer product based on a safety approach is an activity that must consider the interrelation between the product itself, the user and the environment - taking account of normal use and foreseeable misuse, particularly with regard to children, the elderly and disabled - presenting low risk to the user. It is extremely important that industrial design and manufacturers are fully aware of the potential for accidents associated with the product they produce.

Data from The Department of Trade and Industry's Home Accident Surveillance System (Home Accident Surveillance System - HASS, 1998) points out that, in the United Kingdom, accidents in the home result in over 4000 deaths per year. In addition, it is estimated that almost three million people seek medical attention as a result of non-fatal home accidents. The number of home accidents in 1996 continue to form a large proportion (33%) of all accidents, almost as many as work (26%) and traffic (11%) accidents taken together. These data give the clear impression that the home is the most dangerous single location in Great Britain, more dangerous than the road. Consumer products, as a whole, make a considerable contribution in this statistic.

The statistical data from HASS shows that the high incidence of accidents in the home is predominant among the very young and old people. A possible cause of this is because these people spend more time at home. Furthermore, children are inquisitive and unaware of the dangers that surround them; elderly people have their mental and physical skills decreased and
so are more vulnerable. Table 2.1 shows the number of accidents involving mobility aids covered by the *Home Accident Surveillance System* (HASS) and *Leisure Accident Surveillance System* (LASS) in 1996.

Factors that lead to accidents are predominantly present during product use and are dependent upon the product design, the environment in which the product is being used, and the characteristics and behaviour of the user. Ergonomics can provide a major contribution in the field of product safety ensuring that the user is fully considered at the several product development stages.

Wilson and Kirk (1980) state that a product can be defective in two ways: a) products which were not produced as planned but which include some manufacturing fault or which were incorrectly inspected and b) products which were produced as planned, but which are dangerous to the public or to their owners. In fact it is not sufficient just to design products which are safe when used as intended; improper use must also be considered.

The contribution of design is fundamental to the production of safe products. A number of authors (Abbott and Tyler, 1997; Cushman and Rosenberg, 1991; Jenkins and Davies, 1989; Kreifeldt, 1984; and Ryan, 1987a) state that design is probably the biggest cause of product failure. Copper *et al.* (1997) state that some wheelchair accidents occur as a result of poor design.

Table 2.1

Number of accidents involving mobility aids in 1996 covered by the *Home Accident Surveillance System* (HASS) and the *Leisure Accident Surveillance System* (LASS)

<table>
<thead>
<tr>
<th>Products</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HASS</td>
</tr>
<tr>
<td>Walking stick/cane</td>
<td>106</td>
</tr>
<tr>
<td>Walking frame</td>
<td>291</td>
</tr>
<tr>
<td>Crutch/caliper</td>
<td>33</td>
</tr>
<tr>
<td>Other walking aid</td>
<td>3</td>
</tr>
<tr>
<td>Unpowered wheelchair</td>
<td>50</td>
</tr>
<tr>
<td>Powered wheelchair</td>
<td>26</td>
</tr>
<tr>
<td>Unspecified wheelchair</td>
<td>192</td>
</tr>
<tr>
<td>4-wheel mobility vehicle</td>
<td>0</td>
</tr>
<tr>
<td>Unspecified mobility vehicle</td>
<td>1</td>
</tr>
</tbody>
</table>
Falling and tipping-related accidents are the primary accidents connected to wheelchair use. As cited in Copper et al. (1997), Kirby and Ackroyd-Stolarz report a study involving 651 records collected by the Food and Drugs Administration (FDA) in the United States between 1975 and 1993, in which types of wheelchair injury and engineering factors leading to injury were examined. Figures 2.1 and 2.2 show the results. According to the first figure, it can be seen that the number of users who suffered fractures using their wheelchairs is almost half of the whole sample of recorded wheelchair injuries. The second figure shows that the vast majority of recorded engineering factors involved in wheelchair injury was related to mechanical and frame failures.

Cushman and Rosenberg (1991) and Ryan (1987a) point out that product’s failure frequently occurs shortly after the product had been purchased by the consumer. During the mid-life stage consumers can expect, on most products, a relatively long period of reliable and safe use. Failures in this stage may be attributable to unforeseen changes in product use. In the later stage of product life, when it begins to wear out, failure probability increases.

Figure 2.1
Breakdown of recorded wheelchair injuries (Kirby and Ackroyd-Stolarz, as cited in Copper et al., 1997)
At this point product failures are usually caused by accumulated stress in materials, abrasion, environmental factors, etc. Some physical tests can be used to test materials and components to predict product failures. Ergonomics is likely to be most useful in foreseeing faults during the initial stages of the product design process.

**Human error**

Until quite recently, product failure was essentially attributed to user error. Although this is no longer the main approach, human error continues to be an important and useful point to be considered during hazard analysis. In this context, hazard can be understood as a set of circumstances (conditions/situations) that has associated with it the potential risk of causing injury (Christensen, 1987; Cushman and Rosenberg, 1991; and Stadler-Estrin and Estrin, 1987)

Human error can occur wherever human beings are involved in carrying out tasks. With users handling consumer products it is not different. However, human error can be controlled and sometimes predicted before injury or damage occurs. The startling increase in the complexity of products will inevitably lead to errors and problems in use.

When people interact with a product, they will often be engaging in some form of problem-solving exercise. The best solution to perform the action is dictated by such factors as available information, state of the product, user's cognitive repertoire, and the user's
experience with other similar products (Baber and Stanton, 1994). Task analysis can be considered a valuable tool for error identification.

An extensive discussion of human error can be found in Baber and Staton (1994), Kirwan (1990, 1992a and 1992b) and Reason (1990).

**Product-safety analysis, standards and regulations**

The degree of hazard associated with a product is often difficult to quantify, but there is a point when the hazard, under specific circumstances, will increase the risk to a degree that the probability of injury is great enough to make it predictable (Stadtler-Estrin and Estrin, 1987). In order to guarantee that products should not contain or present hazards that may cause injury to the user, or persons coming into contact with the product, safety analysis and tests should be carried out.

The design of consumer products, and also products for the disabled, is subject to many governmental standards, regulations, local codes and product standards with an emphasis on safety. As most of them have the force of law, the first step in the initial design stages is to verify what law, codes, standards, and regulations are applicable to the design problem.

Standards for disability equipment are listed and indexed in the British Standards Institute Catalogues (BSI 1991) and the International Organization for Standards (ISO). Standards for medical devices are mandatory and some of them are applied to equipment for the disabled (including wheelchairs). These standards are described in *The Medical Devices Regulation, Consumer Protection, No. 3017, 1994*.

Attending to safety standards and regulations is an essential part of the design of a safe product. However, they just define the minimum requirements for safety. These kinds of standards and regulations may cover specific product attributes, testing procedures, or product performance.

According to Wilson (1984) it is possible to reduce accidents by improving design through the implementation of safety standards. It is certain that as higher standards are enforced, there will be more pressure on manufacturers and designers to improve the quality and, above all, the safety, of consumer products.

The Consumer Protection Act 1987 places new and more onerous demands on producers of goods with regard to safety. The general safety requirement means that it is a criminal offence
to supply unsafe consumer goods in the United Kingdom. The Act states that: "a person should be guilty of an offence if he supplies consumer goods which are not reasonably safe having regard to all circumstances." These circumstances include: "the manner in which the goods are marketed and any instruction or warnings given with the goods, any published safety standards for those goods, the means, if any, and the cost of making the goods safer." So, meeting safety standards is essential for manufacturers protect themselves against product liability.

**Product liability**

Product liability usually results from the application of negligence, breach of warranty or strict liability in tort. Product liability law provides a formal mechanism for addressing issues related to product safety and resolving legal disputes involving injuries or death. It refers to legal action taken under tort in which an injured party (the plaintiff) seeks to recover damages for personal injury or loss of property from a commercial provider of a product in whole or part (seller, designer, manufacturer, distributor, etc.) because the plaintiff alleges that the injuries or loss resulted from a defective product (Kreifeldt, 1992 and Sanders and McCormick, 1993).

Ryan (1985) discusses some recent law cases in which courts have found manufacturers liable for injuries associated with the use of their products. The products in question conformed to existing safety standards but were found to be defective because they did not provide that degree of safety expected by the consumer. Hence, reaching minimum requirements for safety may not be enough.

The details and implications of the introduction of strict liability to the United Kingdom law of tort concerning injuries caused by defective products have been extensively covered. See, for example Abbott (1980, 1997), Dewis et al. (1980), Hunter (1992) and Wilson and Kirk (1980).

The growth in product liability cases has created a demand for ergonomics experts, both in the initial design to make products safer and in the courtroom (Sanders and McCormick, 1993). Ergonomists can play an important role in the court, as expert witnesses, providing testimony to clarify technical issues.

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1Tort. The term in common law systems for the civilly actionable harm or wrong, and for the branch of law dealing with liability for such wrongs (Abbott and Tyler, 1997).
In addition to product safety, a range of product features constitute the properties which will enable the product to meet users' needs. User needs will be discussed in the next sub-chapter.

2.4 Defining consumer needs: a tool for the design of products with a competitive edge

A customer is an individual who, or group of individuals that, have a need and make a purchase by receiving products in return for payments (the same is true for services). Usually the words customer, consumer and user are used synonymously. In this thesis customer is defined as the person who buys the good or service and consumer or user is someone who effectively uses the product. It is important to observe that sometimes the customer plays the same role as the consumer/user, when he or she buys the product for his or her own use.

According to De Bont, Schoormans and Wessel (1992), a user's preference for a specific product can be regarded as the result of a match between characteristics of the products, including design and style, and the product demands of the user. Of course, users (subject to certain constraints) will attempt to buy the product with the best match. This processing of matching is a form of user information processing and is influenced by several factors based mainly on the user's personal ability to differentiate, to discriminate and to integrate information.

In a competitive market place, a user can normally choose freely to seek satisfaction among several distinct versions of the same product and is under no obligation to continue using this particular product.

People have their own aspirations, values and status symbols. Marketing strategies extensively explore these characteristics of human beings in order to sell products. However, marketing strategies have been applied very timidly to products for independent living, largely because actually the main customer is the N.H.S. or other government agencies and not the actual person who uses the product. With the global market breaking down boundaries, competition is increasing and the figure of hundred of thousands of disabled people is a segment in the marketplace to be considered by any company aiming for success with mass production.

It is a common sense that the products designed for the disabled population have to meet the specific medical or therapeutic needs of that population. In fact, apart from the needs resulting from their disabilities, which are crucial, the needs of the disabled population are the same as
those of the able-bodied population in terms of aspirations, uniqueness, values and status. Problems arise when designers perceive disabled people as isolated sets of symptoms rather than whole people with needs for products that represent their lifestyle. The result of this can be inappropriate products which, in many cases, have their styling associated with medical and assistive products. These latter products, frequently contribute to stigmatising the user. This, in its turn, often leads to products being rejected and abandoned even though they may be of clinical benefit. Products with these characteristics contribute to people with disabilities been perceived as in need and surviving and serve only to increase, at a psychological level, a person's sense of being disabled.

According to Barber (1996), if the design of products for independent living is purely to solve a problem based on the physical and medical needs of the people who will use them, the only values that will be reflected in the product are those of need and dependency. This, continues the author, betrays an underlying assumption that the people who rely on the products have no expectations in life beyond those of safety, security and survival. Although these expectations are essential for all people, they should not be considered to the exclusion of intended lifestyle, image, status and identification, considered, by designers and manufactures, essential ingredients for the success of any product, however practical its purpose.

2.4.1 Needs, wants and requirements

The concept of needs and wants have been defined, without consensus, by a number of authors including Engel, Blackwell and Miniard (1993); Mitchell (1981); Mowen (1990) and Solomon (1996). To avoid misunderstanding needs and wants are used synonymously in this thesis.

Mitchell (1981) has defined requirements as those characteristics of a process, product or place which should be provided to allow an individual to function effectively, safely, comfortably and easily. If requirements are considered as the inputs from the environment which are needed by the user to permit optimum function, demands, on the other hand, represent the output which is needed by a user from particular equipments or environments. According to the author, requirements represent specific expressions of general needs.

Ulrich and Eppinger (1995) have distinguished needs and requirements (used by the authors, and in this thesis, as synonymous with specifications). They argue that needs are not specific to a particular concept and are independent of any product that may be developed, so designers should be able to identify customer needs without knowing if or how they will
eventually address those needs. On the other hand, requirements do depend on the selected concept. These selected concepts are defined by, for instance, what is technically and economically feasible, what competitors offer in the marketplace and by customer needs, as well.

General considerations about consumer needs

All consumers have needs to be met and the product features should be responsive to those needs (Juran, 1988). Observing consumer needs is today a powerful tool for the design of competitive products. Consumer needs are requisites, desirable or intrinsic, to be fulfilled by the product or service. Some have higher priority for consumers than others. It is essential to identify consumer needs and establish priorities so that they can be useful to the engineering team during product development. Pugh (1991) says that any mismatches that arise between company products and the real needs of the consumer seem only to be solved over a long period of time.

Griffin and Hauser (1993) say that engineers require greater detail on consumer needs than is usually provided by the typical marketing study. According to Harris (1990) the market research used in the formulation of product specifications fails to reflect user needs fully. At this level of detail it is important to establish trade-offs during engineering design by defining, for example, the kind of consumer for which the product will be designed and specific product characteristics which they might want to be part of the product.

Harris (1990) states that if on the one hand more and more companies are spending more and more money on trying to sell mediocre products, on the other hand the successful companies are investing heavily in ergonomics and design and producing products that are more desirable to own. In this way, the importance of identifying a consumer need or wish to purchase a product and using market pull to sell the product should be considered. According to the author, long-term approval and acceptance of a product lies with users developing an affinity for the product and a belief that it meets their needs. A necessary condition for product success is that a product offers perceived benefit to the customer and it will do just that when it satisfies needs (Ulrich and Eppinger, 1995).

According to Holt (1989) many engineers in their design activities concentrate their attention on the technology and neglect the problems and the needs of the user. Consumer needs provide the designer with the potential to obtain feedback on the performance and acceptability of the design among users and they enable the designer to make modifications that will improve the original design in terms of their requirements (Brown, 1983). If feedback
is lacking the design process runs the risk of becoming increasingly divorced from the reality of use. Designers need an effective way to represent user needs in the design process (Harker and Eason, 1984). The product development process translates consumer needs on functional requirements into specific engineering and quality characteristics (Gryna, 1988).

In terms of the buying process, the consumer needs to presuppose expected benefits which include an evaluation of alternative products before the purchase. An initial process of need recognition gives information that will permit the start of the evaluation of alternatives. According to Engel, Blackwell and Miniard (1993) there are three determinants of need recognition: a) information stored in memory, b) individual differences and c) environmental influences. The success of the alternative evaluation is defined only after the purchase and it may result in the decision of buying or not buying a similar product next time. Furthermore, during this alternative evaluation, state the authors, it is not just the extent to which products meet expectations in terms of efficiency and effectiveness that determine user satisfaction, but other benefits of buying the product play an important role.

It is obvious that user needs vary one from the other and that in a modern first world society user needs are established more by social or emotional factors than biological needs (food, shelter, etc.). Competitive markets have many products that are so much alike in practical or functional terms that a customers' choice is often determined solely by the psychological perception of how the product will perform for them. Thus, products have both denotative (rational, functional, conscious level) and connotative (emotional, affective, unconscious level) aspects (Gregory, 1982). The author states that products are collections of meanings and in order to be successful it is necessary that they communicate satisfaction at both the rational and irrational level. Consumers often choose products they associate with a certain life-style, believing that the qualities represented by the product image somehow correspond to their own or will somehow rub off onto them (Solomon, 1996).

Griffin and Hauser (1993) define the "voice of the customer" as a hierarchical set of "customer needs" where each need (or set of needs) has assigned to it a priority which indicates its importance to the customer. If listening to the "voice of the customer" during the design process seems obvious, it does not always correspond to the reality. Holt (1989) cites several studies in which authors have checked companies in USA, Germany, Italy, Norway and UK and concludes that in too many places the user is considered a nuisance.
Product requirements

Establishing product requirements is the next step after consumer needs have been identified. This procedure involves providing specific guidance about how to design and engineer a product using measurable data. Consumers usually express their needs using their own language. The design team needs to have this information in a quantitative data as free of subjective interpretations as possible. In this way, product requirements can be understood as a set of specifications that translates consumer needs into precise and measurable data in order to produce products that are technically and economically realisable.

2.4.2 Consumer satisfaction and dissatisfaction

As a result of meeting or not meeting consumer needs, users will express their satisfaction or dissatisfaction in using the product. Consumer satisfaction can be defined as the consumer’s response to the evaluation of the perceived discrepancy between prior expectations (or some other norm of performance) and the actual performance of product as perceived after its consumption (Tse and Wilton, 1988). According to Anderson and Sullivan (1993) there is growing managerial interest in customer satisfaction as a means of evaluating quality and as a criterion for diagnosing product or service performance.

Satisfaction may be considered as a major outcome of marketing activity once it provides useful data in terms of postpurchase phenomena such as attitude change, repeat purchase, positive word-of-mouth and allegiance to a brand (Churchill and Surprenant, 1982). The authors state that since the early 1970s the volume of theoretical consumer satisfaction research has been increased impressively. Most of these studies have used some variant of the disconfirmation paradigm. According to the authors, an individual’s expectations are: a) confirmed when a product performs as expected, b) negatively disconfirmed when the product performs more poorly than expected (known as dissatisfaction) and c) positively disconfirmed when the products performs better than expected.

Consumers are usually engaged in evaluating products that they use into their daily activities and consumer satisfaction/dissatisfaction is determined by the overall feelings, or attitudes, a consumer has about a product after it has been in purchased (Solomon, 1996). In this way, product satisfaction and product dissatisfaction are two important concepts to be understood. According to Juran (1988):

- **Product satisfaction**, occurs when product features fully reflect customer needs.
• **Product dissatisfaction**, occurs when products have deficiencies and these characteristics do not reflect fully customer needs.

Mano and Oliver (1993) characterise product satisfaction as "an attitude-like postconsumption evaluative judgement with the evaluative aspect of that judgement varying along the hedonic (pleasantness) continuum" (p. 451). Juran (op. cit.) argues that product satisfaction and product dissatisfaction are not opposites. The author states that a) the first one has its origin in product features and is why clients buy the product; b) the second one has its origin in nonconformances and is why customers complain.

In a model of satisfaction as a function of expectation and disconfirmation, Oliver (1993) points out that consumers are posited to form preconsumption expectancies, observe product (attribute) performance, compare performance with expectations, form disconfirmation perceptions, combine these perceptions with expectation levels and form satisfaction judgement. Therefore, this model postulates that satisfaction acts as a mediator between preexposure and postexposure attitudes.

In terms of product design, consumer satisfaction is compounded of visual appeal, "feel", functionality, expectations and aesthetics (Kreifeldt and Hill, 1976). Certainly a successful design needs to consider these aspects altogether. Concentrating on any one aspect to the detriment of another may cause dissatisfaction. In terms of products designed for the disabled population, the medical and therapeutic characteristics of the product are part of its functional features which, in conjunction with the other product's features, must meet user needs and contribute to express consumer satisfaction.

Hauser et al. (1994) draw attention to the fact that many papers in the marketing and total-quality management literatures have focused on the measurement of customer satisfaction: e.g.: developing and testing more precise measurement scales; using scales and focusing on the link between satisfaction and future sales, purchase intention, loyalty; testing variables of satisfaction in order to understand satisfaction formation in conjunction with behavioural explanation, etc. Some critics of customer satisfaction measurement argue that customer satisfaction surveys are ineffective if they are not tied to customer behaviour.

As this thesis focuses on products for the "disabled independent living", the next sub-section will identify, describe and analyse products which aim to satisfy the needs of this special population, with emphasis on wheelchairs.
2.5 Design for disabled people: analysing the needs of a special population

2.5.1 General considerations about the disabled population

An increasing segment of the world population is being reported to have some disability. According to 63 surveys conducted in 55 countries by the United Nations Disability Statistics Database, as cited in Kumar (1997), the prevalence of disability reported in various countries varies between a low of 0.2 per cent in Peru to a high of 20.9 per cent in Austria.

Sandhu and Wood (1990) state that the number of disabled people in the United Kingdom is around 6.561 million. This means that, in U.K. alone, at least one out of every eleven citizens is physically or mentally disabled. The Special Needs Research Unit at Newcastle Polytechnic estimated for the Commission of the European Communities, in a document entitled Demography and market sector analysis of people with special needs in thirteen European countries (Sandhu and Wood, op.cit.), that the range of disabled people, expressed as a percentage of the total population within the thirteen European countries, varies from 13.1% in West Germany through to 10% in Greece. In the United States there are approximately 33 million people - corresponding to 15% of the population - who have sensory, motor or cognitive disabilities (Elkind, 1990). The Disability Statistics Compendium of the United Nations, as reported by Kumar (1992), stated that 2.4% to 20.9% of the total population in some of the participating countries are disabled. However as the author points out, the number of people who fall into the disabled category may have been grossly underestimated due to a lack of standardisation in criteria and reporting.

Determining the exact number of individuals with disabilities or with limitations attributable to aging is difficult. In reality, estimated numbers of the disabled population may be sometimes imprecise because they can consider people with multiple disabilities in multiple categories. Estimates vary considerably as a function of the definition of disability used. However, the numbers expressed above are sufficiently large to guarantee that a very significant part of the population needs special treatments (e.g. provision of equipments or carers or both) to be able to develop his or her abilities and capabilities to live an ordinary life to the full.

According to Vanderheiden (1990), the serious impact the very large population of disabled people has on mass-market products is beginning to be recognised by manufacturers. Also, many governments are becoming more aware of the problems arising out of this large number. Apart from humanitarian concerns, the costs to society that result from the need of special
assistance required by disabled persons (unemployed or non-independent living) are very high. Furthermore, there is a significant loss to society of these individuals' productivity, in terms of the work force, given that, according to Elking (1990), at least in the United States, half of the disabled of working age are unemployed. He also states that half of the disabled population lives at or near the poverty level. Kumar (1997) states that the low employment among persons with disability is not unique to a few countries but is a general feature across most countries. Even if the disabled person is employed, concludes the author, he or she makes far less money than their able-bodied counterpart. These facts represent a social problem of very large amplitude.

2.5.2 Defining disability and associated concepts

Physical or mental limitations can be classified on three levels: impairment, disability and handicap (based on Kroemer et al., 1994; Mital and Karwowski, 1988; Nichols, 1976; Pirkl, 1994; Soede, 1990; and Torrens and Kay, 1995).

- **Impairment**, a result of diseases or accidents, is characterised by losses or abnormalities in part or all of a limb, organ, tissue or other structure of the body including the systems of mental function. Thus, impairment is a medical or clinical disability. E.g.: hearing, stiffness of a joint or loss of a limb.

- **Disability** is any restriction or lack of functional ability, resulting from an impairment, to perform an activity in the manner or within the range considered normal for a human being. E.g.: communication problems due to hearing loss or mobility problems due to joint stiffness. The man who has had a leg amputation and has an artificial leg is no longer able to run as fast as he once could with two normal limbs.

- **Handicap** is a disadvantage, for a given individual, resulting from an impairment or disability, that limits or prevents the fulfilment of a role that is normal (depending on age, sex and social and cultural factors) for that individual. Handicap can also be considered as the social and economic disadvantage that results from impairment or disability. Again taking the example of somebody who had had a lower limb amputated, the disadvantage of having an amputated limb will depend entirely upon the patient's age, his job, where he or she lives and the family situation.

There are some difficulties in using the terms impairment, disability and handicap consistently. The Census Bureau of the U.S. Department of Commerce controversially considers, in its Statistical Abstract of the United States (as cited in Elkind, 1990), limited literacy as a kind of disability. Arguments against this classification consider that this condition is not a
physiological or psychological disability but something that can and should be remedied throughout education. The author introduces a classification based on the categories used by the Census Bureau to collect data about disabilities. This classification is given in Table 2.2. Note that this classification considers handicap and impairment as varieties of disability. This conflicts with the definitions given above.

Hale (1979) controversially points out that, physical disability, no matter how or by what it was caused, is a medically determined fact that can be defined and described explicitly. Some disabilities may seriously handicap a person in one situation and not in others. A concert pianist, for instance, who loses a finger is seriously handicapped concerning his or her career but may be able to perform most other usual activities. Another important factor to be observed, according to the author, is that sometimes a handicap can be minimised or even completely eliminated a) through the use of suitable aids, e.g.: equipments, devices and aids in general; a friendly environment at home, work, transport and in public places and b) through constructive and realistic attitudes. Sometimes, states the author, a person's view of his or her disability is more handicapping than the disability itself. It is curious that Hale does not mention help from other people.

A contrary point of view to that of Hale is put forward by Vanderheiden (1990). He states that it is important to say that there is not a clear line of demarcation between people who are categorised as disabled and those who are not. If a certain performance or ability is under focus, what can be observed is a distribution including a small number of individuals who have exceptionally high ability, a large number of individuals with mid-range ability and another

<table>
<thead>
<tr>
<th>Types of disabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory</td>
</tr>
<tr>
<td>Visually handicapped</td>
</tr>
<tr>
<td>Hearing handicap</td>
</tr>
<tr>
<td>Motor</td>
</tr>
<tr>
<td>Orthopaedic impairments</td>
</tr>
<tr>
<td>Cognitive</td>
</tr>
<tr>
<td>Specific learning disabilities</td>
</tr>
<tr>
<td>Speech impairments</td>
</tr>
<tr>
<td>Mentally retardation</td>
</tr>
<tr>
<td>Illiterate and semiliterate</td>
</tr>
<tr>
<td>Emotionally disturbed</td>
</tr>
<tr>
<td>Other health impairment</td>
</tr>
</tbody>
</table>
longer tail representing individuals with little or no ability in that particular area. In this way, a person who performs poorly along a distribution in one dimension (e.g. vision) may perform excellently with regard to another dimension (e.g. hearing or IQ). Therefore, continues the author, most individuals do not consistently fall at only the lower or upper end of distribution but generally fall into different positions depending on the particular ability being measured. So, the distinction between "able" and "disabled" groups may not be simple since it involves a continuous function rather than a simple dichotomous "able-disabled" distinction. The disabled community refer to those without disabilities as "TABs" or "temporarily able-bodied" because human beings experience temporary and/or functional limitations during their lives (through, for example, illness and accident and through the natural processes of development and ageing).

2.5.3 The design of products which include the disabled

Consumers, in general, are comprised of an extremely heterogeneous population in terms of physical and mental ability. Differences of age, size, shape, weight, etc. for both able-bodied and disabled persons make designing products to satisfy the whole range of such diversity practically impossible. With handicapped people, their handicap exarcebates individual differences, which makes it more difficult for the designer.

The use of adequate aids, sophisticated or simple, can transform the daily life of the disabled. As a function of the actual stage of technology, many products that, some time ago, seemed possible only in science-fiction are now a reality. On the other hand, many devices which are readily available are standard, inexpensive and, in some cases, tailor-made for one individual. From a simple home-made reacher that retrieves dropped articles, to a sophisticated breath-controlled switch that operates a computer keyboard, people with disabilities can find a large range of products that aid them to live a more independent life.

Thanks to the advance of science and technology, people can expect to live longer, recover more fully from illness, and lead active lives in spite of trauma. But, according to the article "Can a chair design change your life?" (Design, 1997), a public that is used to miraculous surgical techniques, bio-engineering and medication, is also used to the bondage of crutches, wheelchairs and stairlifts that seem to come from a different age or civilisation.

Hollerith (1980) citing Dreyfuss states that, generally speaking, products are merely extensions of a human being's abilities. For example: the telephone simply lets people talk over longer distances; the airplane allows people to cover greater distances more quickly; a
computer allows people to calculate quickly and accurately; a pencil allows people to communicate thoughts without having to speak them and gloves will allow people to use their hands in extreme temperatures. Following this thinking, Hollerith points out, spectacles let people read and see more clearly; a hearing aid makes sound more audible; an artificial arm allows a person to use a hand and a wheelchair allows the user to "walk". The author concludes: "We may, therefore, say that all products are prosthetic devices in that they all extend the capabilities of the users" (p. 93). The virtue of this line of thought is to eliminate the status of "special product" and de-stigmatise what are now referred to as prosthetic devices: just as, the last thinking of a spectacle user is that he or she is wearing a prosthetic device.

According to Kanis (1988), the use of everyday products can turn an individual disability into a handicap. There are two approaches to tackle this problem:

- By adaptation of existing products and the development of special aids or
- By taking into account the limitations and capabilities of the disabled in the design of new products.

Disabled people represent a significant proportion of consumers in terms of their buying power. But, in fact, when a product is specific to a special segment of the disabled population the economic buying potential decreases substantially and consequently may not receive enough design attention. On the other hand, disabled people have difficulties in using effectively or safely standard consumer products because of their impairments.

**Databases on disabled capacities and limitations**

If, on the one hand, a large amount of data about the capacities and limitations of different groups within the non-disabled and non-elderly members of the general population are available, on the other hand data related to people with disabilities are still rare and urgently required. However, if designers wait until statistically representative data are available a large number of products that turn a person's disability into a handicap will certainly continue to proliferate (Hollerith, 1980). Indeed, rarely has the industrial designer had sufficient information available to him or her related to the various handicaps and how they would be affected by the design that he or she is working on. Disabilities and functional limitations of aging are now more frequently cited in textbooks and included in data tables than they were in the past. However, dissertations and data are not as useful to designers as they should be.
Chapter 2: A Review of the Literature

Kumar (1997) advocates the need to develop an extensive and relevant database related to people with disabilities and able-bodied including data on a) strength, endurance and range of motion; b) people's capabilities in standard activities such as pinching, gripping, lifting, pulling and pushing from the point of view of strength and also ability to sustain them; c) motion at different body joints (upper extremities, trunk, head, neck and lower extremities) and d) balance, stability, capabilities of sight and hearing.

Designing for the disabled and the able-bodied population

Although making compatible products for both disabled and able-bodied people has been a very difficult task, products usable by disabled consumers will usually be well-accepted among a portion of able-bodied and aging population, especially if those products do not carry with them a stigma of handicap (Mueller, 1989). Products designed for those with disabilities, keeping the able bodied in mind, and vice versa, would nicely avoid the standard marketing problem of segmenting the handicapped from the able-bodied, asking how many handicapped there are, and the reaction that the market is too small to address.

Producing products that can be used by the largest number of users possible, including the disabled and ageing, is both an economic and social strategy that helps to contribute to product success. This is true because, enlarging markets, products become less expensive than lower-production "specials products". Vanderheiden (1990) advocates that in some cases creating a design that is more accessible to both the able-bodied and disabled contributes to a) decreasing the costs involved in manufacture or maintenance/support of a product (e.g. signal tones and light in a lift, in advance of its arrival at the floor, has solved accessibility problems without increasing costs) and b) increasing the functionality for able-bodied users including benefits such as lower fatigue, increased speed of operation and lower error rates (e.g. kerb cut, television subtitles, etc.).

According to Torrens and Kay (1995), the investment in research and development for some disability products is sometimes disproportional to the return from the product. To make the product economically viable other markets may need to be found. In this way, the challenge for designers is to elaborate design specifications able to integrate the needs and characteristics of special populations as part of a broader population.

There are several different terms for defining the concept of design for the largest population possible, including design for all, design for a broader average, universal design, design for people at all stages of their lives and transgenerational design. In fact, all of these terms are sound common sense within the context of the "ergonomics approach".

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Universal design is defined by Vanderheiden and Vanderheiden (1992) as a method that covers the design of products for all people and encompasses all design principles. Vanderheiden (1991) has also introduced the concept of accessible design, a subset of universal design. According to the author, accessible design focuses on design principles that extend the design process for mass market products to include persons who, because of personal characteristics or environmental conditions, find themselves on the low end of some dimension of performance (e.g. seeing, hearing, reaching, manipulating). People with this type of performance are considered the lower ability tail of universal design.

It is important to be clear that although elderly and disabled people should be included in the design process, it is not possible to design all products and devices so that they are usable by all individuals. There will always be a segment of individuals who are unable to use a given product. Because of the diversity of disabilities, the number of individuals with any one particular type or combination of disabilities is much smaller compared with the population as a whole (Vanderheiden, 1990). In spite of this, states the author, is more difficult to accommodate this population in the overall design process because of the many dimensions that need to be considered. Furthermore, in the same way that, economically speaking, it is unreasonable to design everything to be usable by everyone, it is equally unreasonable to produce special designs for each major consumer product to accommodate the different disability groups. Some special aids and other devices will continue to be necessary to fulfil those needs that accessible mass-market design cannot effectively meet. So, the best and most economical approach appears to be making mass-market goods more accessible through a design that carefully tries to include disabled and non-disabled altogether respecting their differences and necessities.

Vanderheiden and Vanderheiden (1992) point out four different approaches to make products more accessible, in order of desirability. It is important to observe that it may be necessary to use one or a combination of these approaches to achieve the desired level of accessibility.

- **Direct accessibility**, corresponds to producing modifications, incorporated into the initial product design phase, which can significantly increase accessibility and usefulness to individuals with functional impairments; e.g. Mouse Keys of Macintosh computers that allow the user to move the cursor across the screen using the numeric keypad rather than the mouse.

- **Accessibility via standard options or accessories** (from the manufacturer), means to provide adaptations or alternatives to standard design when it is not possible to design the standard product to make it directly accessible for some disability populations; e.g.
availability of microwave ovens control panel with ridges around each button and some
type of tactile identification of button function to replace the usual buttons which are not
easily distinguishable by touch.

- **Compatibility with third party assistive devices**, means the establishment of
  cooperation between mass market manufacturers with assistive device manufacturers
  facilitating efforts of third party manufacturers in a number of ways, including using
  standard approaches, providing appropriate connection points, advance access to new
  versions of products and technical assistance in understanding and properly attaching
  accessories to the product; e.g. keyguards and accessories to keyboards and providing
  compatibility between standard computers with alternative input devices to fit people with
  a variety of severe physical disabilities.

- **Facilitation of custom modifications**, when all the other approaches prove to be
  impractical or uneconomical the best solution may be to carry out custom modifications of
  the product; e.g. adaptations of automobiles for use by drivers with physical impairments.

In addition to the four approaches advocated by Vanderheiden and Vanderheiden (1992), it is
important to call the attention to the fact that in those cases where none of the above
approaches work because of extreme disability, it is invariably necessary for the affected
person to be partially or wholly assisted by a carer.

According to Feeney and Galer (1981), the main difficulties in finding generalizable
ergonomics solutions to the problems presented by disability, in all its many varied forms, are
related to goals, classification and measurement:

- **Goals** are based on two approaches: a) the first one states that people who are physically
  impaired are different in their capacities or characteristics and consequently need special
  arrangements to use standard equipments which are designed for the non-disabled
  population. Hence, many gadgets and adaptations are on the market to enable those with
  impairments to use standard equipment which is designed for the non-disabled population;
  b) the second approach points out that, if when designing products and environments for
  all users, the requirements and capacities of impaired people are incorporated into design
  solutions, the need to use special aids and adaptations would disappear and impaired
  people would be better integrated into society. Certainly, some limits of this approach
  must be observed since the blind, the deaf and those who use wheelchairs will always need
  special care, but on the other hand handicapped people with more common functional
  impairments may take advantage of a "design for all" approach. But, it is obvious that
certain members of the impaired population are so limited in their capacities that any
design solutions must be tailored to their individual requirements.
• **Classification** of impairment is described in medical terms and, although adequate to identify and prescribe medical and therapeutic treatment procedures, does not provide a basis for the assessment of physical and mental abilities which can be used by the ergonomist and designer.

• **Measurement** and analysis of body dimensions of disabled people are extremely difficult because they present skeletal deformity and variation so that reference points, usually applied to the general population, are inappropriate and the variations in stature and shape are impossible to manage.

In terms of designs for the disabled, the *Disabled Living Foundation* (1992), in a paper entitled "Equipment that needs Designing", has suggested a strategy that points out that people with different disabling conditions have difficulty performing similar tasks. So, DLF suggests that by identifying common aspects of difficulties of task performance, generic solutions that may be applied to overcome parts of an individual's impairments will also help other individuals with different impairments. Torrens and Kay (1995) state that the implications of identifying generic solutions to the designer and manufacturer are that a large market can be identified, more economic manufacturing processes used and investment in research and development might be more possible. Kumar (p. 30, 1997) concludes that "given the size and significance of the population with disability (due to aging, trauma or disease), the rationale of extensive application of rehabilitation ergonomics is not only economically viable but profitable".

Cushman and Rosenberg (1991) point out that, in general, design solutions including the disabled fall into four categories:

• Improving access to displays and controls, e.g. increase size of lettering on displays and labels, use displays with high contrast and a wide viewing angle, place the control panel on the front surface of the product, etc.

• Simplifying product operation, e.g. make operation of the product self-evident, minimise cognitive demands by providing appropriate task aids (such as adequate labels, operational sequence diagram and pictograms) and simplify user manuals, etc.

• Providing redundancy for sensory information, e.g. use both visual and auditory displays to convey the same information, provide redundancy for coded information, (such as simultaneous use of colour coding and brightness coding) and provide several types of feedback - visual, auditory and tactile - when feasible, etc.

• Tailoring the product to meet the needs of the individual user, e.g. provide capability for adding prosthetic devices to meet needs of specific individuals (such as image enhancers, speech synthesisers, headphones, touch screens), provide brightness, contrast and loudness
controls and provide capability for users with deficiencies in colour vision to select colours when any type of colour coding is used.

As has been cited many times throughout this work, the inclusion of users into the very beginning of the design process is essential. Taking the design for all approach into account, understanding able-bodied and disabled users' abilities and limitations is a crucial starting point in the development of a new product.

Figure 2.3 shows the user pyramid (or triangle of disability) that represents all users in their daily activities and the incidence of disability of varying severity that affects them (Benktzon, 1993; Benktzon et al., 1994; Feeney and Galer, 1981). At the base of the pyramid are non-handicapped and older users with slight disabilities. (e.g. some deterioration in strength, sight or hearing). In the middle part are people with more serious disabilities due to illness or age (e.g. people who needs aids - wheelchairs, some special equipments, etc. - to perform activities considered normal for a human being). At the top of the pyramid are people with severe disabilities (e.g. people with very little strength or mobility in arms or hands).

2.5.4 Classification and characteristics of products for disabled people

Classification of products for the disabled

The Nordic Committee on Disability Aids, as cited by Watson (1984), has established a classification of aids for people with disabilities that has become a standard within the European Community. Table 2.3 shows the classification and some examples.

Figure 2.3
The "user pyramid" showing levels of disability
Table 2.3
Nordic classification system for aids for disabled persons

<table>
<thead>
<tr>
<th>Types of aids</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aids for therapy and training</td>
<td>Aids for inhalation, circulation and dialysis therapy; stimulators; aids for continence training, etc.</td>
</tr>
<tr>
<td>Orthoses and prostheses</td>
<td>Prostheses of upper and lower limbs; orthopaedic shoes; etc.</td>
</tr>
<tr>
<td>Aids for personal care including clothes and shoes</td>
<td>Aids for toileting; thermometers; barometers; personal scales; etc.</td>
</tr>
<tr>
<td>Aids for transportation and locomotion</td>
<td>Walking aids; car adaptations; mopeds; cycles; wheelchairs; mobile patient lifts; orientation aids; etc.</td>
</tr>
<tr>
<td>Household aids</td>
<td>Cooking aids; dish washing aids; aids for eating and drinking; housekeeping aids; sewing and mending aids; etc.</td>
</tr>
<tr>
<td>Aids for adaptation of homes and other premises</td>
<td>Tables; light fixtures; chairs; beds; support devices; door and window openers/closers; safety equipments; etc.</td>
</tr>
<tr>
<td>Aids for communication, information and signalling</td>
<td>Braille and similar systems; manipulators and robotic arms; electric-optical aids; writing, reading and drawing aids; telephonic aids; audio-video aids; hearing aids; alarm systems; etc.</td>
</tr>
<tr>
<td>Aids for handling of other products</td>
<td>Package openers; extenders; forehead, chin and mouth stick; remote control aids; push-bottoms; knobs; latches and handles; grips and holders, etc.</td>
</tr>
</tbody>
</table>

**Characteristics of products for the disabled**

Kroemer *et al.* (1994), based on the thinking of Batavia and Hammer, point out some characteristics of assistive devices including:

- **Affordability**, the extent to which the purchase, maintenance and repair causes financial hardship to the consumer
- **Dependability and durability**, the extent to which the device operates with repeatable and predictable levels of accuracy for extended periods of time
- **Physical security**, the probability that the device will not cause physical harm to the user or other people
• **Portability**, the extent to which the device can be readily transported to and operated in different locations
• **Learnability and usability**, the extent to which the consumer can easily learn to use a newly received device and can use it easily, safely and dependably for the intended purpose
• **Physical comfort and personal acceptability**, the degree to which the device provides comfort, or at least avoids pain or discomfort to the user, so that the person is attracted to use it in public or private
• **Flexibility and compatibility**, the extent to which the device can be augmented by options and to which it will interface with other devices used currently or in the future
• **Effectiveness**, the extent to which the device improves the user's capabilities, independence and objective and subjective situation
• **Ease of assembly and maintenance**, the attribute of a product not to demand excessive strength, over-exertion or difficulties of understanding in assembly and maintenance
• **Ease of repair**, the availability of suppliers, spare parts and accessories and facility of customer repair or supplier repair.

### 2.5.5 Equipment for disabled mobility

Mobility, one of the prime needs of a human being, is fundamental to health, social integration and well-being of people. Wheelchairs, walkers, hoists, lifts and ramps increase outdoor and indoor mobility of the disabled. Equipment for disabled mobility is a subset of the group *Aids for transportation and locomotion* of the Nordic classification system for aids for disabled persons.

This Ph.D. research intends to learn some lessons to apply to some equipment for disabled mobility design, particularly wheelchairs, collected from users’ opinions. Therefore, it is important to consider some definitions, classifications and characteristics of this kind of product. In general, equipment to improve mobility among the disabled can be divided in two groups: walking aids and wheelchairs.

#### 2.5.5.1 Walking aids

A walking aid is a kind of device with the function to transfer to the arms part of the load that is borne by the lower spine, pelvis and legs and to give support when there is weakness of muscles or disordered balance through diseases of the nervous system or inner ear (Houghton, 1991). According to the author, changes in the design of equipment have been made in
weight, in grips (easy to hold), in correcting angle, in the ease of adjustment in length, in the providing of stability on various surfaces and in handles to provide a better distribution of the load over a great surface area of the palm. New materials provide some challenges to future designs. Table 2.4 shows several types of walking aids, their characteristics and some examples of types (based on Houghton, 1991 and Mandelstam, 1993).

Houghton (op. cit.) points out the followings characteristics of walking aids (applied depending on the model):

- Assembly
- Adjustability
- Easy access/egress
- Manoeuvrability
- Provide good posture
- Provide good support
- Provide good handgrips
- Stability
- User security
- Easy maintenance.

Table 2.4
Types of walking aids

<table>
<thead>
<tr>
<th>Types</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing frames</td>
<td>Helps to encourage support weight through bones and joints and prevent contractures at the hip and knee; e.g. standing frames that assist a person to stand or be used as a transfer or walking aid; standing frames which allow variation of posture, etc.</td>
</tr>
<tr>
<td>Walking frames</td>
<td>Contributes to reducing weight through the legs and assists balance; e.g. fixed height frames; adjustable height frames, triangular walking frames, folding walking frames, etc.</td>
</tr>
<tr>
<td>Miscellaneous walking aids</td>
<td>E.g. Parallel bars, three-wheeled folding walkers, rollators, trolleys, etc.</td>
</tr>
<tr>
<td>Walking sticks</td>
<td>Used as aids in partial support of the weight and for balance; e.g. walking sticks with different shaped handles (straight, curved, D-shaped, moulded, swan-neck and off-set), fixed walking sticks, adjustable walking sticks, reflective sticks, folding sticks, tripod and tetrapod sticks, etc.</td>
</tr>
<tr>
<td>Crutches</td>
<td>Used to support weight through elbow, axilla or both; e.g. single and doubled adjustable, crutches with tripod or quadrupod base, etc.</td>
</tr>
</tbody>
</table>
One of the issues which has not been well dealt with in the following section 2.5.5.2 (which begin in page 53) is the issue of clinical categories of wheelchair users. This issue has been addressed in Kumar (1997), Chapter 10, pages 247-248 ("Wheelchair ergonomics", Cooper, R.A. et al.). The following account of wheelchair user disability etiology is given based on the position in Britain and the U.S.A.

"Disability involves limitations in actions and activities because of mental and physical impairments. Over 14 per cent of the US population is limited in selected activities, with some of these limitations making wheelchair use necessary. Each year the National Centre for Health Statistics conducts National Health Interview Survey on Assistive Devices. This survey showed that there were 1,411,000 wheelchair users in the USA in 1992 (National Center for Health Statistics, 1992\(^1\)). Arthritis is one of the leading causes of activity limitation in the USA and is second in prevalence to orthopedic impairments (La Plante, 1991\(^2\)). The quantity and epidemiology of wheelchair user etiology has changed over the past 40 years. Between 1980 and 1990 alone, the use of wheelchairs has increased 96.1 per cent (McNeil 1991-92\(^3\)). Advances in the medical arena have lead to many methods of prolonging life, that increasing the demand for wheelchairs.

There are numerous grounds for a person to need wheelchair assistance. These causes fall into two major categories: traumatic injury and chronic and degenerative disease. The table over the page presents data obtained in a survey conducted by the British Ministry of Health which gave the diagnosis per hundred of patients who obtained wheelchairs in a controlled study.

---

It is estimated that 5 per cent of people over 70 years old are wheelchair users (Sonn and Grimby, 1994\(^4\)). This age specific prevalence of disability is therefore higher for elderly persons, which places them in a large subcategory of wheelchair users (Morbidity and Mortality Weekly Report, 1994\(^5\)).

For the elderly, the more common causes for wheelchair requirement are arthritis/rheumatism, hypertension, diabetes, cardiac and respiratory disease (Pickles and Topping, 1994\(^6\)). The most prevailing reason these patients give for requesting a wheelchair is arthritis and unsteadiness (18.2 per cent), with strokes and frequent falls ranked second and third respectively. Most of these patients (54.5 per cent) use their wheelchairs all the time (Brooks, 1994\(^7\)).

\[ \begin{array}{|l|c|} 
\hline
\text{Condition} & \text{(Per cent affected)} \\
\hline
\text{Arthritis} & 28 \\
\text{Organic nervous disease} & 14 \\
\text{Cerebral vascular disease} & 13 \\
\text{Other bone injuries and deformities} & 11 \\
\text{Lower limb amputations} & 9 \\
\text{Cerebral palsy} & 8 \\
\text{Traumatic paraplegia} & 7 \\
\text{Respiratory and cardiac disease} & 5 \\
\hline
\end{array} \]


Some of the other product's characteristics that may be evaluated by product tests (subsection 2.3.4, page 25) may also be applied to walking aids.

2.5.5.2 Wheelchairs

Most people who suffer from disorders such as cerebral palsy (loss of control over movement), muscular dystrophy (loss of muscular strength), and multiple sclerosis (motor incoordination) may require the use of wheelchairs. Frequently, some type of paralysis results in wheelchair use. It may be in the lower half of the body (paraplegia), in all four limbs (quadriplegia), or in either the right half or left half of the body (hemiplegia). Paralysis may be accompanied by diminished body strength in other parts of the body. But, it should be noted that not all people using wheelchairs have completely lost their mobility.

More than 500,000 people in the U.K. use a wheelchair and, as the population ages towards the end of this century, this number will increase (Barrett et al., 1998 and Kelsall, 1993). Most users consider wheelchairs as an extension of themselves because they permit increasing independence, energy saving and a better integration into social life.

Wheelchairs should maximise users' mobility, independence, comfort and confidence. Kelsall (op.cit.) points out that the basic requirements for a wheelchair are a) to provide a stable and adjustable seat, which is easy to use and manoeuvre, both by disabled persons and carers and b) be aesthetically attractive.

There are hundreds of different wheelchair models with a range of sizes, weights and prices and, as well, an extensive number of special features, extras and accessories to cover most needs. The market provides wheelchairs to be used at home, on the street, folding, with or without a motor, sports wheelchairs, etc. The basic standard wheelchair for personal use has a straight back and arms, that are fixed to the chair, large drive wheels at the back, castors at the front, brakes and, usually, removable footrests (Hale, 1979). Modified versions of the basic chair design include: models designed for one-hand propelling with special double-rimmed wheels that can be mounted on either side; models for leg amputees with drive wheels set further back to compensate for the shift in weight; models for hemiplegics which have a lower seat to permit foot propelling; sport models and small and adjustable chair models for children and growing youngsters.

According to Holden et al. (1988), the typical user of wheelchairs may be classified as: a) ambulatory but weak, with low exercise tolerance, painful arthritic joints, or poor coordination; b) mobile, non-ambulatory (can walk very little and only with supervision); and
c) immobile (individuals with limited tolerance for walking due to lower limb amputations, respiratory disease, stroke, or severe heart problems. The majority of users are elderly (Royal College of Physicians of London, 1995) and a significant proportion can walk independently but have low exercise tolerance (Hunter, 1987).

Generally speaking, there are three classes of vehicles for disabled mobility which include wheelchairs. Figure 2.4 (based on Barrett et al., 1998; Disabled Living Foundation, 1993; Kelsall, 1993; Kelsall, 1994 and Weyers, 1986) shows the description of each category illustrated with some examples. A more extensive description of the different sorts of wheelchairs shown in Figure 2.4 is provided in Appendix 2.1 (page 365).

Figures 2.5 and 2.6 show the main components of standard manual and electrical wheelchairs. These components are explained in Appendix 2.2 (page 371) using information provided by Barrett et al., 1998; Disabled Living Foundation, 1993 and Kelsall, 1993.

Apart from medical and therapeutic issues, wheelchair design involves studies related to industrial design, engineering and ergonomics. The ergonomics approach to wheelchair design must include a variety of techniques from physiological to behavioural assessment. Both the approach of the ergonomist and that of the industrial designer should include investigations on a) data related to body dimensions, physical workload, functional demands, posture, subjective evaluation and product safety; b) tasks including transferring, driving, sitting, braking, folding and loading and c) the environment in which the wheelchair will be used. The correct approach to these topics is absolutely necessary to meet user needs. Furthermore, when a carer is required to push a wheelchair, the workload of this second user is as relevant to wheelchair design as that of the physically handicapped person.

Recently the number of innovations in wheelchair design has increased relative to old fashion designs. However, few manufacturers have used, for instance, some technologies available from the racing bicycle industry in order to produce lighter, stronger and more manoeuvrable wheelchairs. Wheelchairs with these characteristics will certainly contribute to improving the mobility and independence of their users.

Oldenkamp (1990) states that if a new wheelchair is to be designed, it is important from a marketing point of view, to establish the market position of this new product: which partial problem of mobility should this wheelchair solve and what other products already solve related mobility problems.
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CLASS 1 VEHICLES
Manual Wheelchairs
(children and adults)

Standard self-propelled wheelchairs
Designed generally with large rear wheels and pushing rims, these indoor and outdoor wheelchairs are foldable and suitable for use by a person who has sufficient upper limb strength, stamina and ability to propel and manoeuvre the chair safely.

Attendant-propelled wheelchairs
Designed to be pushed by an attendant. The typical model usually has rear wheels with pneumatic tyres and swivelling front castors with solid tyres.

Pushchairs
Comprised, usually, of lightweight folding frames and canvas slings seat.

High performance lightweight wheelchair

Special manual wheelchairs
They are designed for specific purposes (e.g. sport or high performance lightweight wheelchairs) or to provide a specific function (e.g. tilt-in-space).

Sports wheelchairs

Others manual wheelchairs

1. Rigid frame
2. Folding frame

3. Typical model
4. Caster wheelchair
5. Porter wheelchair

6. Typical model

7. Comfort wch.
8. Rigid frame
9. Folding frame

11. Tennis wheelchair
12. Racing wheelchair
13. Hand cycle

14. Tilt-in-space
15. Elevating seat
16. Stand-up wch.

Roller Ramply
Scootaway Ramply

Aylesbury 453 Novice
Gillochance Chair No. 514 DMA
Euro Chair Braden

Zipper 2 Quikie

Comforts Sunrise
Action Pro T Invacare
Sota SL

Quatro RUK
Top End 7.0 Invacare
Top End Eliminator GB

Quinto 75
Marga Goiris
Levo Compact LC

Car Chair Company Ltd
Figure 2.4
Classes of mobility vehicles (including wheelchairs) for the disabled and elderly (cont.)

**CLASS 2 VEHICLES**
Electric Wheelchairs and Scooters
(children and adults)

**Electrical wheelchairs**
Battery operated wheelchairs usually controlled by a joystick. They can be used indoors and/or outdoors to cover medium to long distance range.

18. Indoor only
19. Indoor/outdoor
20. Outdoor only

![Images of wheelchairs for Classes 18-20]

**Electrical wheelchairs for children**
Battery operated wheelchairs usually controlled by a joystick. They are more compact, adjustable and mainly for indoor use.

21. Typical model

![Image of a typical model for children]

**Special electrical wheelchairs**
Electrical wheelchairs with features designed to meet specific users' needs.

22. Position and reclining
23. Outdoor front-wheel drive wheelchair
24. Stairclimbers wheelchairs

![Images of wheelchairs for Classes 22-24]

**Scooters**
Three or four wheeled vehicles for indoor or outdoor use. Scooters can cover medium or long distances and can be dismantled for transporting.

25. Indoor/outdoor
26. Outdoor

![Images of scooters for Classes 25 and 26]

**CLASS 3 VEHICLES**
Electric Wheelchairs and Scooters
(users over 14 years)

**Electrical wheelchairs**
Same characteristics as the Class 2 outdoor wheelchair with features of a Class 3 vehicle.

27. Typical model

![Image of a typical model for Class 27]

**Scooters**
Same characteristics as the Class 2 outdoor scooter with features of a Class 3 vehicle.

28. Typical model

![Image of a typical model for Class 28]
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Figure 2.5
Components of a typical model of a manual wheelchair

Figure 2.6
Components of a typical model of an electrical wheelchair
According to Woude (1993), from an ergonomics perspective the demands set to the wheelchair-user combination can be formulated in three major areas of interest: a) the vehicle mechanics of the wheelchair, b) the functional capacity of the wheelchair user and c) the wheelchair-user interface. Certainly, it is probably in the last named that ergonomists can provide more contributions.

Barrett et al. (1998) and Kelsall (1993) state some general considerations that must be taken into account when choosing or purchasing wheelchairs:

- **Suitability**: a person's ability to propel the wheelchair, the method of propulsion, fit to the user in different postures, matching the user's weight and balance (including ease of modification, ease of access/egress, etc.)
- **Adjustments**: the frequency with which wheelchair components will need to be adjusted and how easy adjustment is
- **Comfort**: pressure sores due to long-term use, type of material used in upholstery and the physical condition of the user (bone prominence, sensitive skin, perspiration, etc.). Engel (1993) defends the transfer of knowledge about comfort on modern office chairs to wheelchair design
- **Acceptance of equipment**: wheelchairs must be attractive to their users, of good appearance and people should be able to use them with ease and confidence
- **Dimensions**: compatibility with the user's size and shape
- **Safety**: stability in use, no sharp edges, no apertures where fingers may catch, no insecure or collapsible parts or easily removable small parts which may be swallowed or lost
- **Durability**: good fatigue resistance to frequently occurring loads
- **Easy cleaning**: upholstery and padding which is easy to clean and dry, no inaccessible corners
- **Ease of transportation and storage**: weight, dimensions, easy to fold up or dismantle
- **Ease of repair and availability of spares**: availability of experienced facilities and reasonably priced of spare parts and accessories
- **Reasonable price**: good value for money.

These properties are similar to those stated in the evaluation of products in general, given on page 25.

Barrett and Kelsall also state that the following factors need to be taken into account when choosing a wheelchair:
• The physical measurements of the user and the wheelchair. Sitting height, sitting length, lower leg length, and hip width, for the wheelchair user. Seat width, seat height from the ground, seat depth from front to back, backrest height, for the wheelchair.

• The person's functional impairments and abilities. The ability the user has to propel the wheelchair (considering his or her strength, ability to grip, the weight of the wheelchair, the size of the castors and so on) and the method of wheelchair propulsion (either by the user or the carer).

• The social and environmental factors. The user's lifestyle, and characteristics of the home and the environment where the user lives.

• The costs of purchase and maintenance.

Reviews, recommendations and a large number of reports on wheelchair development and its use have been published by authors as Barrett et al. (1998); Cooper (1995); Cooper et al. (1997); Cunniffe (1974); Engström (1993); Fenwick (1977); Kelsall (1993); Platts (1971); Vanlandewijck, Spaepen and Theisen (1997); Woude et al. (1993); and Zacharkow (1988) and journals, including Biomechanical Engineering, British Journal of Occupational Therapy, Prosthetics and Orthotics International, Rehabilitation & Progress Reports, Rehabilitation and Research Development. A comprehensive study about the evaluation and development of wheelchairs is provided by Kamenetz (1969).

The British Standards Institute draws up guidelines with which manufacturing industry must conform to try and ensure safety and effectiveness. Standards for disability equipment are listed and indexed in the British Standards Institute Catalogues (BSI 1991). Manufacturers who have had their products successfully tested to satisfy the requirements essential for them to be considered safe and fit for their purpose, can claim the CE marking. A product which has the CE marking can be freely marketed throughout the European Community without further control given that it meets the legislative requirements of the relevant member state.

According to Cooper et al. (1997), the American National Standards Institute (ANSI)/RESNA and the International Organization for Standards (ISO) have developed standardised tests for wheelchairs. The results of which are disclosed to the public. These standards allow the user to select a wheelchair based upon performance, safety and dimensions. The standards serve as a guide to avoid design-related accidents that may occur, based upon the disclosed information.

The next section analyses the currently available methods in design and manufacture of products based on user needs.
2.6 Methods based on user needs for the design and manufacture of products

2.6.1 General considerations

Times have changed and, consequently, products have also changed. In practice, products move on a continuous spectrum from traditional to modern (Gryna, 1988). For example, the advent of microwave cooking has changed the food industry from traditional to modern. The earliest automobiles and telephones were traditional in simplicity but now are modern in complexity. The change from traditional to modern, states the author, is often gradual and can mask the need for new approaches in product development including additional manufacturing and managerial methods and technological tools.

Manufacturing is generally defined as the conversion of raw materials, generally in a large-scale operation, into products. The basis of modern manufacturing is to accomplish this conversion with ease, quickness and economy. Quality is a powerful tool used by companies worldwide to guarantee the strength of their products so that they remain competitive.

As was cited previously in this thesis, the concept of quality adopted here is a user-based one as defined by Juran (1988). It consists of specifying those product features which meet the needs of consumers and thereby provide product satisfaction.

Quality is an ambiguous term that is easily misunderstood depending on the context in which it is used. In everyday speech, its synonyms range from luxury and merit to excellence and value. According to Garvin (1988), in terms of academic literature, the concept of quality varies with the group using them. Each group has a different analytical framework and its own terminology. Marketing people, engineers and manufacturers have different interpretations of quality: user-based, product-based and manufacturing-based approaches. This frequently results in conflicts and serious breakdown in communication. To overcome this problem a broader perspective is required on quality within this three approaches. All the principal approaches to quality are vague and imprecise when it comes to describing the basic elements of product quality (Garvin, op. cit.).

Garvin identifies eight categories of quality:
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- **Performance**: the primary operating characteristics of a product. E.g. acceleration, handling, cruising speed and comfort for an automobile; sound, picture clarity and colour for a television set; etc.
- **Features**: those secondary characteristics that supplement the product's basic functioning. E.g. different fabric cycles on a washing machine; automatic tuners, stereo sound on a colour television set; etc.
- **Conformance**: the degree to which a product's design and operating characteristics meet pre-established standards
- **Durability**: the amount of use one gets from a product before it physically deteriorates or needs replacement
- **Reliability**: the probability of a product's malfunctioning or failing within a specific period of time
- **Serviceability**: the speed, courtesy, competence and ease of repair
- **Perceived quality**: composition by indirect perceptions inferred from various aspects of the product. Image and reputation of the product, for instance
- **Aesthetics**: how a product looks, feels, sounds, tastes or smells.

These categories represent diverse concepts: measurable product attributes, individual preferences, objectivity, time, fashion, inherent characteristics of goods, attributed characteristics, etc. The diversity of these concepts helps to explain the relationship between the different approaches and the categories of quality: the product-based approach on performance, features and durability; the user-based-approach, on aesthetics and perceived quality and the manufacturing-based approach, on conformance and reliability.

The rapid growing of a very competitive market requires quality in all aspects of the company's operations, with things being done right first time and defects and waste eradicated, as much as possible, from operations. This kind of approach is known as Total Quality Management (TQM). The goal of TQM is to base product development on customer needs. Customer satisfaction is the company's highest priority and is obtained by providing a high-quality product and continuously improving the quality of the product to maintain a high level of customer satisfaction (Erhorn and Stark, 1994). Thus, it is no exaggeration to say that a thorough and accurate understanding of customer and market demands is the key to successful new product development (Shindo, Kubota and Toyouni, 1990).

Customer needs and product specifications are useful for guiding the conceptual phase of product design. However, during the later activities of the product development phases teams often have difficulty linking needs and requirements to the specific design issues they face (Ulrich and Eppinger, 1995). According to the authors, for this reason, *Design for X* (DFX)
methodologies are usually practised by teams. The "X" may correspond to one of dozens of quality criteria such as reliability, robustness, serviceability, environmental impact or manufacturability. Examples of these methodologies are: Design for manufacturability (DFM), Design for Assembly (DFA) and Design for Automation.

There are some methods that try to anticipate potential problems in manufacturing to the product design stage like, for example, Functional Cost Analysis, Failure Model and Effect Analysis, Functional Trees, Taguchi Method, Quality Function Deployment, Kansei Engineering and so on. The unique methods which are based firmly on an assessment of customer needs are Quality Function Deployment (QFD) and Kansei Engineering. They will be discussed in the next two sub-sections.

2.6.2 Quality Function Deployment (QFD)

QFD could be defined as a product (service) development process based on interfunctional teams (marketing, manufacturing, and engineering) who use a series of matrices, which look like "houses", to deploy customer input throughout design, manufacturing, and service delivery (Griffin and Hauser, 1993). According to the authors, QFD uses perceptions of customer needs as a lens by which to understand new product characteristics and service policies affecting customer preference, satisfaction, and ultimately, sales.

The main goal of QFD is to ensure that customer satisfaction and consumer needs are its inputs. In truth, QFD is a method that tries to translate the "voice of the consumer" into product requirements. In other words, it translates the consumers’ demands into design targets and major assurance points to be used throughout the production stage. QFD is a way to ensure design quality while the product is still in the design stage (Akao, 1990). It is particularly suitable for complex products or processes and should not be used as an isolated process in a sector of a company or in a supplier.

Quality function deployment has been broadly used, in the last decade, by hundreds of companies worldwide. QFD was originated at Mitsubishi’s Kobe Shipyards - Japan, in 1972 and was subsequently brought to the United States in the middle of the 80s for initial application at Ford and Xerox. Menon et al. (1994) say that QFD is now at a mature stage of implementation and can sustain the claim that it is an effective tool for systematic capture of consumer needs and addressing those needs in a structured manner within multi-functional product development teams. Several different kinds of industries have successfully applied
QFD, notably for automobiles, aero-space, copiers, defence, consumer goods, electronics, textiles, computers (main-frame, mid-range, work station and personal) and software.

Successful accounts of using QFD are reported by a number of authors including Pugh (1991), Sullivan (1986), King (1989) and Zairi (1993). Sullivan (op. cit.) reported that in 1979 two years after the Japanese automobile company, Toyota, had launched a new van, the use of QFD enable the company to obtain a reduction of 20% in their start-up costs; a further reduction of 38% in 1984 and a cumulative 61% reduction in 1984. During this period, affirms the author, the product development cycle was reduced by one third with a corresponding improvement in quality because of a reduction in the number of engineering changes.

QFD uses a visual data-presentation format carried out by a series of translation matrices which have a similar structure (in the form of houses). Although QFD could basically use four "houses" to present data, this number could vary depending on the properties and complexity of the product and the level of detail required. The main four linked houses conveying the customer's voice through to manufacturing are named: House of Quality (HOQ), Parts Deployment, Process Planning, and Production Planning. It is important to observe that the "hows" - the roof (House I, Figure 2.7) - of the HOQ (engineering characteristics) are transformed into the "what" of the House II. In its turn, the "hows" of the Parts Deployment' house (parts characteristics, House II) are converted in the "whats" of the next house (House III) and so forth. An overview of the House of Quality (House I) that constitutes the QFD process is given below (adapted from Akao, 1990; Hauser and Clausing, 1988; Menon et al., 1994; Pugh, 1991 and Sullivan, 1986). The other Houses (II, III, and IV) are not subsequently analysed in detail as they relate to the manufacturing process and not to product design.

The House of Quality

The House of Quality (HOQ) of QFD links customer need to the desired and specific product characteristics. According to Hauser and Clausing (1988), the HOQ is a way to summarize basic data in a usable form for the engineers. It represents the customer's voice for the marketing team and is a method to discover strategic opportunities for managers. Indeed, the house encourages all of these groups to work together to understand one another's priorities and goals.

Maybe the most important step during the design of a HOQ is the first one: capturing the user needs. Having an accurate "voice" from the right "consumer" is critical to the success of QFD. The design of this house evolves seven distinct phases described as follows. Figure 2.7 shows
the components of the QFD house of quality. A more detailed discussion about QFD is given in Chapter 6, sub-section 6.2.4 with emphases on the design of wheelchairs. An example of a partially complete QFD table is shown in Chapter 6, Figure 6.3, page 300.

**First phase - Identifying User Needs (The "whats")**

The process starts by capturing what the user requires in the product and establishing a relative prioritisation. This will generate a "What list", the basis of the *User requirement* component (Component 1 in Figure 2.7).

Figure 2.7
Components of the QFD house of quality
User Requirements (URs) are composed of the consumer own phrases - derived from market research and competitor analysis - that they use to describe products and product characteristics. A QFD matrix for the design of a wheelchair is illustrated in Figure 6.3, page 300. It shows the house's basic concept. A typical application has 30 to 100 User Requirements, such as: "reduce weight of wheelchairs", "produce foldable wheelchairs", "allow easy traverse of difficult terrain", "easy to remove wheels", etc. Some may include demands of regulators ("safe in a side collision"), needs of retailers ("easy to display"), requirements of vendors ("satisfy assembly and service organisations"), and so forth. The accuracy and quality of this first phase is crucial to what follows. It is also the most difficult because it requires the procurement of the real user needs and not what the team thinks that user needs.

Second phase - Attributing relative-importance weights to User Requirements

Some requirements have different levels of importance for the user and to satisfy them designers have to trade off one benefit against another. Statistical techniques can be used to allow users to state their preferences with respect to existing and hypothetical products. Weighting, representing prioritisation of user requirements, is displayed in the HOQ, after the column of user requirements (Component 2 in Figures 2.7).

Third phase - Establishing product characteristics (The "hows")

Users' needs are typically subjective expressions helpful in developing an understanding of what the users want. However, they offer little guidance about how to design and engineer the product (Ulrich, 1995). Phase 3 of the design of HOQ corresponds to describing the user requirements in the language of the designer/engineer. The team identifies those measurable aspects of the product or service which, if modified, would affect users' perceptions generating a "How list" of design attributes. Product/engineering characteristics or requirements depend on the use of which the product is put. Along the top of the matrix is a list of those technical characteristics that affect one or more user attributes. These characteristics - named Engineering Characteristics (ECs, Component 3 in Figure 2.7) - will be developed as the basis for subsequent product design and process development and must be described in measurable terms. The engineering characteristics will be deployed through design, manufacturing, assembly and technical assistance in such a form that a product's final performance meets user requirements.
Fourth Phase - Establishing relationship between different engineering characteristics

The HOQ's roof is the Correlation Matrix (Component 4, Figure 2.7) which specifies the relationship among the engineering characteristics. It helps the design/engineering team to specify the several engineering features that have to be improved collaterally. A cross-verification permits identification of critical information when designers/engineers need to balance the trade-offs in terms of user benefits.

Fifth Phase - Designing the Relationship Matrix

The Relationship Matrix (Component 5, Figure 2.7), the body of the HOQ, is a relationship matrix that displays judgements (or experiments) indicating which design attributes or engineering characteristics items affect user requirements by how much. The degree of correlation will be defined using appropriate numbers (9 = strong, 3 = moderate and 1 = weak) to determine the strength of each correlation. This evaluation will be established by the project team, in a consensual way, based on experience, user responses, statistical studies or controlled experiments. The absolute and relative importance will be given for each engineering characteristics (Components 7 and 8 in Figure 2.7). See details on how to attribute absolute and relative importance in Chapter 6, page 301.

Sixth Phase - Identifying consumer perceptions and service complaints

This phase is to identify the degree of competitiveness, using a user preference chart, to obtain user perceptions between in-house and competitor products and service complaints related to each user requirement (Component 6, Figure 2.7). Ideally, these evaluations are based on scientific surveys of customers carried out by marketing teams. This section of the HOQ enables direct assessment of the proposed specification and determines the potential positioning of the in-house product against the competition. This procedure identifies strong and weak points of the product and gives the opportunity for improvement.

Seventh Phase - Assessing competitors

In this phase Units of measurement are given to each engineering characteristics (Component 9, Figure 2.7) and a comparation is made with the competitor's specifications for each of the product's engineering characteristics.
Eighth Phase - Defining technical difficulty and objective target value

Once the team has identified the user requirements and linked them to engineering characteristics, rows which summarize target values for each engineering characteristic (Component 11, Figure 2.7) and the technical difficulty (Component 12, Figure 2.7) of changing design attributes/product characteristics/engineering requirements are included at the bottom of the HOQ.

The house of quality of Quality Function Deployment is now completed. It is important to observe that the detailed structure of the matrices can vary depending on the application.

The process of QFD continues after finishing the house of quality. Other linked houses conveying the user's voice through to manufacturing will be designed. These houses have the same structure as the HOQ and the "hows" of one stage becomes the "whats" of the next (Figure 2.8). They are summarised below:

- Parts Deployment
  The second house of QFD (see II in Figure 2.8) links engineering characteristics to actions to be taken to define part characteristics. An engineering characteristic (e.g., "bending system in the aluminium tubing") - the "how" from the analysed HOQ - can become the Part Characteristics - the "what" - of the Parts Deployment house. These part characteristics can be "include flexible junctions in the middle part at the ends of the tubing", for instance.

Figure 2.8
The translation process of linked houses of QFD
• Process Planning
The third matrix of QFD (see III in Figure 2.8) links action to implementation decisions such as manufacturing process operation. Once more, the "how" of the previous matrix - Part Deployment house - become the "what" of this matrix. For example, include "flexible junctions in the middle part and at the end of the tubing" ("how") of Part Deployment house will be allocated in the vertical column ("what") of the Process Planning house. The "what" of this matrix can deploy important process operations, like "make a hole in each tip of the tubing and insert a screw in each": the "how" of this matrix.

• Production Planning
Finally, the fourth house (see IV in Figure 2.8), links the manufacturing process operation to Production Planning with detailed operation requirements. The key Process operations, like "make a hole in each tip of the tubing and insert a screw", become the "whats", and production requirements - operator training, diameters and other dimensions - become the "hows".

The success of QFD is strongly linked to the organisation of the team. All difficulties in maintaining communication and conflicting objectives amongst team members must be overcome. According to Menon et al. (1994) one other important issue to be taken in account when applying QFD is the adequacy of the support tools. The product development process is frequently so detailed and complicated that no one individual can comprehend it all, and the implementation of QFD can falter through the lack of suitable tools - an applied computer technology, for instance - to guide the team through the maze of information.

2.6.3 Kansei Engineering
No discussion of user-centred design methodologies would be complete without some reference to Kansei Engineering (KE). It is a new consumer-oriented product development technology that aims to transform customers' perceptions, feeling and mental images into a tangible product (Nagamachi, 1995; Horiguchi and Suetomi, 1995). When a consumer wants to buy a new product, he or she expresses the wish with words such as "gorgeous, beautiful and strong with an inexpensive price". KE is able to interpret and transfer the psychological implications of these words to the details of the design of the product (Nagamachi, 1994).

According to Noro (1993), kansei is a Japanese word that has no exact English word to describe it. The closest translation for Kansei can be feeling, sensibility and comfort, but none of them is said to appropriately denote it. For this reason, kansei is used in its Japanese form.
Ishihara et al. (1995) claims that KE, in addition to helping the customer to select a product that fits his or her feeling also provides the designers with a tool to link consumers' feelings and design. To obtain relations between Kansei and design details, several analyses must be made to determine which types of external appearances and functions produce what kind of feelings. KE has been applied to fashion design, automobile doors, car interior design and office chairs.

KE is a not yet a mature technology. It seems to have a very promising future mainly with the use of virtual reality. Apart from the several successful accounts using KE, Nagamachi (1995) states that many problems still remain to be solved. Because KE is relatively immature and in need of further development and because QFD incorporates (or can incorporate) the essential features of KE, it is not discussed further.

2.7 Summary of important points from the literature

This chapter has provided an overview of the literature currently available on ergonomics and product design applied to the design of products for disabled mobility. Some important lessons applicable to disabled issues have been learned. These are summarised below.

Looking for ergonomically well designed products

- Users of consumer products are often untrained, unskilled, and unsupervised. They may be of any age, of either sex, or any physical condition; and may have widely varying educational, cultural, and economic backgrounds.
- Consumers often do not buy consumer products just because of their inherent utility but also because of the subjective values attached to them.
- The increase of competitiveness in modern consumer markets has stimulated companies to emphasise quality.
- Reducing losses during product manufacturing, reducing warranty claims, reducing product development cycle time and improving user satisfaction are objectives of quality.
- The necessity to deliver quality, which is based on the customer, to either the able-bodied or the disabled consumer, is a question of survival for companies.
- Ergonomics plays an important role in guaranteeing usability and, consequently, better performance for consumer products in general, and products for the disabled in particular.
- The balance between aesthetics, usability and manufacture/technology will distinguish good and bad designs and, consequently, ergonomically well designed products.
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- Ergonomically well designed products are those which consider a wide variety of users - the everyday user, the curious, old people, children, male, female, the healthy or unhealthy - offering safety, efficiency, comfort and aesthetic satisfaction, under normal conditions of use, and under foreseeable conditions of misuse. Although, in general, not all user satisfaction factors are necessarily ergonomic, ergonomically well designed products aim to guarantee user satisfaction.

- The design of products for the disabled is frequently guided to solve the problem within the context of the users' disability rather than taking into account the users' aspirations, desires and lifestyle as well as fulfilling its functional role.

**Ergonomics and Product Design**

- Ergonomics and product design perform distinct, but not incompatible, roles in the design of ergonomically well designed products for both able-bodied and disabled people.

- Although recognisable friction between ergonomics and product design has been mentioned by a number of authors, they are unanimous when they affirm that this disagreement needs to be overcome.

- Ergonomics plays three traditional roles in product development: a) identification of user needs, b) user interface design and c) test and evaluation.

- There are two fundamental psychological principles of design to make products understandable and usable: a) providing a good conceptual model and b) making things visible. These principles make the users the focal point of the design.

- The unique way to carry out design, with the user at the centre, is to use ergonomics from the beginning of the product development process.

- There are three main techniques which are currently used by product designers: CAID (computer-aided industrial design), task analysis and usability testing. These latter two have been used in the domain of ergonomics for several decades.

**The product design process**

- The product design process is a method composed of a set of rational and systematic procedures with the objective of conceiving and developing physical products to be employed by users.

- It is also a series of compromises between several product requirements: function, performance, reliability, usability, appearance and cost. To find the exact solution is sometimes very difficult and a compromise has to be established between several acceptable solutions.

- The design process for consumer products can be summarised as consisting of six main sequential, or sometimes concurrent, phases: a) specification; b) conceptualisation; c)
modelling and prototyping; d) product evaluation; e) production and f) marketing and evaluation.

- The measurement of the interaction between consumers and products can provide requirements to improve the product's ergonomic specifications and general qualities. Only by such an approach can inadequate designs be identified.
- Usability tests are an important and essential part in the product development process. They are concerned both with: obtaining user requirements prior to or initiating the product design process and in the early stages of design; and with evaluating products when they have been built.
- The necessity to evaluate consumer products physically and ergonomically comes from the necessity of manufacturers to evaluate their new products and compare them with those already on the market, especially those of competitors.
- An extremely difficult problem, faced by the manufacturers of products for disabled populations, is that on the one hand the manufacturers need to produce the highest possible volume of products to reduce manufacturing costs, whilst on the other, these products should suit the users' individual capabilities and limitations. Taking into account individual needs, the use of the "design for all" approach and modular design may be the solution to this problem.
- Attending to safety standards and regulations is an essential part of the design process.

**Consumer needs**

- Apart from needs resulting from their disabilities, which are crucial, the needs of the disabled population are the same as those of the able-bodied population in terms of aspirations, uniqueness, values and status.
- Marketing strategy explores widely the consumer product characteristics which aim to meet people's aspirations, values and status symbols. However, marketing strategies have been applied very timidly to products for independent living. This is mainly because the main consumer is the N.H.S., or other government agencies, and not the actual people who use the product.
- Investigating consumer needs provides the designer with the potential to obtain feedback among users on the performance and acceptability of the design. The feedback enables the designer to make modifications that will improve the original design.
- As a result of meeting or not meeting their needs, users will express their satisfaction or dissatisfaction with the product.
- In terms of product design, consumer satisfaction is compounded of visual appeal, "feel", functionality, expectations and aesthetics. Concentrating on any one aspect to the detriment of another may cause dissatisfaction.
In terms of products designed for the disabled population, the medical and therapeutic characteristics of the product are part of its functional features which, in conjunction with the other product features, must meet user needs and contribute to consumer satisfaction.

**Design for the disabled population**
- The number of disabled people in the United Kingdom is around 6.561 million. More than 500,000 of these are wheelchair users.
- The serious impact the very large population of disabled people has on mass-market products is beginning to be recognised by manufacturers.
- When a product is specific to a special segment of the disabled population the economic buying potential decreases substantially and consequently may not receive enough design attention.
- Differences in age, size, shape, weight, etc. for both able-bodied and disabled persons make designing products to satisfy the whole range of such diversity practically impossible.
- However, designing products for those with disabilities, keeping the able bodied in mind, and vice versa, respecting their differences and needs, would avoid the standard marketing problem of segmenting the handicapped from the able-bodied.
- Products usable by disabled consumers will usually be well-accepted among a portion of the able-bodied and aging population, especially if those products do not carry with them a stigma of handicap.
- Although elderly and disabled people should be included in the design process, it is not possible to design all products and devices so that they are usable by all individuals.
- The ergonomics approach to wheelchair design must include a variety of techniques from physiological to behavioural assessment.
- Both the approach of the ergonomist and that of the industrial designer will contribute to meeting user needs and should include investigations on a) data related to body dimensions, physical workload, functional demands, posture, subjective evaluation and product safety; b) tasks including transferring, driving, sitting, braking, folding and loading and c) the environment in which the wheelchair will be used.

**Methods in design and manufacture of products based on user needs**
- The rapid growth of a very competitive market requires quality in all aspects of a company's operations, with things being done right first time and defects and waste eradicated, as much as possible, from operations.
- Customer satisfaction is the company's highest priority and is obtained by providing a high-quality product and continuously improving the quality of the product to maintain a high level of customer satisfaction.
In view of the statements above which comprise the lessons learned from the literature review, it can be seen that there are now well established design methods and practices which seem to be acceptable. The question then is whether in the field of wheelchair design these methods and practices are used effectively. To that end this thesis will examine the views of the stakeholders involved in the design and use of wheelchairs - the designers, the therapists, the rehabilitation engineers, the users and their carers - to see whether in fact what is regarded as being good practice, in terms of design process, design outcome and meeting wheelchairs users' requirements, is actually implemented. In the light of the results of the investigations with the stakeholders and the information contained in the literature review, a method for wheelchair design, which has the user as the centred core, will be produced (if necessary) aiming to improve design practice in this sector. Finally, the method will be introduced to a number of designers to see to what extent it is acceptable to them.
Part 2: FIELD STUDIES

- Approaching the process of wheelchair design
- Approaching the process of wheelchair supply and prescription
- Approaching the process of wheelchair use
Chapter 3: Approaching the Process of Wheelchair Design

3.1 Strategy and design of the field study with wheelchair designers

A field study was carried out to bring to light how a sample of designers approaches the design of wheelchairs, what kind of data they need from users and what demands disabled users make in the design of equipment to enable or enhance mobility. For this purpose, a sample of design practitioners working in organisations in England, Scotland and Wales was interviewed. For reasons of commercial confidentiality they collaborated on the condition that they would not be identified. After close investigation, it appeared that the majority of wheelchair models (of which there are many) are produced by a very few manufacturers and their associated designers. The designers who participated in this survey represent companies which provide the vast majority of wheelchairs produced in the United Kingdom.

The organisations that took part in the survey were comprised of: a) companies that produce wheelchairs on a large scale; b) companies that produce wheelchairs by requirement, on a customer-build basis; c) a governmental organisation (hospital) that develops and provides wheelchairs for people with mobility problems and d) one company that produces a battery driven vehicle.

The field survey involved both a) completion of a questionnaire to be answered with the guidance of an interviewer and b) the sending out of questionnaires by mail to some places which were inaccessible to the interviewer. From the six questionnaires sent by post just one was returned. The total number of wheelchair manufacturers identified in the United Kingdom is currently 21 companies (Kelsall, 1993).

The work was conducted in two stages. The first, comprising the pilot questionnaires, involved a total of three interviews. The second comprised the eight remaining questionnaires
of the sample. This gave us a total of ten interviews with designers plus one questionnaire sent by post. The final version of the questionnaire did not undergo any alteration from the pilot version, except for the inclusion of one specific question about costs. All the interviews were tape-recorded and transcribed.

The "Questionnaires for Wheelchair Designers" comprised 43 questions (see Appendix 3.1, page 375). Most were open-ended questions to permit the interviewer to ask further questions and have further discussions. The questionnaires were divided into eight parts:

- Personal data
- Exploratory questions about ergonomics
- Exploratory question about design method(s)
- Exploratory questions about design specifications (identifying user needs, using literature data and using standards)
- Exploratory questions about conceptualisation in design
- Exploratory questions about prototyping of products
- Exploratory questions about production
- Exploratory questions about product evaluation and marketing

A descriptive analysis of the answers obtained from the sample is outlined in the next section and subsections. As conceptualisation and prototyping are parts of the design method, it was decided to analyse the items "Exploratory questions about conceptualisation" and "Exploratory questions about prototyping" with the topic "Exploratory question about design method(s)".

### 3.2 Analysis of questionnaires

#### 3.2.1 Personal data

The sample of design practitioners in this survey consisted of one Ph.D. Rehabilitation Engineer, two Mechanical Engineers (one of those a M.Sc. Biomedical Engineer and current PhD Student), one Metallurgical Engineer, one Industrial Designer and six people with Secondary school/Technical Training. They occupied different positions in the organisation such as proprietor, research and development manager, project manager, product development manager, rehabilitation engineer, design engineer and technical engineer. All those interviewees who were also owners only had secondary school and/or technical training
educational background. They were proprietors of small companies with several years of experience. The largest companies were divided into several departments and the people responsible for managerial functions or product development sectors generally had a higher educational background.

### 3.2.2 Exploratory questions about ergonomics

Just three people in the sample had formal academic training in ergonomics, as part of educational programmes in other disciplines. Although everyone had heard the word "ergonomics" no one knew exactly what it meant, which is surprising given what is stated in the previous sentence. For some, the concept of ergonomics is related to product comfort and its convenience in use; for others, it is associated with physical aspects of the human body. Very few people in the sample were able to identify ergonomics as something beyond the product development domain.

Respondents were unanimous in referring to the importance of ergonomics in the design of wheelchairs. According to them, ergonomics should be considered a) to provide comfort, ease and convenience of use for both user and carer; b) to identify the most efficient use of disabled peoples' limited physical resources; c) to recognise different strengths, abilities and reaches of people with different degrees of disability; d) to contribute to the understanding of the wheelchair as part of a disabled mobility system, i.e. the wheelchair as an extension of the disabled body and an extension of their ability to become mobile; and, finally e) to be responsible for the man-machine interface, particularly in respect to some aspects such as manoeuvrability and control, and seating design.

Curiously, as has been seen already, on the one hand respondents regarded ergonomics as important in contributing to wheelchair design, on the other hand the use of ergonomics in wheelchair development process leaves much to be desired. What will be reported in the next sections is that when ergonomics has been used by respondents in the design process, it has been done with an unsystematic approach.

### 3.2.3 Exploratory question about Design Methods

It was found in the survey, as previously mentioned, that companies broadly fell into two groups. On the one hand there are companies that produce wheelchairs on a small scale, as required on an individual customer basis (hereafter called "small companies"). On the other
hand there are companies that produce wheelchairs on a large scale, using mass-production techniques (henceforth called "large companies"). It is important to clarify that the words "small" and "large" companies used here refer only to the companies' type of production. Other factors, such as the volume of production, size of the company and its profits, are not taken into account when using these words. In view of this, it does not make sense to try compare, in terms of design process, "small" companies, producing wheelchairs by particular individuals, with the group of large companies which produce wheelchairs in a mass-production scale.

Flowcharts will be used below in the description and analysis of the product development process for some of the small and large companies which took part in the survey. For practical reasons, seven companies - three small and four large - were selected for this description and analysis. Four companies were eliminated: the first was a hospital (which is not a wheelchair manufacturer), the second was a manufacturer of scooters and the other two were already reflected in the seven chosen to be analysed below.

The selection of the seven companies, after the interviews with their designers, was done in terms of the identification of those which illustrated good design practices and those which did not. The analysis will be carried out in the light of what the literature pointed out as good design practice (see the Literature Review, Chapter 2, for a more detailed discussion).

The concept of good design practices adopted here refers to those practices which are able to trade-off several requirements through diverse product development phases, such as user requirements, design requirements and manufacturer requirements. As was shown in the literature review (Chapter 2, page 20), the traditional product design practice consists of a sequential process where each stage starts only when the previous one is completed (known as sequential engineering). Broadly speaking, in this process marketing identifies the needs for new products, price ranges and the performance expected by customers or potential consumers. The design and engineering departments receive specifications from marketing, and commonly work independently developing the technical requirements and final design details. This traditional approach mainly emphasises the functional aspects of the product, without considering other user requirements or process life-cycle requirements during the early stages of product development.

The modern approach takes customers into account capturing requirements from users and carrying out the product design process based on those requirements. According to what was mentioned in the Literature Review, it seems to be evident that this approach does produce a
better product. Hence, the term "good design practice" in this work addresses a systematic and integrated approach to the product design process, combining user, product and manufacturing to obtain viable solutions. Companies which adopt this modern approach are considered to produce good design practice in the forthcoming analysis.

3.2.3.1 Description of product development in companies which produce wheelchairs on a small scale ("small companies")

The three most significant (in term of design practice) small companies selected from the sample (henceforth called companies A, B and C) are characterised a) by designing wheelchairs from the individual requirements of users with special needs and b) attending to people with different degrees of disability. These special needs may require that the wheelchairs are designed to support overweight people or have some adaptations such as a ventilator carrier, an oxygen bottle carrier, a firm backrest, thoracic support, pelvic support, a head control, special leg rests and controls for leg rests and pressure relieving cushions.

Company A

Company A admits to not using a systematic approach in designing wheelchairs. Each product is built in a personalised way to meet special needs and is different from any other. The company uses a basic existing format and then incorporates the special needs into the final product design (Figure 3.1). After the design process, the final product ends up as a response to what customer requirements are, in terms of factors such as shape, size, weight and colour.

The company's owner and designer is a wheelchair user. No formal design method is followed through the design process. As each wheelchair is custom-built, direct contact with the user permits the design to meet individual user requirements.

Figure 3.1
Company A
**Company B**

The design process of Company B starts by capturing special seating needs (Figure 3.2). The individual's seating needs are identified and a prescription is written by bioengineers, rehabilitation doctors, physiotherapists or occupational therapists. The company has its own seating system that can be fixed quickly and easily. There is an attempt to build the wheelchair to look aesthetically pleasing. The design is carried out following some line drawings and written notes. A working prototype is manufactured. The design is discussed and evaluated by the team and sent to be evaluated by the Medical Devices Agency (M.D.A.) at Blackpool. Details are improved in the manufacture of the joints found in the structure of the wheelchair. The final product is manufactured as a full size working prototype based on the existing system. The respondent stated that his company is able to alter quickly and easily the main design of the wheelchair to incorporate any of the user needs that may arise.

According to the respondent, users do not take part in the design process. He pointed out that most users have limited or no communication abilities. Technical personnel are consulted on behalf of users. As with Company A, the design is based on the designer's technical expertise and assumptions about users' expectations. The company is predominantly an NHS supplier.
Company C

Company C starts the design process by carrying out a full assessment of the user (Figure 3.3). This includes patient's measurements, evaluation of his/her medical problems by a qualified nurse with the engineer - combining engineering requirements with medical needs - and the analysis of the home environment. The user requirements define the design criteria for the wheelchair. Every wheelchair is designed individually to meet a particular user's requirements. The company has a basic concept design which includes motor sizes, speeds, wheel sizes, castor sizes, a range of batteries and a range of controllers. A prototype is built incorporating some adaptations to suit individual needs. The prototype is checked by staff members. Adjustments are carried out before the wheelchair is sent to be checked by the user. If needs be, other adjustments are made before delivery.

The product design process carried out by Company C is quite similar to that of Company B. It is also based on designer expertise and assumptions of user needs. It is important to highlight the involvement of professionals in the health area, together with the engineer, to do a full assessment of the user. This seems to be a good practice in trying to overcome communication problems with severely disabled users.
3.2.3.2 Description of product development in companies which produce wheelchairs on a large scale ("large companies")

Apart from being responsible for a substantial amount of wheelchairs produced in the United Kingdom, the four companies analysed below were selected from the sample because they seemed to be the most representative in terms of design practices including: traditional sequential design, market-driven design and integrated design.

**Company D**

![Flowchart of Company D's product development process](image)

Outline specifications (from high level management and sales)

- Creativity sessions (brainstorming, forced connections, etc)
- Choice of 2 or 3 plausible solutions
- Development of more complete sketches and models
- Rendering (3/4 fairly viable solutions to the original specifications)
- Choice of 1 solution to be developed and detailed
- Development of chosen solution

**Production of 1st prototype**

- Evaluation
  - OK?
  - Not OK?

**Production of 2nd prototype**

- Evaluation
  - OK?
  - Not OK?

**Test chair (put through rigorous tests)**

- Evaluation
  - OK?
  - Not OK?

**Production**
Chapter 3: Wheelchair Design

The Company D design process starts with the specifications being outlined from high level management and sales (Figure 3.4, previous page). Creative sessions are carried out to identify broad solutions to the problem without getting down to detailed issues. The many ideas are distilled into two or three plausible solutions that are developed more fully via sketch renderings and models. After that, one solution is chosen by the designer to be developed and detailed.

Before building the first prototype, the solution is evaluated and modifications are made. When the first prototype is ready, evaluation and modifications will occur again. This will generate the second prototype. The process of constantly modifying the product continues through the second prototype. It will generate the test wheelchair that will be put through rigorous test before production.

This is a very traditional design process. The decisions are made by managers and technical personnel without any involvement of the users. It is important to point out that, although on the one hand it is very positive having several evaluations constantly applied through the various phases of product development, on the other hand it is negative that users do not take part in any of these phases.

Company E

The systematic method used for this company in its design process is based on an integrated approach of the several product design process phases (Figure 3.5). An integrated approach here means having some of the several phases of the design process (concept/product design, engineering design and manufacturing/production) carried out simultaneously. The company has a design protocol through which it goes in the various product design process stages.

The process starts off with a market brief. It is responsible for identifying user needs. This is consolidated through several conceptual stages starting from an appropriate staff selection who are capable of thinking horizontally and vertically and ending up with the application of creative techniques, such as brainstorming. The company tends to involve other people from outside the design team in problem solving. Few concept ideas come up from creative sessions that are modelled in three dimension form. Modelling at this level does not mean modelling the product itself but just aspects of the product. Small and large scale models are used to simulate functionality. Following that, functional tests are carried out to evaluate individual aspects of the product against the market brief. Then the design process gets into the product design stages.
Figure 3.5
Company E

1. Market dept produces market brief including user needs
   - Systematic design
   - Staff selection
   - Brainstorming
   - Trial and Error
   - Reviews/Meetings

2. Production of concepts/ideas

3. Using of model concept

4. Test/evaluate functional tests of individual aspects against Market Brief

5. Product design starts make Form and Function work together

6. Component parts drawn in detail

7. Build prototype

8. Engineering Tests

9. Laboratory Type User Test (against Market Brief)

10. Manufacturing against marketing brief analysis

11. Issues of drawing for tooling

12. Field Trial

13. Product approval and release

14. To production

15. Engineering

16. Manufacturing

17. CONCEPT/PRODUCT DESIGN

18. ENGINEERING DESIGN

19. MANUFACTURING DESIGN
At this point, the design takes the concept and ideas and starts making form and function work together into a format which actually meets the needs of the user. The market brief and product design are then evaluated together.

The product design process is followed by and overlaps with engineering design, which involves details of component parts. A prototype is built and tested. Just after having completed engineering testing in the prototype, the team allows it to be used by a wheelchair user, under controlled conditions, within the company, for a few days. It is called the "laboratory type user test". Those tests are compared against the original market brief. A second prototype is built incorporating recommendations from the user tests. Methods of manufacturing are assessed and at the same time, the process of production starts earlier than is usual in traditional design. A manufacturing against marketing brief analysis is carried out. Drawings are made for tooling. Next, a test and development phase begins which relates all that back to the estimated cost of the wheelchair. This is a complex area, including the technical support information and user information. After product approval and release the product finally goes to production.

Undoubtedly Company E seems to follow one of the best design practices for large companies in the sample. The several design phases occurring simultaneously can be considered as the strongest point of the design process described above. In this way, the design practice is consonant with modern product design approaches. The company considers user requirements from the very beginning and through several phases of the design process. This is another very positive point. The contact with users is made by the marketing personnel. The user requirements are included in the market brief which will guide all the design process. The respondent stated that the company carried out some user tests. The disabled people who take part in those tests are either company employees or some people with whom the company has a good relationship. As mentioned before, this is not good practice in terms of having a good representation of user population. Company E is one of the few companies in the sample that employs qualified industrial designers as part of the product design team.

Another good design practice reported by the respondent is the emphasis given by the company to the development of product concept. It is very positive to involve people outside the design area in the generation of new ideas because requirements perceived from different points-of-view can be included. The criteria in the selection of people for the design team (creative people) is very important as well. Adopting three dimensional modelling to analyse and evaluate concepts of individual aspects of the product is also a very good design practice. Although the respondent mentioned the product design as a step after the conceptual phase, it
is important to clarify that the development of concepts and ideas is indeed an integral part of the product design process as well.

Company F

Company F specialises in wheelchairs for sports practice. The majority of employees in this company, including the proprietor, are disabled people using wheelchairs. The respondent pointed out that the company also designs everyday wheelchairs taking ideas from the experience of designing sport wheelchairs. Company F starts the product design process by initial paper design (Figure 3.6). The design goes through the functional aspects of the wheelchair. Then it moves on to the design of the frame structure and the strength of the chair. A prototype is built and checked with either sports people or everyday users. The prototype is sent to be used by two or three different testers for several weeks. The people who take part in these tests are usually company employees or customers who are in regular contact with the company. Changes are made with the agreement of the tester who takes the wheelchair again for a further six months of individual use. Once the wheelchair is fully and properly tested it is put into production.

Evidence shows that the product design process carried out by Company F is based completely on presumptions about users' expectations. There is no systematic method to generate, evaluate and select ideas when designing the wheelchair. The product design process is based mainly on the designer's previous experiences and on the fact that he and the majority of his staff are wheelchair users themselves. It was concluded from the very confident attitude shown by the respondent (company owner) during the interview, that he felt what was
good for him and his staff was good for the customers as well. The company carried out an informal evaluation of the prototypes with some users but without taking account of the needs of the range of the disabled population in which the company was interested.

Company G

Company G is one of the largest manufacturers of wheelchairs in Europe. The company is structured in a way that it has distinct departments for manual wheelchairs, powered wheelchairs and scooters. Each one of those departments has specific managers subordinate to a general product manager. Each product manager is completely responsible for the production and performance of all new products in the marketplace. They are involved in all design stages and the various steps need his approval before going through to the next.

The product design process begins initially with the requirements being captured from customers and dealers by the Marketing Department (Figure 3.7). People are allocated to the design team depending on the kind of product to be developed (manual wheelchair, powered wheelchair or scooter). The marketing and design teams work together to define product specifications. Usually, a lot of the design is based on components already used in other wheelchairs. This is a current practice of the company for economic reasons.

Preliminary drawings are done on paper by designers and approved by the product manager. Prototypes of the parts designed are built and approved by the product manager as well. All the parts of the whole product are assembled to produce the full prototype. The product manager checks if the prototype fits the requirements. Two or three examples of the wheelchairs are made and sent to dealers and typical users to be evaluated. Frequently the company produces dealer panels to evaluate the latest products under development. The evaluations involving dealers and users are carried out by the Marketing Department. Next, the product manager tries to obtain approval from the company's directors. He has to convince the directors that the product will enhance the company's reputation, that the prototype fulfils requirements, and by implication that the finished product will sell. The first samples are produced and have to be signed-off by managers before full production.

Company G designs wheelchairs in quite a traditional way. Each design phase starts only when the previous one has finished. Furthermore, the company has a hierarchical approach in the design process. Several design phases need the approval of managers to follow through to the next. Sometimes it may represent lack of dynamism and agility in the design process.
Figure 3.7
Company G

1. Marketing captures requirements from customers and dealers (colour and size range, market segment, type of user)

2. Allocate people to design team

3. Marketing and design teams define specification

4. Design of the whole product (Preliminary drawings)

5. Product Manager approval

6. Assembly of prototype parts into the whole product (Full Prototype)

7. Make 2 or 3 examples of chairs

8. Dealers and some users evaluate chairs

9. Sign off prototype

10. Production of first samples

11. Managers sign off first production chairs

12. To full production

Product manager has to convince direction that product is what they need and prototype fulfils requirements.

Take parts already developed

OK?
The respondent emphasised the role of dealers in the wheelchairs evaluation. He argued that the importance of their involvement is to persuade them that the wheelchair will be a good product and a selling success when launched on the market. Although the company has a dealer panel, it does not have a user panel. The respondent admits the limitation of this approach since dealers are not actually using the wheelchairs, but only selling them.

The involvement of users is done on an informal basis by the marketing personnel. According to the respondent, the Marketing Department is the only one which has direct contact with users in this company. This practice has generated some problems of communication between the marketing people and the design team when identifying the needs of the user.

3.3 Exploratory questions about design specifications (identifying user needs, using literature data and using standards)

3.3.1 Identifying user needs

It was generally agreed by the design practitioners that they try to take account of the range of needs of disabled people when designing wheelchairs. Smaller companies that produce custom-built wheelchairs made to meet individual requirements naturally have the closest contact with users in some phases of the product development process. Those companies usually sell directly to users. They have a face-to-face approach, designing according to what the users have requested. These companies usually work in a niche market. They produce wheelchairs for very disabled people or people with special needs which are usually not covered by the large-scale production companies.

A different approach is adopted by the large-scale production companies. The designers in these companies generally have direct or indirect contacts with users. The very few designers who make direct contact with users do so in an unsystematic way. Some of them obtain advice from the disabled people that are employed in their company, others ask for advice from users with whom the company has a good relationship. The difficulty with listening to users employed by the company is that they may not represent the widest range of users a) because the company employs people who are employable, so maybe they are not as physically disabled as other users, and b) according to respondents, the workforce tends to be people who may be in a wheelchair through injury which occurred in middle life, so the
youngest and oldest are out of this range of people. Talking to users that are "on-hand" is also an inadequate approach. This can lead to results that do not correspond to reality because the subjects may not represent the whole population of users at all.

Indirect contacts with users are made using feedback from the Marketing Department and/or other in-house professionals such as occupational therapists. Using this approach, designers do not have direct contact with users. All information is obtained from someone who has the direct contact and who transmits the information to designers on behalf of the real user. Of course this approach is not the most appropriate if the people are not properly trained. It is common sense that meeting people in the field, identifying their problems and producing product requirements based upon users' real needs is the best approach in terms of product development methodology.

Half of the people (six) from the sample mentioned that they have had problems in the establishment of wheelchair user needs. The major problems identified were a) finding out exactly what the user wants; b) continually needing to assess changing trends and expectations; c) needing to make judgements based on other sources of information (e.g. Marketing Department); d) users adapting their wheelchairs and not seeing new ways of doing certain activities or better ways of achieving certain ends; e) the problem of managing the extensive range of individuals needs and f) the problems of communication with the end user.

Some solutions for designers to overcome the problems identified above could be: a) to try to have some direct contact with users, as well as using skilled intermediaries who not only pick up appropriate information but also transmit it in a useful way to the designer and b) the use of an appropriate method of gathering information from representative users based on a systematic approach, such as interviews, surveys, checklists, group discussions and observations.

Problems of communication on the user side tend to be more difficult to manage the more severe the user disability. Respondents said that quite a lot of severely disabled people cannot even speak. Few of them use a synthesiser or computer devices to improve communication skills. Others have their carers or their occupational therapists with them. The designer problems remain in correctly interpretation to what the user wants; and what other people see he or she wants. One way to overcome this problem is, with the support of the carer or prescriber, to produce some sketches of the whole wheelchair or components and try to get the approval of the user with a yes-no answer system.
Most respondents (seven) have affirmed that they carry out market and/or marketing research. Of these, just two used this technique systematically. The others collected information informally talking with some users and/or healthcare professionals. Four companies recognised that they do not carry out market(ing) research.

According to the respondents, the information gathered from market(ing) research is translated into design requirements by: a) using statistics to determine user group and population characteristics, then analysing the problems identified to find opportunities for innovation and b) incorporating useful suggestions into the product design.

Amongst the companies that carry out market(ing) research, three admit to having problems using data from this technique in their design work. The major problems identified were: a) the data obtained are never specific enough, needing some interpretation; b) the data are very limited and difficult to access and c) there is a failure in communication between the designer and the Marketing Department making it difficult to get the right information. In view of this, two important points should be addressed: a) the claim of limited, and difficult to access, data is clearly associated with those companies which carry out market(ing) research on an informal basis and b) failure of communication undoubtedly denotes organisational problems in the company.

3.3.2 Using data from the literature

Less than half of the sample declared that they use information from the ergonomics literature in their design work. Some of those referred to ergonomics literature as just anthropometric data gathered from reports or other documentation. Very few use ergonomics books or journals. It was found that just one respondent - a qualified industrial designer - claimed to use ergonomics information to help in the definition of design requirements. The others, although they reported that they use information from the ergonomics literature in their design work, did not answer satisfactorily as to how they translated that information into design requirements. The unique person who uses ergonomics literature in his design work stated that the problem in using these data is in the establishment of a compromise between acceptable solutions with regard to the large range of disabilities.

While very few people use data from the ergonomics literature in the design activities, the vast majority use information from scientific work on disability in their design work (such as that published in the MDD - Medical Devices Directorate Reports; publications from the Disabled Living Foundation and The Disability Information Trust and from journals such as the
Journal of Rehabilitation and the IEEE Transactions on Rehabilitation Engineering. All nine respondents that answered this question affirmatively used information gathered and published by the Medical Devices Directorate and the Disabled Living Foundation.

The predominant use of scientific literature and the low use of ergonomics literature may be justifiable since the data provided by the scientific works on disability are much more specific to this field of knowledge than those provided by the ergonomics literature. Furthermore, as was mentioned previously, the vast majority of the design practitioners involved in the survey did not have any training in ergonomics. This may cause them difficulties in dealing with the ergonomics literature.

According to the respondents, the information which they have gathered from the scientific sources on disability are translated into design requirements by: a) keeping a library of this information for reference when needed; b) using them as source of inspiration and c) putting the recommendations into practice.

Just three people mentioned any kind of problem using data from these scientific sources in their design work. The problems identified in the use of scientific data are: a) the large quantity and variety; b) they are not always directly relevant and c) they are not clear and sometimes poorly defined, so that it is up to the manufacturers to decide what they need to comply with. The problem of the quantity and variety of information in the modern day is a reality in almost every field of human activity. To evaluate and select the most useful data for a particular activity is a hard exercise and needs a good sense of judgement. Respondents were troubled by a lack of clarity and definition in some recommendations, guidelines, directives and standards. This was particularly mentioned in relation to M.D.D. reports and will be repeated later when standards are discussed.

Half of the sample - six people - pointed out that they use more popular and everyday magazines or newsletters on disability in their design work (e.g. Disability Now, Carers World, Arthritis News, Spinal Injuries Association Newsletter). The newsletter Disability Now was consulted by almost all respondents. The remaining half of the sample stated that although they read magazines and newsletters on disability regularly, they did not use them in their design work.

According to people who used magazines and newsletters on disability in their design work, they used the information gathered from these magazines in design requirements by: a) looking for inspiration; b) keeping aware of information; c) keeping a library of information
for reference and d) putting recommendations into practice. No problem was mentioned by respondents in using data from magazines or newsletters on disability in the designers' work. The majority of respondents - eight - answered positively when asked if they used information gathered about competitors' products in their design work. One of the respondents, from the public organisation, did not have any competitors because it does not sell its products but lends them or provides them under the aegis of the National Health Service.

The kind of information gathered about competitors' products that companies used in their design work were: a) catalogues, brochures, leaflets and technical specifications obtained mainly at exhibitions; b) information provided by customers; c) personal observation of design features of competitor products and d) obtaining an idea of where and why competitors are aiming their sales targets.

Companies translated the gathered information into design requirements by: a) producing chairs of similar specifications to their competitors; b) keeping awareness of what competitors are doing and seeing if that is something that could improve the quality of their own product; c) keeping files of literature and, if any design might be useful, making a sketch of it and putting it into a file to be possibly used in the future and d) producing a list of specifications; writing down all the specifications on a big chart; comparing what their own company is proposing to do with the specification on a chart; and finally making a sort of value judgement based on the information obtained from competitors' products to say whether that specification for a new product is sensible or not. One of the respondents admitted to buying competitors' products very often and taking them apart to see how they had been produced.

Two respondents answered positively in terms of having any kind of problem using information gathered about competitors' products in the design work. The first one mentioned the difficulty in getting an overview of competitors strategies as the main problem. The second mentioned that ISO standards demand that when a wheelchair is described in catalogues, technical specifications have to be laid out giving its performance details. However, although many catalogues and brochures follow this ISO regulation for producing literature, the information in them could not be considered totally reliable. Many manufacturers claim, in the technical specifications of their catalogues and brochures, that their wheelchairs have a certain performance that actually does not correspond to the reality.
3.3.3 Using standards

The United Kingdom is one of the few countries in Europe which until very recently manufacturers did not have to meet a mandatory standard to produce wheelchairs. Certain standards concerned with wheelchairs and/or their components are now mandatory. In spite of this, the use of standards was almost universal among all the respondents in the survey. Just one admitted not using standards. Companies that have a contract with the National Health Service need to get their chairs through the tests carried out by the Medical Devices Authority (M.D.A.), at Blackpool. These tests incorporate the requirements included in some standards.

The majority of respondents stated that they use more than one standard in their design work. They usually use ISO in conjunction with other(s), possibly BSI, CEN, EUN or some national standard applied for foreign countries. Most of the standards that they use are applied throughout the wheelchair components.

Independent of whether wheelchairs are produced on a large or small scale, respondents pointed out that standards play a varied and important role in their design work. They stated that standards are:

a) essential to guarantee acceptability in some countries, mainly in the European Community;
b) a good marketing tool;
c) important to user safety;
d) the only way to meet the design needs appropriately and

e) the way to have the wheelchair conform to the requirements to be approved by the M.D.A.

According to respondents, information on standards is translated into design requirements:

a) literally, as a translation from the written standards directives because they are constraints;
b) making sure materials and components meet required standards; and

c) writing out all standard requirements, particularly where there is actually or potentially conflict, on to a big chart and trying, as much as possible, to combine them altogether.

Half of the respondents that used data from standards in their design work stated that they had some problems in this practice. They pointed out the following problems using standards:

a) they are sometimes ambiguous and quite hard to translate;
b) wheelchair standards are continually being changed and take years to get published;
c) standards take away a lot of freedom during the design process and

d) sometimes it is a nightmare to make the wheelchair attain about ten national standards with different, and sometimes contrary, requirements.
Chapter 3: Wheelchair Design

The largest companies that took part in this survey usually export wheelchairs. They reported that Great Britain is not a very big market, unlike the United States and Northern Europe. To export to these countries they have to get certain approvals and comply with regional standards and directives, such as those stated by the Swedish Handicap Institute. These standards are completely voluntary. Although standards would be a minimum requirement, some respondents pointed out that they go beyond those limits, applying their own inspection procedures and more rigorous test criteria on safety and strength. It is important to mention that just one respondent stated, without being specifically asked, that he designs wheelchairs trying to take account of areas of potential misuse and lack of care and attention by the users.

3.4 Exploratory questions about production

The main objective of the questions related to production was try to identify if the companies which produce wheelchairs are familiar with the new methods used in the design and manufacture of consumer products which are based on customer demands as a means to define product requirements, particularly "Quality Function Deployment" and "Kansei Engineering". All respondents said that they were unaware of any of these methods.

3.5 Exploratory questions about product evaluation and marketing

All respondents claimed that they carried out physical tests on their wheelchairs. Some of them carried out in-house tests, others sent the wheelchairs to universities, laboratories or agency test houses, such as the M.D.A. at Blackpool, the Swedish Handicap Institute or the TUV of Germany. Companies which export wheelchairs usually submit them to distinct test houses abroad.

Respondents said that the tests that are done are on: static stability, dynamics, manoeuvrability, braking, climbing ability, speed and range, fatigue, electrical safety, stress analysis and fatigue analysis of the frame structure. One company reported that it was involved in the production of wheelchair parts in two university research projects. According to it, the research projects that were being developed with their support were: a) the development of electronic controls and sensory systems for remote sensing of obstacle and b) a "smart wheelchair". The company did not give further details about the projects. Almost all
tests developed in-house are simple. These include tests of climbing ability, using a small ramp and a test to see how far the wheelchair can climb and it suitability on a rolling road and rough ground. Other more complex tests are carried out mainly at the M.D.A.

It is important to observe that some very informal tests were reported as well. A company reported that apart from the tests on the frame structure, other tests such as stability dynamics, manoeuvrability and brake speed are all done in the field by disabled people with whom the company has a good relationship. They use the products and report the good and bad things in the product and what needs to be changed.

Three respondents reported that ergonomics tests on wheelchairs were carried out by themselves or another agency. One reported doing it in a systematic way. He mentioned carrying out tests using some models: three two-dimensional flat models (for the adult male, adult female and child) and a three-dimensional human mannequin, which is a humanoid shape, with a mass of 100 kilograms. A second respondent reported carrying out informal user trials aimed at seeing what happened in a real environment: how the chair performed in a real house, how it went in a real car and how a real family coped with it. The third respondent said he usually sent the wheelchairs to the M.D.A. which tested them on safety and dimensional compatibility.

The majority of respondents - eight - admitted to comparing their products with those of competitors. It is important again to remember that the hospital did not have any competitor. The methods used by the companies to effect the comparison against competitors' products are: a) direct comparison (visual, dimensional and financial checks); b) user reaction at shows and exhibitions; c) talking anonymously to employees of other companies at shows and exhibitions; d) market assessment and sales performance and e) buying some competitors' products and analysing them. The vast majority of respondents rated their products physically, ergonomically and aesthetically superior to those of their competitors. Just one admitted that his products were ergonomically and aesthetically inferior to those of competitors.

All the companies which took part in this survey unanimously reported using feedback from their customers after sale to obtain further information about their own products. Small companies, which are direct sale organisations, usually have a closer relationship with customers. Sometimes customers are repeat customers or have come from recommendations. So, for this kind of company, feedback is usually based on direct face-to-face contact. Larger companies have several ways to get feedback from users. They do it by: a) customer complaints, usually via customer service; b) user comments at shows and exhibition; c)
monitoring users after the launch of any new product; d) questionnaires sent to users after sale and e) indirect user feedback provided by sales representatives' comments.

The last question in the survey tried to identify what role "costs" play in the design of wheelchairs. Respondents were unanimous saying that it played a very important role. Companies which sell to the National Health Service stated that it always demands low cost products, sometimes sacrificing quality. Some respondents called attention to the fact that although costs have an essential role, "function" and "specification" should be addressed as the main factors in the design process.

3.6 Lessons learned and major features of the data

A number of lessons have emerged from the survey about how designers go about designing wheelchairs and how they try to meet the specifications, both physical and ergonomic. It is important to point out that, apart from being extremely time consuming, the analysis of the data collected from respondents was difficult to carry out because the answers given by them to specific questions did not usually follow a natural order and required an effort from the researcher to provide a coherent framework and to identify conflicting viewpoints. Another point to be considered concerns the true meaning of what was said by respondents. Some companies' actions may not be reflected in their words, i.e. although the respondent mentioned a good design procedure, it did not necessarily follow that the company actually did what it said.

Broadly speaking, the designers who participated in the survey carried out the design process based on their assumptions about users' expectations. Such assumptions are based on: a) the designer's previous experience in dealing with wheelchairs and related products; b) the designer's own experience as a wheelchair user himself; c) the expertise of other practitioners (e.g. occupational therapists); and/or d) some opinions obtained directly from the potential users or their representatives (e.g. carers). The goodness or badness of the interactions between the final product and its users are commonly based on these designers' assumptions. As a result of designers not using systematic methods, the predictions of the product's usage and performance may not match users' expectations.

This survey has revealed that several phases of the design methods carried out by the respondents vary significantly from one company to another. It seems that such diversity occurs basically due to: a) the majority of companies not following a methodology with a
systematic approach during the design process; b) the wheelchair's design process is carried out based mainly on the designer's experience of his job and his everyday life; c) most companies commonly designing new products which are frequently based on already existing models; d) the companies dealing with different markets, with distinct kinds of demand - public customer (represented by NHS) and private customer (mass-production scale and custom-built scale) -, which leads to different methods of production and e) the vast majority of design practitioners in this survey not having an appropriate background involving industrial design qualifications.

Ergonomics, as viewed by the respondents in the survey, is generally concerned with product comfort and convenience in use, or physical aspects of the human body. Although respondents regard ergonomics as important in contributing to wheelchair design, its truly effective use in wheelchair development process has yet to happen.

Two broad types of error may be identified in the analysis of the design process in the survey: "errors of omission" and "errors of commission". The first refers to something that the manufacturers or designers failed to do in the design process but which they should have done. The second refers to the manufacturers or designers doing something which they should not have done. This is actually the opposite of omitting something. It is important to point out that some errors that were identified for some companies may not be necessarily true for another.

Generally speaking, the main errors of omission, identified for both small and large companies, are a) the lack of a systematic approach in the design process and b) not considering the users' requirements in the several design phases. However, it is important to say that the lack of using a systematic approach and not considering the users is not necessarily a guarantee of bad design. On the other hand, going through all the appropriate processes, does not guarantee a good design. It is possible for an inventive designer to produce good result without following an appropriate design method and not taking account of the users' needs in the several design phases. But design is not common sense. In a broad way, good design can be identified in those products whose features contribute to improve users' performance with a minimum of stress and a maximum of efficiency. However, with the use of a systematic approach and users' needs being taken as a guide in the design process, the probabilities are that the final product will be improved to match customer needs in terms of greater safety, efficiency, comfort, convenience and better aesthetics.
Errors of omission were also identified when small companies that took care of very severely disabled people did not try to overcome communication problems by involving other professionals in the health area for their advice.

As was mentioned in the chapter on the Literature Review, design specifications are only one part of the total list of specifications in a product development process which includes marketing, engineering, manufacturing and finance. These other aspects were not considered in depth in the analysis. However, even within the topic of design specifications some companies failed to carry out part or whole phases of the design specification - such as identifying users' needs, evaluating competitive products, establishing user profiles, defining product performance requirements and determining design constraints. Unfortunately anthropometric data available in the literature to define the body sizes and shapes of the disabled is almost non-existent. Designers are destined to fail even if they are actively searching for this information. This is one of the reasons pointed out by the respondents to the survey for the low use of information from the ergonomics literature.

The lack of appropriate design specifications turns the phase of conceptualisation of a new wheelchair into a difficult matter. Very few manufacturers in the survey were involved in the process of developing and producing entirely new wheelchairs. Broadly speaking, most of manufacturers preferred to redesign existing wheelchairs rather than to design new products. So, some techniques of creativity - brainstorming, for instance - were most used in the generation of new wheelchair components rather than in the designing of new wheelchairs as a whole.

The use of representative three dimensional models for the selection and development of the most promising concepts was not frequently found amongst the manufacturers in the survey. When this technique was used, the involvement of the users in the evaluation of models and prototypes left much to be desired.

Furthermore in the whole sample just one respondent mentioned that he designed wheelchairs trying to take account of areas of potential misuse and lack of care and attention by the users.

Some errors of omission during the phase of evaluation and marketing happened because few companies assessed customer feedback after the product had been launched onto the market. When this occurred it was generally done by reports from repair services or complaints against malfunctions of the product. In those companies which have a Marketing Department, the assessment of users experiences after the product had been launched onto the market, or even
the involvement of users during the phases of design process, was usually carried out in an unsystematic way.

The main error of commission identified in the analysis was the fact that managers, technical personnel and designers made decisions without involvement of users. This is highly undesirable from all points of view. Thus, designs may not have matched what users required or wanted. Some outcomes of mismatches between the product and the users - such as accidents, human error, product-induced health problems, under-use or non-use of a product - may therefore occur.

Consulting technical personnel on behalf of users with slightly or severely limited communication abilities may be considered an error of commission in the design process of small companies. The ideal process should involve the designer, technical personnel and health professional to overcome communication problems. Of course there may be some situations in which this kind of approach would be difficult to adopt.

On the one hand, the use of a hierarchical approach embodied in the design process of some companies - i.e., several design phases needing the approval of managers to follow through to the next - can result in keeping the process constantly under control; on the other hand it can be counterproductive resulting in lack of dynamism, agility and flexibility.

As was mentioned before, Company E represents one of the best examples of design practice for large companies. This is true because Company E: a) incorporates in its design process all the major phases of the design methodology stated in the literature; b) considers the users' needs from the beginning of the project and c) adopts an integrated approach in accordance with the modern techniques of product development. However, it is important to call attention to the fact that there is not one "ideal process" applicable to all situations. Each company has its own goals and segments of the market to deal with and should devise its design process in line with those demands. Of course some principles ought to be followed in order to obtain the best results.

The combination of design for an individual and groups of individuals represents a constant challenge to designers. It was observed that the majority of the companies in the sample were using a basic model of wheelchair in which some technical requirements were incorporated to produce a new product. The minimisation of the number of parts in the product, through component integration and the modularity of its parts, is considered a strong factor in a successful design and should be taken into account in the wheelchair design process.
Another point to be considered is that all the respondents questioned about costs stressed the importance of this item in the design process. Almost all the wheelchairs in the market were made using low-volume manufacturing techniques - made of tubular steel, bent and welded - and designed for fabrication in small volumes. Maybe the solution should be the design and manufacturing of wheelchairs in a manner similar to that used to produce high-volume contemporary consumer products (Feeney, 1995). A high volume production may be justified by the millions of users world-wide. The incorporation of a user-centered design into the product development process, the use of modern techniques of production in high-volume manufacturing plants and the adoption of techniques of mass marketing in its commercialisation will generate the required sales volumes with the consequent decrease in the product's price. Of course a project of such magnitude would demand a collective effort of government and private companies to be successful.
Chapter 4: Approaching the Process of Wheelchair Supply and Prescription

4.1 The provision of wheelchairs

Wheelchairs are mainly provided in the United Kingdom through the following sources:

- the National Health Service (N.H.S.)
- social service departments
- several charity organisations
- several dealers spread throughout the country

The source which supplies the wheelchair will depend on which basis the application is made: permanent or temporary loan, free of charge or private purchase. The initial approach needs to identify if the wheelchair will be used on a long or short-term basis.

4.1.1 The provision of wheelchairs on a permanent basis

Obtaining a wheelchair on a long-term basis can be done either a) free of charge or b) by private purchase.

4.1.1.1 The supply of wheelchairs for long-term use obtained free of charge

In the United Kingdom the National Health Service is in charge of the provision of wheelchairs on long-term loan, free of charge, for people with permanent mobility problems which make walking difficult or impossible. The NHS Wheelchair Service is organised on a district-wide basis, often based at the local district hospital: the District Wheelchair Service Centre (DWSC). In many instances this is complemented by a supradistrict or regional service
which addresses more complex needs such as special seating and non-standard electronic control systems.

According to the Royal College of Physicians of London (1995) the aims of the wheelchair service are:

- To provide wheelchairs for all those people with a permanent condition that impairs their ability to walk
- to provide as comprehensive a service as possible that includes consideration of comfort, function, posture and pressure relief
- to maintain and repair wheelchair equipment in a responsive, rapid and effective manner and
- to respond to changing medical and social needs of wheelchair users, with provision of different wheelchair systems when necessary.

The Royal College also reports that the overall need for wheelchairs has increased. For example in 1990/91 the N.H.S. issued 167,496 wheelchairs at a cost of £38.7 millions and in 1991/92 there were 172,224 issues at a cost of £43.7 millions. Jelier and Turner-Smith (1997) state that the 1994-1995 unit cost values for wheelchair provision, as supplied by the Personal Social Services Research Unit, listed the cost of a basic self-propelled or attendant-propelled chair as £68; £139 for lightweight, active-user chairs; and £318 for powered wheelchairs.

The demand for wheelchairs is high and centres are therefore limited in the range of wheelchairs they can provide. The financial trend is that the user population is increasing by approximately 57,000 (10%) every year, while services are expected to make efficiency cuts of 3%-11% (Prosthetic and Wheelchair Committee, 1996). Patient expectation is felt to have increased over recent years. According to a report from Heart - Horizontal European Activities in Rehabilitation Technology (Buhler, 1994), in order to keep this free service in spite of its limited budget, the design of wheelchairs, mainly electrical, provided by N.H.S. has not really been substantially advanced. The service is unsatisfactory and, as a result, patients have sometimes to submit to long waiting times. According to Cornwell and Kavanagh (1996), the N.H.S. wheelchair service currently has insufficient funding to provide users with the best technology available to meet their total mobility requirements.

The range of wheelchairs and accessories provided by N.H.S. is extensive, with several hundred permutations available. The range of wheelchairs and accessories varies depending on local policy, budget and priorities of each District. The main types of wheelchairs, for both adults and children, available through the N.H.S. Wheelchair Service are:
Chapter 4: Wheelchair Supply and Prescription

- **Standard manual wheelchairs**, propelled by the user or attendant. These are to be used, full-time or occasionally, by people whose ability to walk is permanently restricted.

- **Powered wheelchairs**. Three types are potentially provided dependent on local policy: a) indoor powered wheelchairs - occupant control (supplied if the person cannot walk or propel themselves indoors in a manual wheelchair); b) outdoor powered wheelchairs - attendant control (supplied if the person cannot propel him or herself in a manual wheelchair, is unable to push it because of the terrain or their own lack of strength and must rely on attendants) and c) indoor/outdoor powered wheelchairs - occupant control.

Although local policy may vary, it is a common policy that the N.H.S. does not provide high-performance wheelchairs and specialist sports wheelchairs. The provision of indoor/outdoor powered wheelchairs is very recent (April, 1996) and the criteria for issue is set locally (N.H.S. Executive, 1996a).

The wheelchairs available at the Wheelchair Service Centres are bought through a central contract system. However, commercial models and adapted wheelchairs, can be provided. Their availability may be affected by the state of the budget and local priorities. A recent scheme has also been launched by the N.H.S., based on the provision of vouchers, worth the value of an N.H.S. prescription, to users who want to invest funds of their own to obtain a better quality wheelchair than that which is available through the N.H.S. (Barrett *et al.*, 1998 and N.H.S. Executive, 1996b). Stockton (1996) has predicted that this regulation will create numerous logistical problems for N.H.S. trusts in England who recently received guidelines for implementation, and that there is a possibility that wheelchair services of the future will be completely provided by the private sector.

Obtaining a wheelchair free of charge from the N.H.S. implies having a referral to the wheelchair service made by a range of professionals including therapists, nurses, and doctors. Apart from the basic criterion of limited walking ability, a number of other criteria, such as available money or models, which may vary between centres, define the individual's eligibility for receiving a wheelchair.

4.1.1.2 The supply of wheelchairs for long-term use obtained by private purchase

In addition to the National Health Service range of wheelchairs, there is an extensive selection of private wheelchairs. As with any consumer product, anyone can buy a wheelchair. Private
purchase might be preferred because a person wishes to have greater choice, or because the statutory services are unable to provide the item required or the length of wait is too long.

Because it is expensive equipment and the fact that the choice of the right wheelchair can make a substantial difference to an individual's independence, the literature universally suggests that the customer obtain as much advice and assistance as possible from a qualified professional, who preferably has no link with a potential retailer. Some organisations, such as Disability Groups and Disabled Living Centres, have professionals qualified to give advice to help people in choosing the right wheelchair. There are also some publications available to help users to choosing the correct wheelchair such as: Department of Health (1996), Kelsall (1993), Getting the best from your wheelchair (1995), People in wheelchairs (1974) and Weyers (1986).

It is also usual for customers to buy second-hand equipment. It can be bought through commercial suppliers or private persons. Many disability organisations publish journals which contain advertisements for second-hand equipment.

Individuals may apply for funds from charitable sources to help finance the purchase and maintenance of wheelchairs.

### 4.1.2 The provision of wheelchairs on a temporary basis

A number of sources are available for individuals to borrow a wheelchair on a temporary basis, e.g. for holidays, outings, short-term medical conditions, or while the user is awaiting delivery of an NHS wheelchair. The average maximum short-term loan period is about three months and the chairs are sometimes loaned free of charge. However, donations are readily accepted for the loan of a wheelchair and some voluntary bodies make a weekly charge, e.g. the Red Cross in Leicester.

According to the Disabled Living Foundation (1993) and the Department of Health (1996), wheelchairs may be obtained through the following sources:

- Hospital via:
  - hospital in-patient loan
  - hospital discharge wheelchair loan
  - hospital wheelchair pools
- Community Nursing Services
District Wheelchair Services

Some organisations such as the British Red Cross and Women's Royal Voluntary Service loan manual wheelchairs on a temporary basis. A number of private hire firms make daily/weekly/monthly hire charges which may vary in amount and with certain conditions attached. The local Disabled Living Centre and some specialised books and newsletter provide information about firms which hire out wheelchairs.

4.2 The process of wheelchair prescription and issue

4.2.1 General considerations

A wheelchair is a practical solution to practical problems (Young, 1988). For most wheelchair users this equipment is not only an aid to mobility, but a key to independence. In view of this, the correct choice of an appropriate wheelchair should maximise mobility, independence, comfort, confidence and quality of life. An unsuitable wheelchair is a source of great frustration, so a good assessment performs an essential role in helping users to choose the wheelchair appropriate to their needs. Datta and Powell (1989) have identified a comprehensive and competent assessment as the single most important factor in the provision of a correct wheelchair. Table 4.1 shows the consequences of inadequate wheelchair provision (Royal College of Physicians of London, 1995). It is important to stress that the problems caused by poor assessment and prescription are not usually serious for occasional users, however for those severely disabled poor assessment and prescription could cause unnecessary restriction in mobility resulting not only in pain but deformity which sometimes reduces the individual's capacity to live independently (McCull, 1986).

According to Stewart (1992) and the College of Occupational Therapists (1995a), an accurate assessment must take account of the individual's physical needs, capabilities, size, health, motivation and strength, as well as their expectations and intellect. The proposed use, for instance: for home, at work/school, and the consideration of the patient's social life and hobbies are essential factors to a successful prescription. Another point to be considered in the appropriateness of a correct model for an individual involves the assessment of home and work environments, and transit facilities. Additionally, the needs of the carer should not be overlooked.
### Table 4.1

Consequences of inadequate wheelchair provision (Royal College of Physicians of London, 1995)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Problem</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>The wheelchair user</td>
<td>• No wheelchair, or one which the occupant cannot control independently, or a broken or worn-out wheelchair</td>
<td>• Loss of mobility&lt;br&gt;• Loss of independence&lt;br&gt;• Decreased stimulation, and depression&lt;br&gt;• Increased fatigue and poorer quality of life&lt;br&gt;• Increased dependence on statutory agencies/carers</td>
</tr>
<tr>
<td></td>
<td>• Wrongly shaped seat and bad positioning</td>
<td>• Discomfort, pain, irritability, depression&lt;br&gt;• Pressure sores&lt;br&gt;• Progressive deformity (especially in growing children)&lt;br&gt;• Loss of function due to poor upper limb control and hand-eye co-ordination resulting in greater dependence, frustration, depression, etc.</td>
</tr>
<tr>
<td>The carer</td>
<td>• Heavy, bulky, ergonomically awkward wheelchair</td>
<td>• Contributes to back problems and fatigue&lt;br&gt;• Can adversely affect relationship between disabled individual and carers</td>
</tr>
<tr>
<td>Health and Statutory Agencies</td>
<td>• Inadequate wheelchair provision</td>
<td>• Increased burden due to greater dependency of wheelchair users&lt;br&gt;• Specific adverse health problems in both users and carers</td>
</tr>
</tbody>
</table>
An opportunity for free discussion of ideas and views should take place during assessment so that the users' wishes can be taken into consideration at all stages of the process. In view of this, the College of Occupational Therapists (op. cit.), has stated that an accurate assessment is dependent upon: a) sound clinical knowledge; b) up to date technical and equipment information and c) good liaison with users.

Young (op. cit.) states that an essential question that needs to be answered is "what does the patient wish to do that he or she cannot do at the moment". The answer will indicate whether the wheelchair is for use indoors or outdoors, or both; whether the wheelchair is for occasional or constant use; whether it should be self propelling or of the push type; whether should be manual or electric; and the accessories that are likely to be needed.

Fenwick's survey in 1997 found that only 11% of patients received an assessment for their chair at a wheelchair clinic. The McColl Report (McColl, 1986), a result of an independent working party established in 1984 by the Department of Health and Social Security, stated, inter alia, that the number of users in unsuitable wheelchairs indicates that standards of wheelchair assessment, prescription and advice are inadequate and has recommended that the various training bodies should review the content of their courses to ensure that student therapists receive appropriate tuition relating to wheelchair prescription during their basic training. Kettle et al. (1992) and Silcox (1995) point out that daily contact with people who use wheelchairs and therapists who work with them suggests that desirable changes in this area since the McColl Report was written are insufficient.

It is important to stress that wheelchair therapists have become specialists in a field where it is necessary to have wide clinical knowledge. In particular, knowledge of neurological and paediatric conditions; a specific understanding of posture and mobility; and the ability to relate these to the ever growing range of available equipment and the environment in which it is to be used by each individual wheelchair user. So, the provision of a good training to therapists is essential to achieve a good standard during the assessment and prescription process (White and Lemmer, 1998).

According to Jelier and Turner-Smith (1997), the training of therapists, including course content and frequency, presently varies dramatically across the country. The Prosthetic and Wheelchair Committee (1996) states that the current areas of training offered by wheelchair services include: awareness of relevant technology and issues concerning wheelchair provision for junior staff, nurses, carers and voluntary groups; pressure care management for therapists and district nurses; and 2 or 3 day local accreditation courses for therapists who are then permitted to prescribe wheelchairs to a recognised standard.
Silcox (1995) carried out a survey to discover the amount of time spent on and some of the content of the training presently available to therapists, both in colleges and from wheelchair services, to enable them to assess patients and prescribe wheelchairs for them. Silcox has found that the situation has improved slightly since the McColl Report in 1986 and that the wheelchair service is providing a comprehensive, structured training programme in some areas and none in others. This consequently means that the service that a customer receives depends upon where he/she lives. A policy of accreditation of therapists to prescribe wheelchairs, following training by the wheelchair service, was one of the recommendations of the McColl Report. The intention was that therapists would no longer require a doctor's signature on a wheelchair form and would be able to complete the prescription process independently. This process is only available in some areas and a national policy would seem to be important both to client and to therapists.

The College of Occupational Therapists (1995a) has produced guidelines for wheelchair training for students of occupational therapy and physiotherapy to ensure all therapists graduating from university have gained a basic knowledge of wheelchair matter.

A survey carried out by Kettle et al. (1992) on 3082 wheelchair users in England has found that, although most users expressed satisfaction with their wheelchairs, a significant number of wheelchair users or carers had experienced major difficulties or discomfort in several areas of use. According to the authors, the problem seems to be that assessment is generally limited to making sure that individuals 'fit' their wheelchairs (although even this is not always achieved). The demands of the social and physical environment in which a wheelchair will be used are often overlooked when assessing wheelchair needs. To overcome these problems, the authors suggest, where they do not already do so, that each wheelchair centre should develop a multidisciplinary approach - with users taking part in all discussions, wherever possible - in which, in addition to the physical characteristics of the user, all social and environmental factors that may affect the choice of wheelchairs are taken into account. Such factors, according to the authors, include limitation imposed upon use of a wheelchair by the demands of indoor and outdoor environments, the level of carer support, including the physical limitations of the carer, and the demands made on the wheelchair by the lifestyle of the individual using it.

Finally, it is important to draw attention to a study which aimed to examine the expectations of wheelchair users and their carers. The results have suggested that carers may have no contact with the wheelchair referrers or prescribers. In consequence there is no formal way of expressing their needs (Smith and McCreadle, 1994 and Smith, McCreadle and Unsworth,
The authors conclude that a correctly prescribed wheelchair benefits both users and carers.

4.2.2 Understanding wheelchair prescription and supply

Although prescribing criteria appear to vary between health authorities (Smith, McCreadle and Unsworth, 1995), it was found that the wheelchair prescription process, independent of its context, follows a similar path throughout the country. The overriding aim of the prescription process is to provide the client with wheeled mobility and a posture which meets the orthopaedic and therapeutic aims and objectives, including function and comfort as well as the client's lifestyle needs. Figure 4.1 is a flowchart which shows the whole process of wheelchair prescription and supply. It was constructed from official accounts of wheelchair prescription and amplified by four health professionals actively engaged in wheelchair prescription.

The prescription process can occur for the person at hospital or in the community (including GPs surgery, home address, day centres or whatever). The question of whether someone is in hospital or the community makes little difference. Most hospital inpatient stays are short. However, wheelchair prescription/provision can take a much longer time. It is important to call attention to the fact that some groups of patients, such as children and those with deteriorating medical conditions, benefit from regular review of their seating.

In the account which follows, separate sections deal with wheelchair prescription in a hospital (4.2.3) and in the community (4.2.4). As stated earlier the prescription processes in the two situations are similar but separating them clarifies what goes on.

4.2.3 Wheelchair prescription for people in hospital

At the hospital, a referral would be made by the authorised professional (consultant, ward sister or hospital therapist: occupational therapist or physiotherapist). The most common is that the hospital therapist would do an assessment of the patient needs and would decide whether a standard wheelchair would be adequate or whether he or she needs a more specialist assessment from the District Wheelchair Service Centre. Each region has a standard Wheelchair Referral Form (see two sample copies attached in Appendix 4.1, page 390) which has to be filled in and then sent to the appropriate wheelchair centre. It can be signed by the consultant/doctor in charge, occupational therapist or physiotherapist.
Figure 4.1
The process of wheelchair prescription and supply (adapted from Disabled Living foundation, 1993)
According to Jelier and Turner-Smith (1992), it has been shown that in most cases, for attendant-propelled, manual wheelchairs, prescription is made from a referral form resulting in little or no contact between the user and the staff at the wheelchair centre.

Correct prescription from referral forms depends on the training and knowledge of the prescriber. A nation wide survey carried out by White (1994) asked how forms with incorrect or omitted information were dealt with. They have found, on the 125 services that responded, a wide variation in the numbers of incorrectly completed or incomplete referral forms received. The procedure used to dealing with incomplete referral forms included: telephone conversation with the referrer (81%), return the form to the referrer (70%) and phone the patient for clarification (41%). An incorrectly filled-in form resulted in time delays in the prescription process and was a waste of time for the staff who had to chase the required information.

The wheelchair prescription with the person at hospital can be provided either for permanent need (long-term use) or temporary need (short-term use) depending on the patient's health conditions.

4.2.3.1 The prescription of wheelchairs for permanent use by people in a hospital

The prescription of a wheelchair for permanent need to a patient at hospital is made by the consultant, occupational therapist or physiotherapist. It follows the steps described below.

**Consultant/therapist prescription form**

The consultant/therapist make an assessment of the patients' needs and fills in the referral form. Usually, if the patient has a special need and the therapists feel that they require specialist help to do the assessment, the hospital may contact the District Wheelchair Service Centre. The latter would then do the assessment within the hospital or the patient would be taken by ambulance to have a local assessment at the Centre. In the latter case, the patient can sometimes try a range of wheelchairs provided by the DWSC while he or she is still an inpatient of the hospital.

**Referral to wheelchair centre**

After the referral form is filled in, it is sent to the District Wheelchair Service Centre. Referral may request provision of a standard wheelchair or a non-standard/modified wheelchair.
Issuing a standard wheelchair
If a standard wheelchair is required, the equipment can be issued straightforwardly depending on the level of priority required and equipment availability. If the patient has low priority or the wheelchair needs some modifications, the patient may be put on a waiting list. Occasionally modifications may be required to wheelchairs to allow them to meet clinical need. The more common modifications required are higher back rests, adjustment of foot plates, extension of brake levers on one side or the other and alteration of mechanisms for removing and replacing the arm rests, change of tyres for particular environments, alterations to handlebars and seat lengths and widths. The patient will receive a follow-up letter or telephone call to review the wheelchair suitability after a lapse of time, e.g. one year. The patient may contact, of course, the Centre if problems develop.

It is important to point out that the National Survey of Wheelchair Users (Kettle et al., 1992) has found that one-third of all respondents in the sample (3082 wheelchair users) had not received (or could not remember receiving) any written instructions concerning the use of their wheelchairs. Also, 60% of wheelchair users in general and about 20% of powered wheelchair users in particular reported that they had received no practical demonstration of their wheelchair. Furthermore, just under half of the respondents did not know of their approved repairer and two-thirds did not know of their local Disablement Services Centre. The authors also suggested that attention should be given to proper follow-up to ensure that the user is in a position to take full advantage of the wheelchair once it has been issued.

Issuing a non-standard wheelchair
Sometimes patients that have, for instance, chronic neurological conditions (such as multiple sclerosis or motorneurone disease) which deteriorate quite rapidly, may need some sort of adaptations on their chairs or sometimes need to have special wheelchairs. When the referral form arrives in the DWSC and the referrer has any concerns about the issue of the wheelchair, the therapists or rehabilitation engineer in the Centre will check the possible queries related to the prescription. They might make a phone call to the prescriber to clarify a problem, bring the patient into the clinic and do an assessment, or, if the patient cannot travel, the specialist therapists or rehabilitation engineer might make a home visit to sort the problem out. The centre will prioritise urgency, e.g. a patient who needed a wheelchair before discharge from hospital would be seen as a priority. The equipment is then issued or, if priority is low, the patient may go on a waiting list. The patient will receive a follow up letter or telephone call to review the wheelchair suitability after a lapse of time, e.g. one year. The patient may contact the Centre if problems develop. If necessary, more frequent follow-ups can be organised.
4.2.3.2 The prescription of wheelchairs for temporary use by people in a hospital

Individuals who need a wheelchair on a short-term basis can borrow it: a) free of charge, b) by the payment of a deposit or c) by hiring. These last two methods are more common for persons in the community and will be discussed in the next sub-topic.

Obtaining wheelchair free of charge

Obtaining a wheelchair free of charge for temporary need by a person in hospital is a process quite similar to provision for permanent need, as previously discussed. A prescription should be made by the doctor in charge or a hospital nurse or therapist. The wheelchair can be issued by: a) hospital, via hospital in-patient loan, hospital discharge wheelchair loan or hospital wheelchair pools; b) Community Nursing Services or c) District Wheelchair Service. If the option is the DWSC, the procedure is identical to that described above for wheelchairs for permanent need.

Paying deposit or hire charges

Local availability and cost of loan may be considered if applicable at a hospital or a voluntary sector such as the Red Cross.

4.2.4 Wheelchair prescription for people in the community

The choice of a wheelchair for a person in the community can be a decision by the individual him or herself, the carer or a health professional. Again two modalities of needs can be identified for the wheelchair users: a) permanent need and b) temporary need.

4.2.4.1 The prescription of wheelchairs for permanent use by people in the community

Obtaining a wheelchair free of charge

The prescription of wheelchairs for permanent need for a person in the community follows the same route as for the individual at the hospital, as previously discussed. The unique difference is that individual needs are primarily identified by GPs, community nurses or community therapists. After assessment, which can be made with the help of DWSC staff, they fill in the wheelchair referral form and send it to the District Wheelchair Service Centre.

Currently, many standard wheelchairs are being prescribed directly from GPs' referrals and recommendations. A survey carried out by McMahon and Dudley (1992) enquired a random
sample of Leeds-based general practitioners about their knowledge of wheelchairs and wheelchair prescribing. Only 1 out 27 who replied said that he had 'good' knowledge of wheelchairs and 20 (74%) claimed to have 'not very good or worse' knowledge of wheelchairs, and that the likely explanation for this was inadequacy of training.

According to a survey carried out by White (1994), over three-quarter of wheelchair services in England accepts referrals from therapist and half from district nurses, while many services accepted referrals from other health care professionals, patient themselves or carers. The survey has shown a clear move away from the medical model proposed by McColl which states that the doctor should continue to establish a patient's clinical need for a wheelchair, but that the type of chair should be specified by a suitably accredited therapist. There has been increasing realisation over the wheelchair service that it does not require a doctor to identify a person whose mobility difficulties indicate the need for a wheelchair.

**Private purchase**

Individuals who decide to buy their wheelchair privately usually may not need any prescription or formal assessment. They can obtain professional advice (independent, e.g. Disabled Living Centres or non-independent advice, e.g. therapist working for a company) or non-authorised professional advice from the sales-person. Professional independent advice in this context means advice from those professionals without any links with private firms.

4.2.4.2 The prescription of wheelchairs for temporary use by people in the community

Persons in the community may have their wheelchair free of charge from the N.H.S., pay a deposit to loan it from a charitable organisation or pay hire charges to a private company.

*Obtaining a wheelchair free of charge*

If the person decides to obtain the wheelchair free of charge, again, the prescription follows the same route as that for the individual at the hospital. Once more the only difference is in the person who prescribes the wheelchair: in this case GPs, community nurses or community therapists.

*Paying deposit or hire charges*

Obtaining a wheelchair from an organisation or private hire firms usually does not need any prescription procedure (including formal assessment).
4.3 Survey of therapists

4.3.1 Strategy and design of the field study of therapists

The therapists, either occupational therapists or physiotherapists, have the responsibility to provide clinical input and in some cases to manage the wheelchair service as well as being the budget-holders. They are, together with the designers and rehabilitation engineers, key persons in the process of design and prescription of wheelchairs.

A field study of the therapists was carried out partly to gain a better understanding of the prescription process, but more importantly to determine what they contribute, actually or potentially, to design. It is important to clarify that, in this survey, the interest was not in design for an individual (bespoke design) or particular adaptations of wheelchairs for specific patient needs. The interest was in the production of wheelchairs on a large manufacturing scale (generic design) directed at a broad group of people.

The sample in this survey consisted of therapists (either occupational therapists or physiotherapists) employed at Disabled Living Centres (D.L.Cs.) or N.H.S. Wheelchair Services. The questionnaire was sent for the attention of the Senior Therapist. The addresses of the Disabled Living Centres were obtained from a list provided by The Disabled Living Centres Council and the addresses of the N.H.S. Wheelchair Services were obtained from a publication provided by the College of Occupational Therapists (College of Occupational Therapists, 1995b).

The "Questionnaire for Therapists" comprised 17 questions divided into four parts:

- Personal Data
- Exploratory questions about ergonomics
- Exploratory questions about wheelchair prescription
- Exploratory questions about wheelchair design.

A descriptive analysis of the answers obtained from the sample is outlined in the section 4.3.2.

4.3.1.1 Ethical considerations

The survey was in accordance with the Department of Human Sciences' ethical guidelines. Responses were confidential and respondents' anonymity was guaranteed. No names were
indicated on the completed questionnaire and results of the research could not be traced to any individual respondent. It was considered unlikely that the nature of the questions in the survey would adversely affect respondents. No other person than the author had access to the completed questionnaires.

4.3.1.2 Survey procedures

The survey was conducted in three stages: a) interview with some therapists; b) the sending out of a pilot questionnaire by mail and c) the sending out of the final version of the questionnaire by mail.

Interviewing some therapists

Interviews were carried out with four therapists (two occupational therapists and two physiotherapists), based in the Midlands, who were actually involved or had been involved with wheelchair prescription (see list of questions in Appendix 4.2, page 396). The objective was to identify: a) the prescribers involvement with wheelchair design and b) the several steps contained in the process of wheelchair prescription in relation to the different contexts in which prescription takes place. The prescribers who were interviewed were unanimous that they had never been involved in wheelchair design, as opposed to prescription.

Pilot Survey

The respondents who took part in the pilot survey were randomly chosen from the list of addresses of N.H.S. Wheelchair Services (College of Occupational Therapists, 1995b) and asked by telephone if they were willing to take part in the survey. A covering letter (Appendix 4.3, page 397) was included to accompany the pilot questionnaire (Appendix 4.4, page 399).

From the total of 9 pilot questionnaires sent out by mail there were six responses. They included in their answers the following suggestions which were incorporated in the final version of the questionnaire:

- The word "patient" was changed to the word "client", which is more commonly used amongst therapists.
- Question 11 was changed to include also the option "Unsure".
- Question 15, originally formulated as "How do you rate the wheelchairs provided by N.H.S. against those provided by private companies?", was inverted and re-formulated to "How do you rate the wheelchairs provided by private companies against those provided by N.H.S."
In view of these few and relatively minor changes, the 6 pilot questionnaires were included in the final sample. The answers provided to question 15 during the pilot phase have received special treatment and will be discussed, when appropriate, in section 4.3.2.

Full Survey
The final version of the "Questionnaire for Therapists" was revised after the pilot survey and sent out to 40 Disabled Living Centres and 152 N.H.S. Wheelchair Services in the United Kingdom.

The total of questionnaires sent out, including 9 pilot questionnaires, was 201. The total number received back including pilot and invalid questionnaires was 98 (48.8%). It is possible that some questionnaires had been passed to the same therapist since some of them may be employed in two or three different Wheelchair Centres.

The covering letter (Appendix 4.5, page 404) accompanying the final version of the questionnaire (Appendix 4.6, page 406) was addressed to the Senior Therapist. Freepost return envelopes were provided with the questionnaire package to facilitate replies. A reminder letter (Appendix 4.7, page 411) was sent out two weeks after the initial posting. A deadline was given in the reminder letter. Almost one-third (n = 26) of the returned questionnaires came within one week of the reminder. Only a few questionnaires were received after the deadline given in the reminder letter.

4.3.2 Analysis of questionnaires

The total number of respondents was 98 from the 201 questionnaires sent out including the pilot questionnaires. Five responses were considered invalid because: a) they were answered by another person than a therapist or b) they were sent back without being appropriately filled in or c) the respondent did not take part in the prescription process. This new figure (93 questionnaires useful for the survey) gave a response rate of 46.3%.

4.3.2.1 Personal data

The vast majority of therapists who answered the questionnaire (n = 93) was comprised of occupational therapists (81.7%). The remainder consisted of physiotherapists (17.2 %). One respondent did not indicate his/her qualification.
Concerning the place where therapists that participated in this survey work, 73.1% of respondents answered that they work in an N.H.S. Wheelchair Service and 25.8% work in a Disabled Living Centre. One respondent did not indicate his/her place of work and another indicated that he/she works both in a Disabled Living Centre and in an N.H.S. Wheelchair Service.

The educational qualification of respondents comprises a vast majority of people with a diploma (85 respondents). A few persons with a first degree (15) and just three with a master's degree. Some persons answered that they have more than one qualification.

When asked if respondents have had any training to enable them to assess clients and to prescribe wheelchair, 82.8% of respondents answered affirmatively against 16.1% who answered negatively. One person did not answer this question. The respondents who answered affirmatively to this question, were also asked to describe the training and give the associated qualification (if any). Almost half of those (46.7%) who answered "yes" to this question affirmed that they had had training in the prescription of wheelchairs, posture and seating provided by one of the following institutions: Mary Marlborough Centre, Stoke Mandeville Hospital, Strathclyde University, Scottish Wheelchair Group, Regional and local D.L.Cs. The remainder pointed out that they had had one of the following sorts of training: a) one day/short courses (29.8%); b) in house training (16.9%); c) "on the job" experience (15.6%); d) attending exhibitions and conferences (9%); e) attending modules as part of under- and post- graduate programme (9%); f) courses provided by wheelchair and seating manufacturers (7.8%); g) other external courses (6.5%) and h) no indication (3.9%). No associated qualification was mentioned by people who had attended training. It was observed that some people may have undergone more than one sort of training, this explains why the total percentage is over 100%.

4.3.2.2 Exploratory questions about ergonomics

All respondents (n = 93) were familiar with the word "ergonomics". When asked what they understand by the word "ergonomics", the answer fell into one of the following categories which stressed: a) relationship between the user/individual and the environment (33.8%); b) physiological and biomechanical aspects (27%); c) man-machine relationship and design aspects (14.6%); d) the task and work activities (13.4%) and e) a mix of the previous and other aspects (11.2%). Table 4.2 shows the most significant answers. The fact that the majority of answers stressed the relationship between the user/individual and the environment and the physiological and biomechanical aspects is a reflection of the respondents' area of
Table 4.2
Some definitions of Ergonomics given by therapists

<table>
<thead>
<tr>
<th>Answers Stressing User/Individual and the Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>- The design of environmental modifications with consideration of the needs of the individual, i.e. anatomical, physiological and psychological aspects.</td>
</tr>
<tr>
<td>- The design or changing of the environment to enable a person to function as effectively as possible, and the amount of effort/time involved.</td>
</tr>
<tr>
<td>- Relationship between the wheelchair in the environment and the efficiency of use of energy for the users.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Answers Stressing Physiological and Biomechanical Aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>- The study of the body’s position, as it makes in carrying out functional activities, and the work environment to facilitate comfort.</td>
</tr>
<tr>
<td>- Design of product to promote ease of use from a biomechanical aspect, promoting good posture, enabling people to make economical use of movement.</td>
</tr>
<tr>
<td>- The study of body movement when carrying out specific tasks to determine the design of equipment and/or systems.</td>
</tr>
<tr>
<td>- The necessary anatomical, physiological and cognitive abilities needed from the worker to carry out a task.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Answers Stressing Man-Machine Relationship and Design Aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Design product and systems which allow optimum use by the user.</td>
</tr>
<tr>
<td>- Relationship between man, machine and the living environment.</td>
</tr>
<tr>
<td>- Relationship between individual and a tool or equipment taking into account the individual’s anatomical, physiological and psychological characteristics to enhance efficiency and well-being.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Answers Stressing the Task and Work Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Study of man in relation to his working environment to enable maximum efficiency with minimum effort.</td>
</tr>
<tr>
<td>- Relationship between worker and work environment including physical and psychological components.</td>
</tr>
<tr>
<td>- Combining physical function with equipment to ensure a task is performed efficiently and comfortably.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Answers Stressing a Mix of the Previous and Other Aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Study of the work/social/recreation environment to ensure design is appropriate for correct posture, positioning, etc. to avoid stress/strain of muscles and joints.</td>
</tr>
<tr>
<td>- The interaction between body, actions, position in relation to the activity being carried out.</td>
</tr>
<tr>
<td>- Interaction of human shape and form with environment.</td>
</tr>
<tr>
<td>- Design to accommodate the average human shape.</td>
</tr>
</tbody>
</table>
work: all of them dealing with the client's physical, medical and postural needs as well as his/her lifestyle.

The number of respondents who did not have any training in ergonomics (52.7%) is slightly greater than the number who had (47.3%). From those who have had any training in ergonomics the vast majority pointed out that they had it as part of their undergraduate training (68.2%). The remainder were distributed between those who a) had training sessions or courses in ergonomics (29.5%) and b) had one day/short-course or no-specified course (13.3%). The total is over 100% because some gave more than one answer. No associated qualification in ergonomics was mentioned by people who had attended training, except for one participant who has a Manual Handling Certificate.

When asked if they think that ergonomics is important in the design of wheelchairs for disabled people, respondents were almost unanimous, 95.7% (n = 93) answering affirmatively (the remainder gave no answer or said that they did not know, but no-one answered negatively). According to them, ergonomics is important in the design of wheelchairs for disabled people for the following reasons (starting from the most mentioned answers, percentage of answers on brackets):

- To achieve a high level of functional efficiency, conserving energy and minimising effort (29.2%).
- To ensure that the characteristics of the wheelchair meet individual needs and lifestyle of the user (18.4%).
- To improve posture, movement and comfort for both user and carer (17.5%).
- To minimise frustration and give independence enabling access to difficult areas and facilitating everyday tasks (14.6%).
- To provide data on safety, fast propulsion, good stability and easy manoeuvring to enable the design of wheelchairs to meet users' needs and wishes (10.7%).
- To provide data to design wheelchairs in order to meet a wide variety of users (6.7%).
- Other reasons (2.9%).

Some respondents also provided the following comments:

- "They are already disadvantaged with a disability, they don't want to be additionally disadvantaged by a wheelchair which is poorly designed."
- "Disabled people are not box shaped and some wheelchairs are in angles of 90°."
- "Most standard wheelchairs in the N.H.S. have the wrong dimensions for the clients."
- "A wheelchair needs to almost become an extension of the user."
These quotations reflect concerns that some therapists have about the design of wheelchairs. Certainly, according to the answers provided in the sample, ergonomics, as a discipline that deals with user needs and requirements, should perform a very important role in wheelchair design. This reinforces the meaning that if designers and manufacturers wish to produce equipment to match user needs, they will have to incorporate ergonomics into the whole design process.

4.3.2.3 Exploratory questions about wheelchair prescription

The vast majority of respondents (87.1%, n = 93) have identified weaknesses in the process by which clients are assessed and wheelchairs prescribed. They have stressed the following as the main weaknesses (starting from the most mentioned answers, number of mentioned answers in brackets):

- Budgetary constraints do not permit clients to be given what they ideally require, or limit the range of wheelchairs available for prescription (22).
- Limitations of equipment provided by the statutory service (20).
- Not enough time is allowed for assessment due to workload and demand (10).
- Clients may sometimes be assessed by staff without experience/no formal training to prescribe wheelchair or poor understanding and clinical assessment skills of prescribing therapists (9).
- The user's condition may change during a long waiting time (7).
- Standard wheelchairs do not fit the client's needs (6).
- There is difficulty in keeping up to date with the large variety of wheelchairs on the market (4).
- Attendants/carers needs are not considered in the process (3)
- Prescribers do not assess clients during functional activities in their own environment (3%)
- The more sophisticated systems are out of price range (2).
- Lack of standards/guidelines for assessment (2).
- Lack of continuity with possible poor follow-up (1).
- Poor understanding of users' needs (1).
- Not always able to provide trial chair for the assessment period (1).
- Limited range of wheelchairs available for occasional and less active users (1).
- Don't provide the clients with enough information about the wheelchair and how to maintain it (1).
- Poor design of wheelchairs causes rejection by the users (1).
The following comments illustrate the opinion of some therapists regarding the prescription process:

- "The prescription is governed by finance."
- "Clients are made to fit standard wheelchairs, the wheelchairs are not made to fit the client!"
- "A wheelchair arrives on their doorstep, they don't know anything about their chair and don't know how to maintain them."
- "Few clients are actually assessed and standard model wheelchairs are prescribed for the majority of users."
- "As we only have a limited range of chairs we sometimes have to try to fit the person to the chair."
- "Wheelchair prescription is always a compromise."

All respondents who identified weaknesses in the process by which clients are assessed and wheelchairs prescribed agreed that such weaknesses have implications for design. When asked what these implications are, the respondents produced some recommendations for the design of wheelchairs (starting from the most mentioned answers and including the number of mentioned answers in brackets) revealing the need to:

- produce wheelchairs with more adaptability/interchangeability and adjustability (17)
- produce lightweight wheelchairs (11)
- keep costs low/produce a cost effective design (10)
- improve design quality/produce an ergonomically designed wheelchair (6)
- produce good information about wheelchair models and features (3)
- take into account the ability of the client, purpose of the wheelchair and environment in which it is to be used (2)
- take carers into account (1)
- consult disabled people during the design process (1)
- produce wheelchairs which are dimensionally improved (1).

It is important to take into account that these recommendations refer to those wheelchairs actually available from the N.H.S. Certainly there are other more expensive models available in the market whose features meet most of the recommendations mentioned above.

Some respondents also produced the following comments:
Chapter 4: Wheelchair Supply and Prescription

• "The design of chairs (N.H.S.) has not changed in years. They fall apart, brakes fail, canvasses tear, footplate fixing don't function."

• "Often people want lightweight chairs or ease of transfer into/out of a car. They rarely comment on comfort unless a full time user."

• "Clients come into the D.L.C. because they are not happy with their N.H.S. wheelchair."

More than half of the sample (54.8%, n= 93) answered negatively when asked "when wheelchairs have been delivered to clients do you subsequently formally collect the views of the users about the wheelchairs which have been prescribed for them?". The remaining answers were: 39.8% which said "yes" and 5.4% with "no answer". Although the question stated the word "formally", some respondents who answered "yes" said that the views were not collected formally. Some respondents who answered "no" argued that they did not collect the views of the users because of pressure of work and lack of enough staff in the wheelchair service. Other respondents said that although they did not collect the views of the users, they felt that they should do so in order to help them to establish to what extent the equipment is being used by clients. According to some respondents clients are usually instructed to contact them if some problems occur. Also, members of user groups make comments and send them to the prescribers. It is important to call attention to the fact that the large majority of respondents who work in D.L.Cs. answered "no" to this question. It is supposed (according to some answers) that the therapists who work in D.L.Cs. are more involved in advising the clients which is the best wheelchair to fit their needs than carrying out a formal assessment, prescription and subsequent evaluation.

The methods more commonly used to collect the views of users about the wheelchairs which have been prescribed for them is by (starting from the most mentioned answers and including the number of mentioned answers in brackets):

• Survey, questionnaires, interviews or focus group (17)
• letter (9)
• follow-up visit (7)
• telephone call (4)
• consultation or involvement with user groups (4)
• formal reviews/re-assessment (2)
• comments received back from unsatisfied users (1) and
• audit process (1).

According to the respondents, these views of users are put to the following use (starting from the most mentioned answers):
Chapter 4: Wheelchair Supply and Prescription

- To discuss/complaint/send feedback back to manufacturers (usually via representatives), dealers or the Medical Device Agency (16)
- to re-assess, if necessary (6)
- to improve the service (6)
- to discuss information with other practitioners and use information in audit projects (5)
- to keep records/information (3)
- to satisfy the patient's needs (2)
- to identify the choice of chairs within range of use (2)
- to improve the prescription skills (1) and
- to improve the prescriber understanding of design problems and features (1).

Amongst those respondents (37 people) who have collected the views of users about the wheelchairs which have been prescribed, 83.8% stated that these views are fed back to designers and manufacturers. They gave the following examples of technical features where they have used the views of clients to assist in the design of wheelchairs:

- Difficulty in use of headrest
- armrest design
- adjustability for armrest
- adjustability of various components
- backrests and seat widths
- insufficient footrest height variation
- footrest angles
- footplate release mechanism
- efforts to reduce wheelchair weight
- position of brake levels and tyres
- upholstery and
- improvement of the controller on powered chairs

The respondents stated that informal recommendations, feedback and complaints received from clients are passed onto manufacturers directly or, usually, via representatives. Some reported that they cannot identify cases where design has changed or the recommendations provided were taken into account. The following comments were made concerning this matter:

- "I see a lot of company representatives and always report back comments from users who visit the centre: it doesn't seem to make much difference!"
"Generally no action is taken if it means money (...) have examples of poor design on several chairs at the moment."

4.3.2.4 Exploratory questions about wheelchair design

The majority of respondents (77.4%, n = 93) answered that they have, at least once, been in contact with manufacturers about problems connected with wheelchairs. When asked if the manufacturers took notice of what they said and whether the manufacturers modified the wheelchair the majority of them answered "unsure" (44.4%) and "no" (19.4%). Just one-third of the respondents answered "yes" (36.2%).

Just over 80% (n = 93) of respondents answered that have never been involved in wheelchair design with a company that mass produces wheelchairs for a large market (12.9% of the sample answered affirmatively and 6.5% gave no answer). According to the respondents, the main contributions that they have provided were:

- comments and suggestions about the design and re-design and
- feeding back comments on design/wheelchair on technical/design problems and user problems.

One point that should be called to attention relates to the concept of mass-producers of wheelchairs in the U.K. In fact it is a matter of relativity and the intention in using this term in the question was only to make clear the difference between companies that produce wheelchairs in a large quantity and the others with a limited production.

A large number of respondents (60.2%, n = 93) said that they would like to be involved in wheelchair design with companies that mass produce wheelchairs for a large market. They said that they could provide the following kind of contribution to wheelchair design (starting from the most mentioned answers and including the number of mentioned answers in brackets):

- Report experience of clients needs in their everyday use, home and workplace (14)
- feedback from users comments/problems (13)
- specify clinical needs, e.g. activity analysis, functional abilities, posture, seating function (9)
- technical issues and general design feature, e.g. easy use, transport, adjustment (7)
comment, evaluate and/or test new products (6)
no specify/no clear (18).

From the respondents who answered that they would not like to be involved in wheelchair design (39.8%, n = 93) some stated that they had no time. Some respondents also stressed the importance of involving users themselves in the design process. The respondents provided the following comments:

- "Wheelchair companies do not, as far as I am aware, even ask therapists or clients for their views. We are presented with new designs as a fait accompli. Presumably someone, somewhere actually using chairs is consulted - I think we are too rural!"
- "Companies seem to rarely come into contact with users."
- "... we are the people that users generally express their concerns to."

The figure of 70% (n = 93) of respondents agree that, in general, the wheelchairs actually in the marketplace are designed taking into account the range of needs of disabled people. They think that because:

- There are a wide range of wheelchairs available
- they suit a large range and needs of people
- some have many adjustments and alterations
- wheelchair users and their representatives are increasingly being involved in the design or are making pressure to improve the design quality
- there are lightweight, multi-functional and 'good looking' wheelchairs available
- there are modular chairs available
- a lot of research has been done and incorporated in wheelchair design and
- some companies have disabled sales representatives who give guidance about design.

Although 66 respondents have made the previous statements to justify that the wheelchairs in the marketplace are designed taking into account the range of needs of disabled people, a lot of them expressed the view that the wheelchairs which most match users' needs are very expensive.

The remaining respondents (30%) do not agree that, in general, the wheelchairs actually in the marketplace are designed taking into account the range of needs of disabled people. They think in this way because the wheelchairs available are:
Chapter 4: Wheelchair Supply and Prescription

- Expensive
- heavy and bulky
- old-fashioned/unattractive
- not user-friendly
- have limited features, variety and flexibility/not versatile
- dimensional incompatibility and
do not use the technology currently available.

One of the respondents has summarised the general feeling saying: "Cheaper chairs have cheaper features".

The respondents were asked how they rate both manual and powered wheelchairs provided by private companies against those provided by the N.H.S. Although some respondents stated that this question is too general and the market is so varied that it is difficult to answer, a majority (87.1% for manual wheelchairs and 82.8% for powered wheelchairs) answered the question. Some respondents, who did not answer the question, stated that the wheelchairs provided by private companies are purchased by N.H.S. anyway, so chairs used by N.H.S. are the same as private chairs. Although this is true, the main objective of this question was to have a portrait of the general feeling of therapists comparing the wheelchairs actually available from N.H.S. in terms of structure, ergonomics and aesthetics with the others obtained directly by the users from private dealers. Naturally it is important to take into account that there are a large range of wheelchairs in the market place which could match the users' needs in terms of structure, ergonomics and aesthetics and that there is also a limitation in the N.H.S. budget which usually makes it difficult to provide the more expensive models.

Another important point is that this question was formulated differently in the pilot questionnaire and in the final version. The pilot questionnaire stated the question as "How do you rate the wheelchairs provided by N.H.S. against those provided by private companies?". To improve the understanding and avoid some interpretation mistakes, it was suggested by respondents re-write the question the other way round. In the final version the question was stated as "How do you rate the wheelchairs provided by private companies against those provided by N.H.S.?" This change was considered in the tabulation of the questionnaires.

Once more the role of costs was emphasised by some respondents. Some of them made the following comments:

- "Often user receives little assessment and companies are more interested in sales than in best fulfilling users' needs."
In Figure 4.2 and all subsequent figures in the thesis, unless otherwise explicitly stated, the \( n \) given in the title or elsewhere in the figure (e.g. Figs. 4.16 and 4.17, page 154) is a number of respondents. The percentage which is given is the percentage of respondents falling into a particular category and NOT the percentage of the total sample. Thus, for example, in Figure 4.2, on page 129, 27.3% of 81 respondents judged manual wheelchairs provided by private companies to be superior to those provided by the N.H.S. in terms of their physical structure.
"Satisfaction of user depends not only on the equipment provided but more on the information and training given. Dissatisfaction is often because the chair does not "cure" the client or they have other problems of an environmental, social or personal nature or no opportunity to learn how to use chair efficiently."

"The problem with private companies is their salesmen often do a 'hard sell' so that the wheelchair, however good, is inappropriate for that particular client."

"I do think that an awful lot of overprescription takes place and we see this frequently. Disabled people are exploited!"

The therapists were asked how they rated both manual and powered wheelchairs provided by private companies against those provided by N.H.S. 81 respondents (n = 93) answered this question. The answers are shown in Figures 4.2 to 4.4 (manual wheelchairs) and 4.5 to 4.7 (powered wheelchairs).

Manual Wheelchairs

According to Figure 4.2, almost half of the sample (40.7%, n=81) considered manual wheelchairs provided by private companies structurally equal to those provided by the N.H.S. 27.3% of the respondents considered them superior and 19.7% inferior. The remainder (12.3%) stated that they did not know.

Figure 4.2

Rating of manual wheelchairs provided by private companies compared to those provided by the N.H.S. in terms of structure.

![Figure 4.2 - Structure (n=81)](chart-image)
Figures 4.3 and 4.4
Rating of manual wheelchairs provided by private companies compared to those provided by the N.H.S. in terms of ergonomics and aesthetics.

**Figure 4.3 - Ergonomics (n =81)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't know</td>
<td>13.5</td>
</tr>
<tr>
<td>Inferior</td>
<td>6.2</td>
</tr>
<tr>
<td>Equal</td>
<td>22.2</td>
</tr>
<tr>
<td>Superior</td>
<td>58.1</td>
</tr>
</tbody>
</table>

Figure 4.3 shows that 58.1% of respondents rated manual wheelchairs provided by private companies ergonomically superior to those provided by the N.H.S. The remaining of the sample rated them as being equal (22.2%) or inferior (6.2%) those provided by the N.H.S. or said that they did not know (13.5%).

**Figure 4.4 - Aesthetics (n =81)**

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Inferior</td>
<td>2.5</td>
</tr>
<tr>
<td>Equal</td>
<td>9.9</td>
</tr>
<tr>
<td>Superior</td>
<td>83.9</td>
</tr>
</tbody>
</table>

The vast majority of respondents (83.9%) rated manual wheelchairs provided by private companies aesthetically superior against those provided by the N.H.S. (Figure 4.4). The remainder of the sample were distributed between equal (9.9%), inferior (2.5%) and did not know (3.7%).
**Powered wheelchairs**

In terms of powered wheelchairs, Figure 4.5 shows that almost half of the sample (45.4%, \(n=77\)) rated the wheelchairs provided by private companies structurally equal to those provided by the N.H.S. 28.6% of the respondents considered them superior, 10.4% rated them inferior and 15.6% answered that they did not know.

According to Figure 4.6, figures are just slightly different from the previous one: 45% of respondents considered the powered wheelchairs provided by private companies ergonomically equal when compared with those provided by the N.H.S. and 37.7% rated them superior. 13% of the sample answered that they did not know and just 3% rated the wheelchairs provided by private companies ergonomically inferior when compared with those provided by the N.H.S.

Figures 4.5 and 4.6

Rating of powered wheelchairs provided by private companies compared to those provided by the N.H.S. in terms of structure and ergonomics.

**Figure 4.5 - Structure \((n=77)\)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't know</td>
<td>15.6</td>
</tr>
<tr>
<td>Inferior</td>
<td>10.4</td>
</tr>
<tr>
<td>Equal</td>
<td>45.4</td>
</tr>
<tr>
<td>Superior</td>
<td>28.6</td>
</tr>
</tbody>
</table>

**Figure 4.6 - Ergonomics \((n=77)\)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't know</td>
<td>13</td>
</tr>
<tr>
<td>Inferior</td>
<td>3.9</td>
</tr>
<tr>
<td>Equal</td>
<td>45.4</td>
</tr>
<tr>
<td>Superior</td>
<td>37.7</td>
</tr>
</tbody>
</table>
Figure 4.7
Rating of powered wheelchairs provided by private companies compared to those provided by the N.H.S. in terms of aesthetics.

![Figure 4.7 - Aesthetics (n=77)](image)

Lastly, Figure 4.7 shows that the majority of respondents (68.8%) rated the powered wheelchairs provided by private companies aesthetically superior to those provided by the N.H.S. 24.7% considered them equal and the remainder rated them inferior (1%) or answered that they did not know (4%).

The therapists were also asked how they rated, generally speaking, the design of wheelchairs provided by the N.H.S. and by private companies in terms of meeting the needs of disabled people. The number of respondents (n = 93) who answered this question varied: 89 people answered it with regard to the wheelchairs provided by the N.H.S. and 80 people answered this question with regard to the wheelchairs provided by private companies. Their answers are shown in Figures 4.8 and 4.9 for both, manual and powered wheelchairs, respectively.

Figure 4.8 shows that 56.2% of respondents rated manual wheelchairs provided by private companies as being "good" in terms of meeting the needs of disabled people and 27.5% rated them as "average". 16.3% of the respondents rated them as "very good". Anybody rated them as being "poor" or "very poor". As far as those manual wheelchairs provided by the N.H.S. are concerned, about 46% of the respondents rated them as being "average" and about 37% considered them "good". Only 2.2% of the respondents rated them as "very good" and, on the other extreme, a small number considered them as being "poor" (12.4%) and "very poor" (2.2%).
Figure 4.9 illustrates the respondent's answers concerned with powered wheelchairs. The figures now show that almost 60% of them rated the powered wheelchairs provided by private companies as being "good" in terms of meeting the needs of disabled people. 24% of the respondents rated them as "average" and 13.9% considered them as being "very good".

Figures 4.8 and 4.9
Rating of manual and powered wheelchairs provided by the N.H.S. and private companies in terms of meeting the needs of disabled people.

Figure 4.8 - Manual Wheelchairs (n=89)

<table>
<thead>
<tr>
<th>RATING</th>
<th>N.H.S.</th>
<th>Private companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>v. poor</td>
<td>2.2</td>
<td>1.3</td>
</tr>
<tr>
<td>poor</td>
<td>12.4</td>
<td>13.9</td>
</tr>
<tr>
<td>average</td>
<td>27.5</td>
<td>24.1</td>
</tr>
<tr>
<td>good</td>
<td>57.1</td>
<td>44.9</td>
</tr>
<tr>
<td>v. good</td>
<td>56.2</td>
<td>34.9</td>
</tr>
</tbody>
</table>

Figure 4.9 - Powered Wheelchairs (n=89)

<table>
<thead>
<tr>
<th>RATING</th>
<th>N.H.S.</th>
<th>Private companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>v. poor</td>
<td>2.2</td>
<td>1.3</td>
</tr>
<tr>
<td>poor</td>
<td>12.4</td>
<td>13.9</td>
</tr>
<tr>
<td>average</td>
<td>24.1</td>
<td>24.1</td>
</tr>
<tr>
<td>good</td>
<td>44.9</td>
<td>34.9</td>
</tr>
<tr>
<td>v. good</td>
<td>56.2</td>
<td>34.9</td>
</tr>
</tbody>
</table>
Anybody rated them as "poor" or "very poor". In regarding to those powered wheelchairs provided by the N.H.S., almost 45% rated them as being "average" and 35% considered them "good". The remainder of the sample rated them as being "very good" (5.6%), "poor" (12.4%) and "very poor" (2.2%).

It is important once more to draw attention to the fact that there are a large number of wheelchair models and makes provided by both private companies and the N.H.S. Sometimes the only difference between them remains in terms of price and limited number of features available from those wheelchairs provided by the N.H.S. The figures described in the Figures above represent only an impressionist view of the respondents and should be considered in a general way.

4.3.3 Major features of data, comments and lessons learned

A number of lessons have been learnt from the survey of therapists. It is important to emphasise that a response rate of almost 50% of questionnaires returned was higher than would normally be expected. Nevertheless it still means that the results have be treated with caution in interpreting the data. This relatively high response rate reflects the interest of therapists in the subject, their concerns regarding wheelchair design issues and their wish to co-operate with research activities. It is important to call the attention to the fact that although the survey was carried out in an impressionistic way, it became clear that a number of people have mentioned some concerns which certainly need to be taken into account by all the stakeholders involved in the wheelchair design, prescription and supply.

The vast majority of therapists who answered the survey were occupational therapists who work in an N.H.S. Wheelchair Service. Although a large proportion of respondents answered that they had had some training to enable them to assess clients and to prescribe wheelchairs, only half of them had attended courses in accredited institutions. The other half of the sample had had one day and/or short courses, in house training and "on job" experience. Certainly all this training and courses are useful in improving professional skills. However a formal reinforcement via specific training, which should be given by a recognised educational body, would help to improve the standard of wheelchair assessment, prescription and advice which was considered to be inadequate by the McColl Report (McColl, 1986). In fact it can be considered that what the McColl Report stated ten years ago still appears to be the case.

All of respondents were familiar with the word 'ergonomics'. Broadly speaking, the goal of occupational therapists is to assist clients in attaining their highest functional performance in
all areas of life, including work, recreation, and home; taking into account their limitations and capabilities, their potential abilities, and the physiological and psychological demands of their work (Rice, 1995). In fact, these goals conform to the intentions delineated by ergonomists especially those who design workplaces and equipment with physical safety and effective work performance in mind. Although therapists and ergonomists share common interests, they have their own particular approaches which can sometimes be integrated by adding ergonomic principles to therapeutic clinical practice. Thus, as a reflection of the therapists' area of work, the majority of the respondents' definitions of ergonomics stressed the relationship between the individual and the environment and their physiological and biomechanical aspects. The views of ergonomics expressed by the therapists are quite different from those expressed by the designers (section 3.2.2, page 77) and the rehabilitation engineers (section 4.4.2.1, page 144) which particularly emphasise the relationship between user, product comfort and convenience to use. This confirm the statement advocated by Meister (1989, page 4) who says that "a conceptual structure is a complex of beliefs on the basis of which those who pursue a particular discipline conduct the operations of that discipline". Therapists, rehabilitation engineers and designers have their own particular beliefs concerning ergonomics that form the basis on which they approach the issues regarding to wheelchair prescription and design.

Although less than half of the sample did not have any training in ergonomics, almost all the respondents agreed that ergonomics is important in the design of wheelchairs for disabled people. They mentioned a number of reasons for this such as: a) to achieve a high level of functional efficiency, conserving energy and minimising effort; b) to ensure that the characteristics of the wheelchair meet the individual needs and lifestyle of the user; c) to improve posture, movement and comfort for both user and carer.

It is important to draw attention to the fact that all the reasons stated by the therapists why ergonomics is important in the design of wheelchairs are part of the set of product requirements which designers have to deal with in the product development process. As design is essentially a matter of compromise, therapists should perform an important role in helping designers choose the best option available because they are the people closest to the users and carers.

Almost all the respondents in the survey identified weaknesses in the process by which clients are assessed and wheelchairs prescribed. Examples of those weaknesses are: a) there are budgetary constraints which do not permit clients to be given what they ideally require, or the range of wheelchairs available for prescription is restricted; b) there are limitations on the equipment provided by the statutory service; c) not enough time is allowed for assessment due to workload and demand.
The majority of the main weaknesses mentioned by the therapists, are related directly or indirectly to financial issues. Costs were mentioned frequently by a large number of respondents. To summarise the respondents' feelings, one of them said: "The prescription process is governed by finance".

The respondents agreed unanimously that such weaknesses have implications for design and indicated the need to: a) produce wheelchairs with more adaptability/interchangeability and adjustability; b) produce lightweight wheelchairs; c) keep costs low/produce a cost effective design; d) improve design quality/produce an ergonomically designed wheelchair; etc.

Some of the recommendations provided by the therapists address the scope of the product requirement, others, such as "take carers into account" and "consult disabled people during the design process" reveal the need to incorporate a user-centred design method into the wheelchair design process. The production of such a method is the main objective of this thesis.

More than half of the respondents answered that they do not have formal mechanisms to collect the views of users about the wheelchairs which have been prescribed for them. Amongst those who collect the views of users a) most of them do it in an unsystematic way and b) almost all of them stated that these views are fed back to designers and manufacturers in the form of complaints related to technical features. Although those informal recommendations were passed onto manufacturers, some therapists reported that they cannot identify cases where design has changed as a result of these or where recommendations provided have been taken into account.

In terms of contact with manufacturers, a large majority of respondents answered affirmatively when asked if they have ever been in contact with the manufacturers about problems connected with wheelchairs. Although on the one hand this is positive, almost two-thirds of these respondents had received no feedback from the manufacturers or did not know if the manufacturers had taken notice of what they had said and whether they had carried out any modification on the wheelchair. It is important to mention that one of the most important principles for guaranteeing quality of service is customer satisfaction. Feedback to the customer (in this case the therapist) contributes to a high level of customer satisfaction. This lack of feedback from manufacturers contributes a) to dissatisfaction amongst therapists and clients; b) to prejudicing the company's image and c) to increasing costs of manufacturing because mistakes already identified by therapists and users may continue to occur resulting in failure and malfunction of some wheelchair components.
One of the most important lessons that has emerged from the survey concerns the fact that almost all the respondents had never been involved in wheelchair design with a company that produces wheelchairs for a large market. This indicates that manufacturers are not yet aware of the contribution which therapists can provide to wheelchair design. Therapists can contribute to the wheelchair design process by providing comments and suggestions a) about user's clinical needs (e.g. activity analysis, functional abilities, posture, seating function); b) regarding individual's physical needs, capabilities, size, health, motivation and strength; c) about the environment in which the wheelchair is intended to be used; d) about technical issues and general design features (e.g. easy use, transport, adjustment) and e) after having evaluated or tested entirely new or re-designed products in the light of their own professional experience. The majority of respondents in the survey stressed that, although they had never been involved before, they would like to be involved in wheelchair design with companies that mass produce wheelchairs for a large market.

Although a large proportion of respondents agreed that, in general, the wheelchairs actually in the market place are designed to take into account the range of needs of disabled people, a lot of them indicated that the wheelchairs which most attend users' needs are very expensive. In fact, there are a large number of makes and models available in the market place. Customers can buy wheelchairs with a large range of features if they can pay for it. The major problems arise with the cheapest models, largely available from the N.H.S. These are more accessible to a large proportion of the disabled population. Most of these models are usually poorly designed with one or more of the following characteristics: heavy and bulky, old fashioned, unattractive, not user-friendly, have limited features, not versatile and do not use the technology currently available. The main challenge for the designer remains in producing a wheelchair which can integrate customer needs with product requirements such as function, performance, reliability, usability, appearance and cost.

The survey tried to obtain an impression of the image that therapists have when comparing, in terms of structure, ergonomics and aesthetics, the wheelchairs obtained directly by the users from private dealers with those available from the N.H.S.

In terms of manual wheelchairs (Figures 4.2, page 129; 4.3 and 4.4 page 130), data show that almost half of the sample considered the wheelchairs provided by private companies structurally equal to those provided by the N.H.S. and 20% rated the first one as superior. The literature shows that defects in seats, tyres and brakes are particularly common (Mulley, 1989); that less than a quarter of hospital wheelchairs are safe and in good working order (Young, 1985) and that more than one in 10 of the wheelchairs used at home need repair (Fenwick, 1977). Furthermore, according to Jelier and Turner-Smith (1997), the repair carried
out by approved repairers is poor and, to keep the costs down, only the bare essentials are being done. It appears to be clear that the technology already available - such as new synthetic solid tyre inserts to replace pneumatic inner tubers; light robust metals; thermal plastic resins - still remains far from the design and development of the wheelchairs currently available through the N.H.S. and the commercial market.

Data also show, according to the respondents, that the manual wheelchairs provided by the private companies are ergonomically and aesthetically superior to those provided by the N.H.S. This fact leads our attention to Barber's (1996) statement that the majority of products supplied by or through government agencies serve only to increase, at a psychological level, a person's sense of being disabled, especially in those who develop a physical impairment later in life. This is because, argues the author, the majority of these products are designed for the physical impairment but not for the person who uses them and his or her desired lifestyle. Certainly this occurs because the main consumer of these products, the N.H.S. and government agencies and not the person who uses them, have as their primary concern mainly, if not solely, to fulfil the wheelchair users' physical and medical needs rather than supply products based on an understanding of users' aspirations, uniqueness, values and status.

As far as powered wheelchairs are concerned (Figures 4.5 and 4.6, page 131 and Figure 4.7, page 132), almost all respondents rated the wheelchair provided by private companies structurally equal (45.4%) or superior (28.6%) when compared with those provided by the N.H.S. The data are practically the same in terms of ergonomics. When asked about aesthetics, again, almost all respondents considered the wheelchairs provided by private companies superior (70%) or equal (24.7%) to those provided by the N.H.S. It should be noted that these latter figures show a clear predominance of the wheelchair provided by private companies in terms of aesthetics. This reinforces the statements of the previous paragraph.

In spite of the limitations of the N.H.S. budget, which usually makes it difficult to provide the more expensive models, almost all the respondents rated the manual wheelchairs provided by the N.H.S. as "average" or "good" in terms of meeting the needs of disabled people (Figure 4.8, page 133). With regard to the manual wheelchairs provided by private companies, results are still more positive when rated in terms of meeting the needs of disabled people. The number of respondents who rated them as "good" and "average" is still higher than the number which gave the same rating to the wheelchairs provided by the N.H.S. In view of the number of models available in the market place and the large range of features that they can have, it seems natural that the wheelchairs provided by private companies should achieve a
better rating than those provided by the N.H.S. in terms of meeting the needs of disabled people.

The results are almost identical for powered wheelchairs (Figure 4.9, page 133). It is important to draw attention to two important points: a) a large number of model and makes are available from both private companies and the N.H.S. so these data can only be considered in a very broad way and b) despite the several problems that can be found in the design of the wheelchairs provided by the N.H.S., the vast majority of respondents believe that they are able to meet the needs of disabled people. It is possible that the large variety of models available and the fact that in the end the therapists themselves are responsible for the prescription process, i.e. they prescribe the wheelchair which will meet the need of the client, are points which may have contributed to the positive rating achieved by the N.H.S. wheelchairs. Certainly the need for a better design centred on the users' needs is still urgent.

One important lesson that has emerged from the survey of therapists is that there is, optimistically speaking, a very tenuous line of communication between the various stakeholders involved in the process of design and supplying wheelchair. A vicious circle of miscommunications occurs on the numerous stages of the chain of conception, prescription and distribution of wheelchairs. Firstly, in terms of conception, the design process is carried out based on the designers' assumptions about users' expectations without hearing users and prescribers. Secondly, in the majority of cases in the prescription process, the wheelchair tends to be prescribed by professionals rather than being chosen by the users with the aid of professional advice, which means that again users are not being heard. Thirdly, the N.H.S. and government agencies, as the main consumers of wheelchairs, have as their only concern the fulfilment of the wheelchair users' physical and medical needs, without taking into account what users and their carers have to say in terms of product satisfaction; what prescribers have to say in terms of their experience in dealing with wheelchairs and their users; and what designers have to say in terms of product requirements, including aesthetics and usability.

The overcoming of the chain of miscommunication should be the first step in the production, prescription and provision of better wheelchairs. This action, would undoubtedly result in enormous benefits for stakeholders. The N.H.S. and government agencies, will have sufficient input to enable them to provide products which will match the users' expectation, without losing money through having them rejected by users and/or being manufactured without having taken into account the new technologies available and advances in the manufacturing process. The prescribers will be aware of the users' requirements and availability of the best options for their clients in terms of meeting their clinical, psychological and social needs. The
users will be certain that the assessment and prescription process will match their needs in terms of mobility, independence, comfort and confidence.

The dialogue between the stakeholders will also contribute to finding solutions to minimise the impact of costs in the whole process. The design of wheelchairs as a consumer product, as discussed in other parts of this thesis, will certainly contribute to a reduction in the costs of production and commercialisation; and an increase in the quality of product characteristics in order to more adequately meet the users' needs.

A good computer database linking the various N.H.S. Wheelchair Services throughout the country, which would provide up-to-date data to the manufacturers and designers and the N.H.S. and governmental agencies, should be the first step to overcome the communication problems. Furthermore, standards using national guidelines, with a margin for some local adjustment, for the assessment of users and provision of wheelchairs with the active participation of the user will provide consistency, uniformity and a central guidance to the wheelchair services. They will also provide a tool for audits and a framework for having the views of clients taken into account.

4.4 Survey of rehabilitation engineers

4.4.1 Strategy and design of the field study of rehabilitation engineers

Rehabilitation engineers play an important role in the process of assessment of users and the prescription of their wheelchairs. They usually work with the therapists to determine the best device to meet the client's needs, or specify modifications and/or integration with other devices the client uses. According to Cooper (1995), the aims of the rehabilitation engineering is to promote the development and application of the most appropriate and cost-effective technology with which to meet the rehabilitation goals of the person with a disability.

The rehabilitation engineers, who work in the N.H.S. Wheelchair Service throughout the country, are the professionals with technical competence to design and carry out modifications and/or adaptation in wheelchairs as required on an individual customer basis. They may have also a strong link with manufacturers because they have the technical expertise to suggest modifications, adaptations and improvement in the design of mass-produced wheelchairs.
Chapter 4: Wheelchair Supply and Prescription

Following the same approach established in the survey of therapists (Section 4.3), a field study of rehabilitation engineers was carried out to obtain a better understanding of the prescription process and, mainly, to determine what is their contribution, actually or potentially, to wheelchair design. In the same way as the previous study with the therapists, in this survey, the interest was not in design for individual (bespoke design) or particular adaptations of wheelchairs for specific patient needs. The interest was in the production of wheelchairs on a large manufacturing scale (generic design) directed at a broad group of people.

The sample was comprised of rehabilitation engineers dealing with wheelchairs and working in the N.H.S. Wheelchair Service in the United Kingdom. Questionnaires were sent including two cover letters: one for the attention of the N.H.S. Wheelchair Service Managers and the other to the rehabilitation engineers. The letter sent to the N.H.S. Wheelchair Service Managers included a Freepost envelope and a form to be filled in if: a) the Service was not assisted by a rehabilitation engineer or b) the rehabilitation engineer who assisted the Service was not expected to visit the office within two weeks of the date of receiving the letter. This approach was decided on as an attempt to have better control over the identification of which Services were assisted by rehabilitation engineers and which were not. The addresses to which the questionnaires were sent was obtained from the publication "Addresses of N.H.S. Wheelchair Services" (College of Occupational Therapists, 1995b). A number of questionnaires were also distributed via the Centre of Rehabilitation Engineering (Department of Medical Engineering & Physics, King's College London) to its associates.

The "Questionnaire for Rehabilitation Engineers" comprised 13 questions divided into three parts:

- Exploratory questions about ergonomics
- Exploratory questions about wheelchair prescription
- Exploratory questions about wheelchair design.

Section 4.4.2 contains an analysis of the answers obtained from the sample of rehabilitation engineers.

4.4.1.1 Ethical considerations

The survey was in accordance with the Department of Human Sciences' ethical guidelines. Responses were confidential and respondents' anonymity was guaranteed. No names were indicated on the completed questionnaire and results of the research could not be traced to
any individual respondent. It was considered unlikely that the nature of the questions in the survey would adversely affect respondents. No other person than the author had access to the completed questionnaires.

4.4.1.2 Survey procedures

The survey was carried out in two stages: a) the sending out of a pilot questionnaire by mail and b) the sending out of the final version of the questionnaire by mail.

Pilot Survey
The respondents who took part in the pilot survey were randomly chosen from the list of addresses of N.H.S. Wheelchair Services (College of Occupational Therapists, 1995b) and asked by telephone if they would be willing to take part in the survey. A covering letter (Appendix 4.8, page 412) was included with the pilot questionnaire (Appendix 4.9, page 414).

From the total of five pilot questionnaires sent out by mail there were three responses. Their answers contained the following comments/suggestions:

- Some concerns were expressed with regard to the size of the questionnaire and a suggestion was made to reduce the questionnaire's length.
- In terms of educational qualification (Question 1), it was mentioned that the vast majority of rehabilitation engineers have O.N.C. or H.N.C. diplomas and that this question would therefore not be particularly relevant.
- It was also mentioned that, the majority of assessment training (Question 2) usually occurs "on the job".

Starting from the need to reduce the length of the questionnaire, and taking into account the previous suggestions, a new version of the questionnaire was produced with the following modifications:

- The section which referred to "Personal Data" in the pilot version was eliminated.
- Question 2 was moved to the next section ("Exploratory Questions about Wheelchair Prescription") and its sub-question deleted.
- The sub-question in Question 3 was deleted.
- Question 5 was deleted.
- A new question was included asking the respondents if there was anything that they thought could be done to improve the design of wheelchairs in the market place.
It was decided to include the pilot questionnaires in the final sample because the changes made were not so significant.

Full Survey
After the revision of the pilot questionnaire, a kit including the final version of the questionnaires was sent out to 163 N.H.S. Wheelchair Services in the United Kingdom. The kit also included: a) two cover letters (one for the N.H.S. Wheelchair Service Managers, Appendix 4.10, page 419, and another to the rehabilitation engineers, Appendix 4.11, page 421) and b) a Freepost return envelope to facilitate replies of the N.H.S. Wheelchair Service Managers (if there was any rehabilitation engineer available) or the rehabilitation engineers themselves. The final version of the Questionnaire for Rehabilitation Engineers is shown in the Appendix 4.12, page 423. A number was given to each questionnaire, corresponding to the number given to each of the N.H.S. Wheelchair Service, so as to enable the researcher to monitor if the rehabilitation engineer working in the Service had or had not replied to the questionnaire. Another kit was sent out three weeks after the initial posting including: a) a reminder letter to the rehabilitation engineers (Appendix 4.13, page 427); b) another copy of the questionnaire and c) a Freepost return envelope. A deadline was given in the reminder letter. Eleven questionnaires came after the reminder letters had been posted.

From the 163 cover letters sent out to the N.H.S. Wheelchair Service Managers, 14 sent the form back saying that: a) the Service was not assisted by a Rehabilitation Engineering (4 answers); b) the rehabilitation engineer would not be visiting the office within the next two weeks (5 answers) or c) the rehabilitation engineer based at the Service had already completed one questionnaire (5 answers). One letter was returned marked as being an unknown address. These answers gave a final figure of 148 Services whose rehabilitation engineers could contribute to the survey.

4.4.2 Analysis of questionnaires

The total number of respondents, including the three pilot questionnaires, was 43 from the figure of 148 N.H.S. Wheelchair Services useful for the survey. All the questionnaires received back were considered valid. This gave a response rate of 29%. There were also 14 questionnaires sent back by the rehabilitation engineer community who had received them from the Centre of Rehabilitation Engineering, King’s College, which kindly agreed to distribute some questionnaires amongst their members. So, the total number of questionnaires received back in the whole sample was 57.
4.4.2.1 Exploratory questions about ergonomics

According to the rehabilitation engineers who answered the survey, the word 'ergonomics' is understood as:

- the relationship between people and their workplace/environment
- the study of the man-machine interface
- the design process to let the user achieve maximum functional benefit with the minimum degree of physical effort
- promoting function by the use of correctly positioned body segments, for optimum and correct performance
- the study of the human body in relation to work/general activities
- the design process to maximise function ensuring the best use of products to enhance ability
- the most appropriate design and positioning of equipment controls and features, including ease of cleaning and routine maintenance considerations
- design for ease of use
- the design process where anatomical and environmental issues are addressed
- fitting of equipment/procedures to people or a particular group of people.

Slightly more than half of the sample (56.1\%, n = 57) answered that they had had some training in ergonomics. The remainders said that had had no training (40.4\%) or did not give any answer (3.5\%).

4.4.2.2 Exploratory questions about wheelchair prescription

All the respondents in the sample were involved in the wheelchair prescription process except one who worked in the Medical Devices Agency, at Blackpool. Almost all respondents (94.7\%, n = 57) had received some training to enable them to assess clients and to prescribe wheelchairs. The majority of them (78.9\%, n = 57) had identified some weaknesses in the process by which wheelchairs are prescribed. The main weaknesses pointed out by the respondents were (starting from the most frequently mentioned answers and number of responses in brackets):

- Budget constraints/pressure to keep the costs to a manageable minimum (18)
- Referrals from professionals who have little knowledge about wheelchairs and their attributes (10)
Chapter 4: Wheelchair Supply and Prescription

- Insufficient time to properly evaluate the user (9)
- A limited range of wheelchairs available (8)
- A long time before the wheelchairs are delivered (3)
- Too much emphasis on clients physical needs, not enough on social needs (3)
- Lack of training from prescribers (2)
- Prescriptions follow local policies in different Health Districts instead of a National Policy/Non-standard approach (2)
- Lack of trial period for users (2)
- There is little considerations for the carer (2)
- Absence of team approach (1)
- Constraints of environmental factors (1)
- Insufficient follow-up (1)
- Prescription carried out without the assistance of a trained rehabilitation engineer (1).

Amongst the 45 rehabilitation engineers who identified some weaknesses in the process by which the wheelchairs are prescribed, 18 indicated that these weaknesses have some implications for design. When asked what these implications were, they produced the following answers (starting from the most frequently mentioned and including the number of responses in brackets):

- Need to produce a multi-adjustable and modular wheelchair (4)
- Design does not take user and carer needs into account (3)
- Need to produce more refined and cost-effective designs (3)
- Wheelchairs available are aesthetically poor (2)
- Wheelchairs not ergonomically designed (2)
- Design used for unsuitable purposes (1)
- Compromise to the best design solution is so far below the level of acceptability that the equipments may be rejected by the users (1)
- If more time was available in the assessment, the prescription would improve with positive consequences to the design as well (1)
- Poor feedback from professionals to wheelchair manufacturers (1).

It is important to draw attention to the fact that the answers above referred to the cheapest models, largely available through the N.H.S. scheme. The more expensive models certainly include features which meet most of the recommendations mentioned by the rehabilitation engineers.
About half of the sample (52.6%, n = 57) answered that after delivery, they formally collect the views of the users about the wheelchairs which had been prescribed. The methods commonly used to collect these views were (starting from the most frequently mentioned answers and including the number of responses in brackets):

- surveys, questionnaires and interviews (17)
- follow-up visit/review meeting (12)
- direct patient feedback (3)
- conversation (2)
- telephone call (2)
- letters (1)
- audit (1)
- feedback from user group (1).

Some of the respondents stated that visits were made just for clients who own powered or special wheelchairs. Others pointed out that questionnaires were only sent after the wheelchair had been on issue for 6/8 weeks, 6 months or 1 year.

According to the rehabilitation engineers in the sample, the views of users collected by them were used in the following ways (starting from the most frequently mentioned answers and including the number of responses in brackets):

- to identify and correct problems (10)
- to improve prescription practice/training and review of procedures (7)
- to be taken into account in future assessment and prescription (4)
- to assess the quality of service (2)
- to get an idea of the quality of equipments from the user point of view (2)
- to obtain the level of customer satisfaction (2)
- to feed them back to manufacturers (2)
- to feed them back to colleagues (2)
- to improve wheelchair design (1)
- to meet new requirements (1)
- to adjust the range and type of wheelchairs provided (1)
- to report to the Medical Device Agency (1).

Some respondents gave more than one answer. This is why the total number of responses is greater than the number of respondents who answered affirmatively when asked if they had collected the views of users about the wheelchairs which had been prescribed.
Some respondents also said that the user views collected by them were used: a) to make suggestions on up-dating design or in the production of new models; b) to provide reports to the National Defect Reporting System, and c) to give presentations in professional meetings.

Amongst those respondents (30 people) who answered positively to the question above, 20 stated that these views were fed back to designers and manufacturers. They gave the following examples of technical features where they had used the views of clients to assist in the design of wheelchairs:

- to solve problems with the rear plastic seat guide, which it was suggested should be metal
- to improve/simplify attendant controls of electrical powered wheelchairs
- to provide an occupant adjustable height armrest
- to alter the position of the footrest release mechanism
- to adjust the foot rest and brake system
- to improve the location of the brake's controls
- to improve the design of wheels to help lift the user
- to reposition the wheels, which were too far apart, thus prejudicing stability
- to redesign a wheelchair, which was previously very heavy, so that the carer could lift the user up kerbs
- to include tray mounting brackets
- to provide control box mountings and adjustments.

4.4.2.3 Exploratory questions about wheelchair design

All except one of the 57 respondents in the sample said that they had been in contact with manufacturers about problems connected with wheelchairs. 30.4% of those respondents affirmed that the manufacturers did not take any notice or were unsure if the manufacturers had take any notice of what they said and consequently carried out any modification to the wheelchair. From the remainder who answered affirmatively (69.6%), some said that the manufacturers took notice of what they said: a) depending on the company; b) sometimes, but not always; c) just because the contact was made via the National Defect Reporting System.

The majority of respondents (73.7%, n = 57) answered that they had never been involved in wheelchair design with a company that mass produced wheelchairs for a large market. According to those who had been involved in wheelchair design, the main contributions that they had provided were (starting from the most frequently mentioned answers and including the number of responses in brackets):
Chapter 4: Wheelchair Supply and Prescription

- given suggestions, taking part in the design team and consultancy (4)
- designing of special wheelchairs (3)
- highlighting problems (2)
- providing the ideas for redesign old models (1)
- giving an initial outline and detail of requirements and specifications (1)
- giving a specification for a product based on a mass production model (1)
- instigating design changes via defect investigations (1)
- carrying out product evaluations before the products were launched (1)
- taking part in ongoing trials in the field (1).

Almost 83% of the respondents ($n = 57$) answered that they would like to be involved, or continue to be involved, in wheelchair design with companies that mass produce wheelchairs for a large market. According to them, they could provide the following kind of contribution to wheelchair design (starting from the most frequently mentioned answers and including the number of responses in brackets):

- knowledge gained from practical experience with users and knowledge of users requirements (13)
- technical contribution, including seating, posture management, ergonomics (11)
- feedback on the problems users have, including design solutions (8)
- suggestions to overcome practical problems of design and improve design ideas (6)
- passing on the views of wheelchair users (4)
- pointing out the problem patients encounter at home (2)
- the design of wheelchairs to suit different markets (2)
- advising on design suitability (2)
- product evaluation (2)
- trials of prototypes (2)
- defining adaptability of the product (1)
- defining durability of the product (1).

A respondent stated that the contributions given by a group of engineers from the regional centre would give manufacturers more confidence to look at change. Another pointed out that some rehabilitation engineers that were wheelchair users themselves could provide a strong contribution to manufacturers.

On the one hand 36 respondents agreed that the wheelchairs actually in the market place were designed taking into account the range of needs of disabled people, while 29 answered that they did not agree. One respondent answered that he/she did not know. The number of
responses to this question was over 57 because many of respondents answered both "yes" and "no".

Those who responded affirmatively thought that the wheelchairs in the market place were designed taking into account the range of needs of disabled people because (starting from the most frequently mentioned answers and including the number of responses in brackets):

- manufacturers have a wide range of models available to meet most of the users' needs (13)
- modular designs, which can be tailored to suit individual, are available (3)
- the standard designs satisfy a large proportion of the market (2)
- they were generally effective (2)
- manufacturers are more aware about disabled needs (2)
- there has been an increase in the involvement of the disabled in the design (1)
- many ergonomics features are incorporated to the design (1)
- many new materials and build options are available (1)
- there are more functional wheelchairs available which can be fitted for purpose (1)
- they are generally light (1)
- they are easy to fold (1)
- they are available at a reasonable price to the N.H.S. (1)
- they are mass produced to reduce costs (1).

It is important to call the attention to the fact that some respondents who answered 'yes' said that this was true just for the upper end of the market.

Those respondents who answered "no" to the question above, thought that because:

- there is a lack of knowledge about users' needs or the disabled are not asked for their opinions (5)
- the wheelchairs are generally designed for those who are least demanding or to suit an average person (5)
- manufacturers can not make one chair to meet all the needs of all the users with a mass produced range (4)
- the price of the chairs is high (4)
- there is a lack of adjustability on standard models (4)
- there are not enough field trials to iron out the design faults (2)
- the smaller percentage who cannot use the standard design are poorly catered for (1)
- problems arise when patients are in the wheelchair for all day (1)
- they are only aimed at the young active user (1)
there are insufficient designs aimed at the geriatric population (1)
the traditional N.H.S. design is very poor (1)
the wheelchairs are too heavy (1)
few of the wheelchairs available are crash tested (1).

The respondents were asked how they rated both manual and powered wheelchairs provided by private companies against those provided by the N.H.S. It is important to point out that with the advent of the voucher scheme all wheelchairs are available to those users who want to invest funds of their own to obtain a better quality wheelchair than that which is available through the N.H.S. The main objective of this question was to gain a general feeling of rehabilitation engineers comparing the wheelchairs actually available from the N.H.S., in terms of structure, ergonomics and aesthetics, with the others obtained directly by the users from private dealers. It is also important to take into account that there is a large range of wheelchairs in the market place which could match the users' needs in terms of structure, ergonomics and aesthetics and that there is also a limitation on the N.H.S. budget which usually makes it difficult to provide the more expensive models.

Fifty three rehabilitation engineers (92.9% of n = 57) answered the question on how they rated both manual and powered wheelchairs provided by private companies against those provided by the N.H.S. The answers are shown in Figures 4.10 to 4.12 (manual wheelchairs) and 4.13 to 4.15 (powered wheelchairs).

**Manual Wheelchairs**
According to Figure 4.10, the majority of respondents (60.4%) rated manual wheelchairs provided by private companies structurally equal to those provided by the N.H.S. The remainder of the sample considered them superior (20.7%) or inferior (13.2%), or answered that they did not know (5.7%).

With regard to the ergonomic features of manual wheelchairs (Figure 4.11), almost all respondents rated the manual wheelchairs provided by private companies superior (47.2%) or equal (43.4%) to those provided by the N.H.S. Almost 8% of the respondents said that they did not know and just 1.9% rated them as being inferior.

Figure 4.12 shows that the vast majority of respondents (73.6%) rated manual wheelchairs provided by private companies as being aesthetically superior when compared with those provided by the N.H.S. The remainder of the sample rated them equal (17%), inferior (7.5%) or did not know (1.9%).
Figures 4.10 to 4.12
Rating of manual wheelchairs provided by private companies compared to those provided by the N.H.S. in terms of structure, ergonomics and aesthetics.

**Figure 4.10 - Structure (n =53)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>Inferior</td>
<td>13.2</td>
</tr>
<tr>
<td>Equal</td>
<td>60.4</td>
</tr>
<tr>
<td>Superior</td>
<td>20.7</td>
</tr>
</tbody>
</table>

**Figure 4.11 - Ergonomics (n =53)**

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<th>RATING</th>
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</thead>
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</tr>
<tr>
<td>Inferior</td>
<td>1.9</td>
</tr>
<tr>
<td>Equal</td>
<td>43.4</td>
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<tr>
<td>Superior</td>
<td>47.2</td>
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</table>

**Figure 4.12 - Aesthetics (n =53)**

<table>
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</thead>
<tbody>
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<td>Equal</td>
<td>17</td>
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<tr>
<td>Superior</td>
<td>73.5</td>
</tr>
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</table>
**Powered Wheelchairs**

As far as powered wheelchairs are concerned, Figure 4.13 shows that 56.6% of respondents rated the wheelchairs provided by private companies structurally equal to those provided by the N.H.S. About 30% considered them equal and the remainder rated them as being inferior (5.7%) or said that they did not know (7.5%).

According to Figure 4.14, more than half of the sample (58.5%) considered powered wheelchairs provided by private companies ergonomically equal to those provided by the N.H.S. Almost 36% of the respondents rated them superior, 5.7% answered that they did not know and no one considered them inferior.

Lastly, when asked about aesthetics, 60.4% of respondents answered that they considered the powered wheelchairs superior to those provided by the N.H.S. and 26.4% rated them equal (Figure 4.15). The remainder of the sample rated them aesthetically inferior (5.7) or said that they did not know (7.5%).

The rehabilitation engineers were also asked how they rated, broadly speaking, the design of wheelchairs provided by the N.H.S. and by private companies in terms of meeting the needs of disabled people. From the total of 57 persons who took part in the sample, 55 answered the question regarding the wheelchairs provided by the N.H.S. and 54 people answered it regarding the wheelchairs provided by private companies. Their answers are shown in Figures 4.16 and 4.17 for manual and powered wheelchairs respectively.

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**Figure 4.13**

Rating of powered wheelchairs provided by private companies compared to those provided by the N.H.S. in terms of structure.

**Figure 4.13 - Structure (n=53)**

<table>
<thead>
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<th>RATING</th>
<th>%</th>
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<tbody>
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</tr>
<tr>
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<tr>
<td>Super.</td>
<td>56.6</td>
</tr>
</tbody>
</table>
Figures 4.14 and 4.15
Rating of powered wheelchairs provided by private companies compared to those provided by the N.H.S. in terms of ergonomics and aesthetics.

**Figure 4.14 - Ergonomics (n =53)**

<table>
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<td>Superior</td>
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</table>

**Figure 4.15 - Aesthetics (n =53)**

<table>
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<tr>
<th>RATING</th>
<th>Count</th>
</tr>
</thead>
<tbody>
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<td>Don't know</td>
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</tr>
<tr>
<td>Inferior</td>
<td>5.7</td>
</tr>
<tr>
<td>Equal</td>
<td>26.4</td>
</tr>
<tr>
<td>Superior</td>
<td>60.4</td>
</tr>
</tbody>
</table>

According to Figure 4.16, 53.7% of respondents rated manual wheelchair provided by private companies as "good" in terms of meeting the needs of disabled people and 29.6% considered them as "average". Thirteen percent rated them as "very good" and 3.7% rated them as "poor". In terms of the manual wheelchairs provided by the N.H.S., the vast majority of respondents considered them as "good" (49.1%) or "average" (41.8%). The remainder rated them as "very good" (3.6%) and "poor" (5.5%).

Figure 4.17 illustrates the respondent's answers regarding powered wheelchairs. The figure shows that 59.2% of respondents rated the powered wheelchairs provided by private companies as "good" in terms of meeting the needs of disabled people and 22.2% considered them as "average. Thirteen percent of the sample rated them as "very good" and 5.6% rated them as "poor". With regard to those powered wheelchairs provided by the N.H.S., the large
majority of respondents rated them as "good" (60%) and "average" (34.5%). The remainder rated those powered wheelchairs as "very good" (3.7%) and "poor" (1.8%).

There are a large number of wheelchair models and makes provided by both private companies and the N.H.S. and it appears that sometimes the only difference between them remains in terms of price and the limited number of features available on N.H.S. wheelchairs.

Figure 4.16
Rating of manual wheelchairs provided by the N.H.S. and private companies in terms of meeting the needs of disabled people.

Figure 4.17
Rating of powered wheelchairs provided by the N.H.S. and private companies in terms of meeting the needs of disabled people.
Lastly, the rehabilitation engineers were asked if there was anything that could be done to improve the design of wheelchairs in the market place. They provided the following suggestions (starting from the most frequently mentioned suggestion and including the number of responses in brackets):

- Manufacturers need to hear from wheelchair users and health care professionals (9)
- More adaptability/greater flexibility in configuration (4)
- The use of lightweight materials should be increased to reduce the overall weight of manual wheelchairs (4)
- A better understanding of users' requirements is needed (2)
- Costs of the wheelchairs should be reduced (2)
- Modern/new "high tech" metals should be included in the manufacturing process (2)
- The design process leading to reducing costs in the tooling and production process should be improved (1)
- More modular wheelchairs to allow for change in patient needs should be produced (1)
- More light, smaller, folding, comfortable wheelchairs should be produced to cater for the elderly population (1)
- More practical and less cumbersome wheelchairs should be produced (1)
- More compact folding systems for special wheelchairs, e.g. recliner and tilt-in-space (all of which are currently heavy and bulky) should be produced (1)
- The design of pushers and handles should be improved (1)
- Safety should be improved (1)
- Seals should be provided on wheel and castor bearings (1)
- More qualified engineers who are themselves wheelchair users should be used (1).

4.4.3 Major features of data, comments and lessons learned

The survey of rehabilitation engineers has revealed a number of lessons. It is important to draw attention to the fact that, as with the therapists, a number of concerns were mentioned by the respondents which certainly need to be taken into account by all the stakeholders involved in wheelchair design, prescription and supply.

One important finding is that most of the concerns pointed out by the rehabilitation engineers and discussed below are similar to those mentioned by the therapists. In view of this, the major features of data introduced in the following paragraphs will be compared with those found in the survey of therapists. It is important to say that, due to the similarity of responses, most of the comments previously made in the analysis of the lessons learned and discussion of
the major features of data of the survey of therapists (section 4.3.3, pages 134 to 140) also apply here. To avoid repetition such comments will not be made again.

One interesting fact can be observed from the definitions of ergonomics stated by the rehabilitation engineers. Most of their definitions were related to the design activities and half of them mentioned the word 'design'. This could be justified by the fact that the understanding of the meaning of ergonomics is a reflection of the respondents' area of work. All of them were involved in the design of equipment and accessories for the disabled user. The statements made by Meister (1989, page 4) and referred to on page 135 of this thesis are also valid here: "a conceptual structure is a complex of individual beliefs that form the basis under which those who pursue a particular discipline conduct the operations of that discipline".

The high number of respondents who did not have any training in ergonomics (40.4%) is quite surprising and is a serious deficiency in the rehabilitation engineers' academic background. Although an analysis of the rehabilitation engineers' curricula was not carried out, it seems reasonable that the professional who claims to have the technical competence to design and carry out modifications and/or adaptations to devices to improve the quality of life of people with disabilities should have a strong background in ergonomics. This should be particularly true for those professionals who work in a clinical setting.

The majority of the respondents in the survey identified weaknesses in the process by which clients were assessed and wheelchair prescribed. Comparing the answers that the rehabilitation engineers gave with those answers obtained from the therapists in their survey (section 4.3.2.3, page 122), it can be observed that the weaknesses most frequently mentioned by the rehabilitation engineers were practically the same five as those identified by the therapists: budget constraints, insufficient time to evaluate users, limitations of equipment available, staff without experience or with no formal training to prescribe wheelchairs and a long time to deliver the wheelchairs. This confirms how many concerns people involved in wheelchair prescription have regarding problems associated with the severe budget limitation, and the provision of adequate training for the professionals responsible for wheelchair prescription. Regarding the remaining weaknesses stated by both rehabilitation engineers and therapists, many of them were also similar and included the lack of standards/guidelines for assessment.

Also a similarity can be observed between answers which both rehabilitation engineers and therapists gave regarding the implications of some weaknesses in the design of wheelchairs. The need to produce wheelchairs with more adaptability, interchangeability and adjustability was the recommendation most mentioned by the respondents in both surveys. Other recommendations included: a) improving design and b) taking users' and carers' needs into
account. A user-centred design method, the main objective of this thesis, would contribute to answering the need for improvements in wheelchair design.

A few more than half of the sample of rehabilitation engineers answered that after delivery they formally collected the users' views of the wheelchairs which had been prescribed for them. The figure of 52.6% rehabilitation engineers ($n = 57$) who answered affirmatively to this question corresponded to 39.8% of therapists ($n = 93$). Collecting users' views performs an essential role in the guaranteeing of providing satisfaction to the client. Both figures are far from an acceptable level. Possibly the figures provided by the rehabilitation engineers were higher than those provided by therapists mainly because the former were more involved with the design, specification and modification of equipments which, in its turn, is closely related to user's acceptance or rejection of a product.

Although all rehabilitation engineers in the sample, with the exception of one, said that they had been in contact with manufacturers about problems connected with wheelchairs, just 20 out of 30 respondents who answered positively to this question, stated that their views were fed back to designers and manufacturers of wheelchairs. It should be concluded that although the communication between rehabilitation engineers and manufacturer has already been established, most of the respondents are not yet aware about the need to report users' views to the designers and manufacturers.

It is important to draw attention to the fact that, although almost all the respondents in the sample said that they have been in contact with manufacturers about problems connected with wheelchairs, more than one-third of those respondents said that the manufacturers did not take any notice of them or were unsure if the manufacturers took any notice of what they said and carried out modifications in the wheelchairs. It was also mentioned that some contacts are made via the National Defect Reporting System. This naturally does not involve a voluntary contribution of rehabilitation engineers to the improvement of wheelchair design and customer satisfaction. This is also similar to what happens to the therapists regarding the same issue, the lack of feedback from some manufacturers contributes to a) dissatisfaction amongst prescribers and clients; b) prejudicing the company's image and c) increasing costs of manufacturing because mistakes already identified by rehabilitation engineers and users may continue to occur resulting in failure and malfunction of some wheelchair components. If manufacturers wish to survive in a very competitive market place it would be of benefit if they took the opinions of prescribers into account as a pre-requisite to producing successful wheelchairs.
Again, one important lesson already learnt from the survey of therapists, is repeated in the outcomes of the survey of rehabilitation engineers. The vast majority of respondents had never been involved in wheelchair design with a company that produced wheelchairs for a large market. This is a strong indicator that manufacturers are not yet aware of the contribution which both professions can provide to wheelchair design. Although the vast majority of respondents in the survey of rehabilitation engineers stressed that they had never been involved before, they did express a desire to be involved in wheelchair design in the future.

Rehabilitation engineers can contribute to the wheelchair design process by: a) identifying users' requirements; b) finding design solutions to problems users may have; c) giving technical advice; d) sharing their practical experience gained from dealing with users; e) highlighting and preventing problems; f) defining users' requirements and wheelchairs' specifications and g) carrying out the evaluation of products and prototypes and field trials. Although some of these contributions are activities which are part of the designers' competence, the rehabilitation engineers have the expertise to enable them to apply the most appropriate and cost-effective technology to solve engineering problems related to the design of wheelchairs.

Opinions were divided amongst the sample of rehabilitation engineers when it was asked if they agreed that, in general, the wheelchairs actually in the market place are designed to take the range of needs of disabled people into account. A few more than half of the responses were affirmative and some of the respondents mentioned that this was true just for the upper end of the market. This corresponds to the most expensive models available in the market place. The same comments concerning the responses to this question in the survey of therapists (page 127) are also applicable here: although there are a large range of makes and models available, only the more expensive have included a number of features which will cater for the majority of users' needs.

The survey tried to obtain an impression of the image that rehabilitation engineers have when comparing, in terms of structure, ergonomics and aesthetics, the wheelchairs obtained directly by the users from private dealers with those available from the N.H.S. A comparison between the views of the rehabilitation engineers in the sample and the therapists is shown in Figures 4.18 to 4.20 (manual wheelchairs) and 4.21 to 4.23 (powered wheelchairs).

In terms of the structure of manual wheelchairs provided by private companies compared with those provided by the N.H.S. (Figure 4.18), the data obtained from the survey of rehabilitation engineers (60.4% rated them equal and 20.7% as being superior) are markedly different from
the data found in the survey of therapists regarding the same issue (40.7% rated them equal and 27.3% as being superior).

Figures 4.19 and 4.20 show that rehabilitation engineers (n=53) think that those manual wheelchairs provided by private companies are ergonomically (47.2%) and aesthetically (73.6%) superior to those provided by the N.H.S. A similar outcome can be observed in the data obtained from the survey of therapists (81 people answered this question).

Figures 4.18 and 4.19
Comparison between the ratings of the rehabilitation engineers and therapists regarding manual wheelchairs provided by private companies and those provided by the N.H.S. in terms of structure and ergonomics.

**Figure 4.18 - Structure of Manual Wheelchairs**

<table>
<thead>
<tr>
<th>RATING</th>
<th>Rehab. Engineers (n=53)</th>
<th>Therapists (n=81)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't know</td>
<td>5.7</td>
<td>12.3</td>
</tr>
<tr>
<td>Inferior</td>
<td>13.2</td>
<td>19.7</td>
</tr>
<tr>
<td>Equal</td>
<td>40.7</td>
<td>60.4</td>
</tr>
<tr>
<td>Superior</td>
<td>20.7</td>
<td>27.3</td>
</tr>
</tbody>
</table>

**Figure 4.19 - Ergonomics of Manual Wheelchairs**

<table>
<thead>
<tr>
<th>RATING</th>
<th>Rehab. Engineers (n=53)</th>
<th>Therapists (n=81)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't know</td>
<td>7.5</td>
<td>13.5</td>
</tr>
<tr>
<td>Inferior</td>
<td>6.2</td>
<td>6.2</td>
</tr>
<tr>
<td>Equal</td>
<td>43.4</td>
<td>58.1</td>
</tr>
<tr>
<td>Superior</td>
<td>47.2</td>
<td>58.1</td>
</tr>
</tbody>
</table>
Figure 4.20
Comparison between the ratings of the rehabilitation engineers and therapists regarding manual wheelchairs provided by private companies and those provided by the N.H.S. in terms of aesthetics.

**Figure 4.20 - Aesthetics of Manual Wheelchairs**

<table>
<thead>
<tr>
<th>RATING</th>
<th>Rehab. Engineers (n=53)</th>
<th>Therapists (n=81)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't know</td>
<td>3.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Inferior</td>
<td>2.5</td>
<td>7.5</td>
</tr>
<tr>
<td>Equal</td>
<td>9.9</td>
<td>17</td>
</tr>
<tr>
<td>Superior</td>
<td>73.6</td>
<td>83.9</td>
</tr>
</tbody>
</table>

About 58% rated those wheelchairs provided by private companies ergonomically superior to those provided by the N.H.S. and 83.9% rated them as being aesthetically superior.

As far as powered wheelchairs are concerned, Figures 4.21 and 4.22 show that the majority of respondents in the sample of rehabilitation engineers who answered this question (n = 54) rated the wheelchairs provided by private companies structurally (56.6%) and ergonomically (58.5%) equal when compared with those provided by the N.H.S. The figures obtained from the survey of therapists (n = 81) regarding the same questions show that 45.4% rated them structurally equal while 45% of the sample rated them as being ergonomically equal.

In terms of the aesthetics of powered wheelchairs (Figure 4.23), data are also similar when comparing the responses obtained from the survey of rehabilitation engineers (n = 54) and the survey of therapists (n = 81). About 60% of the rehabilitation engineers rated the wheelchairs provided by private companies as being superior to those provided by the N.H.S., while 68.8% therapists made the same judgement.

Although the wheelchair design and prescription process was criticised by a substantial number of respondents in the survey of rehabilitation engineers, almost all of them (55 persons answered this question) rated the manual wheelchairs provided by the N.H.S. as being "good" (49.1%) or "average" (41.8%) in terms of meeting the needs of disabled people.
Figures 4.21 to 4.23
Comparison between the ratings of the rehabilitation engineers and therapists regarding powered wheelchairs provided by private companies and those provided by the N.H.S. in terms of structure, ergonomics and aesthetics.

**Figure 4.21 - Structure of Powered Wheelchairs**

<table>
<thead>
<tr>
<th>RATING</th>
<th>Rehabilitation Engineers (n=53)</th>
<th>Therapists (n=77)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't know</td>
<td>7.5</td>
<td>10.4</td>
</tr>
<tr>
<td>Inferior</td>
<td>5.7</td>
<td>10.4</td>
</tr>
<tr>
<td>Equal</td>
<td>45.4</td>
<td>56.2</td>
</tr>
<tr>
<td>Superior</td>
<td>28.6</td>
<td>30.2</td>
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</table>

**Figure 4.22 - Ergonomics of Powered Wheelchairs**

<table>
<thead>
<tr>
<th>RATING</th>
<th>Rehabilitation Engineers (n=53)</th>
<th>Therapists (n=77)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't know</td>
<td>5.7</td>
<td>13</td>
</tr>
<tr>
<td>Inferior</td>
<td>3.9</td>
<td>13</td>
</tr>
<tr>
<td>Equal</td>
<td>45.4</td>
<td>58.5</td>
</tr>
<tr>
<td>Superior</td>
<td>37.7</td>
<td>35.8</td>
</tr>
</tbody>
</table>

**Figure 4.23 - Aesthetics of Powered Wheelchairs**

<table>
<thead>
<tr>
<th>RATING</th>
<th>Rehabilitation Engineers (n=53)</th>
<th>Therapists (n=77)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't know</td>
<td>5.2</td>
<td>7.5</td>
</tr>
<tr>
<td>Inferior</td>
<td>1.3</td>
<td>5.7</td>
</tr>
<tr>
<td>Equal</td>
<td>24.7</td>
<td>26.4</td>
</tr>
<tr>
<td>Superior</td>
<td>60.4</td>
<td>68.8</td>
</tr>
</tbody>
</table>
Figures are almost the same for the therapists ($n = 89$). Thirty seven percent of the therapists rated them as being "good" and 46% rated them as being "average". Results are still more positive with regard to the manual wheelchairs provided by private companies. The number of respondents in both surveys who rated them as "good" and "average" is still higher than the number which gave the same rating to the wheelchairs provided by the N.H.S.: rehabilitation engineers ($n = 54$) rated the wheelchairs provided by the private companies as being "good" (53.7%) or being "average" (29.6%); therapists ($n = 80$) rated them as being "good" (56.2%) or being "average" (27.5%).

In terms of powered wheelchairs provided by private companies meeting the needs of disabled people, the data from the survey of rehabilitation engineers (Figure 4.17, page 154) and from the survey of therapists (Figure 4.9, page 133) are practically the same.

The answers concerned with powered wheelchairs provided by the N.H.S. in terms of meeting the needs of disabled people are quite different. On the one hand most of rehabilitation engineers (55 people out of 57) answered this question and generally rated them as being "good" (60%) and "average" (34.5%). On the other hand the figures from the survey of therapists (89 people out of 93 who answered this question) show that 35% rated them as being "good" and 45% as "average". This is one of the few occasions where opinions obtained from the surveys of rehabilitation engineers and therapists seem to be substantially divergent.

It is important to draw attention to the most frequently mentioned suggestions provided by the rehabilitation engineers for the improvement of the design of wheelchairs in the market place (see page 155). Similar concerns were also expressed by some therapists when they were asked questions about wheelchair prescription and design and justifies the need for a user-centred method in which users and health care professionals may have their voices heard.

Again, it is important to note that most of the comments regarding the survey of therapists are also applicable to the survey of rehabilitation engineers and were omitted to avoid repetition.

The following bullet points highlight the lessons learned from the survey of rehabilitation engineers:

- The majority of findings of the survey of rehabilitation engineers are similar to those from the survey of therapists.
- The majority of rehabilitation engineers in the survey understand ergonomics as an activity of design. This could be justified by the fact that design and engineering are the basis of the activities performed by the rehabilitation engineers. These naturally form the body of knowledge and individual belief system which they themselves use as a basis to translate the principles of ergonomics into their work and work-related activities.
• It was found that a high number of respondents did not have any training in ergonomics.
• The majority of the respondents in the survey identified weaknesses in the process by which clients are assessed and wheelchairs prescribed such as budget constraints, insufficient time to evaluate users, limitations of equipment available, staff without experience or with no formal training to prescribe wheelchairs, and long time lapse before the delivery of the wheelchairs.
• The weaknesses in the process by which clients were assessed and wheelchairs prescribed had some implications for the design of wheelchairs, such as the lack of adaptability, interchangeability and adjustability in a number of wheelchairs available.
• A few more than half of the sample of rehabilitation engineers answered that they formally collected the views of the users about the wheelchairs which had been prescribed for them after delivery. This number seems to be far from the ideal necessary to guarantee providing customer satisfaction.
• Although the communication between rehabilitation engineers and manufacturers had already being established, most of the respondents were not at that stage aware of the need to report users' views to the designers and manufacturers.
• One-third of respondents affirmed that the manufacturers did not take any notice or were unsure if the manufacturers took any notice of what they said and consequently carried out any modification to the wheelchairs.
• The vast majority of respondents had never been involved in wheelchair design with a company that produces wheelchairs for a large market.
• A few more than half of the respondents agreed that, in general, the wheelchairs actually in the market place were designed to take the range of needs of disabled people into account.
• Broadly speaking, the majority of rehabilitation engineers view manual wheelchairs provided by private companies structurally equal and ergonomically and aesthetically superior to those provided by the N.H.S.
• In terms of powered wheelchairs, the majority of respondents rated the wheelchairs provided by private companies as being structurally and ergonomically equal and aesthetically superior to those provided by the N.H.S.
• The sample of rehabilitation engineers was divided when asked to rate the design of manual wheelchairs provided by the N.H.S. in terms of meeting the needs of disabled people, with almost half of them rating those wheelchairs as being "good" and almost half as being "average". The answers regarding those manual wheelchairs provided by private companies were more positive: the majority answered as being "good" and almost all of the remaining rated them as being "average". In terms of powered wheelchairs, the majority of the respondents rated them as being good for both N.H.S. and private market place.
Chapter 5: Approaching the Process of Wheelchair Use

5.1 The process of wheelchair use

There are about half a million N.H.S. wheelchair users in the United Kingdom which represents one percent of the whole population of the country. It is also estimated that there are about 200,000 privately purchased non-powered wheelchairs in use in the UK. Within this large and powerful market there is an astonishingly and worrying high level of dissatisfaction with the wheelchairs currently in use.

Wheelchairs serve as a means of support and mobility for all kinds of people, including those who have acute mobility problems, patients in hospital and others who are temporarily disabled. Hence, there is no such thing as a "typical wheelchair user". The users differ in lifestyle, activities and interests, and are as complex and varied as any group of the population. Likewise, the range of environments and uses for wheelchairs is equally diverse varying from outdoor and sports activities to use at home, places of employment and public buildings.

The wheelchairs contribute to improving users' quality of life, enabling them to maintain or achieve an acceptable level of independence. Certainly, independence and an ability to participate integrally in daily activities are directly related to the comfort, fit and appropriate use of the wheelchair. So, ugly, uncomfortable and cumbersome wheelchairs provoke a negative effect on the user's life and contribute to reinforcing a stigma associated with wheelchairs. If, on the one hand, an individual's taste, interest, uniqueness, values, status and lifestyle are elements extensively analysed by marketing strategists to supply products and services that appeal to varying types of people; on the other, people with disabilities are still perceived as "in need" and "surviving" which is reflected in the design of some products they use, including wheelchairs.
Chapter 5: Wheelchair Use

The wheelchair users range from those who have a sporting active lifestyle to those of a relatively high age, with an inactive lifestyle and limited physical condition with consequences in terms of dependency and decreases in freedom of mobility. Wheelchair use increases with age (Smith, McCradle and Unsworth, 1995) and the wheelchair population is predominantly an elderly population (Goldsmith, 1992; Royal College of Physicians of London 1995). Despite the huge number of wheelchair users, most are intermittent users and only about 25 per cent of users require them all the time (Stewart, 1992).

Wheelchair users' disabilities range from light to severe. They may have neurological damage, due to multiple sclerosis or trauma, for instance; congenital problems such as cerebral palsy and spina bifida; or be one of a vast number of users with arthritis. Wheelchairs also assist those unable to use walking sticks and other aids because of insufficient strength or co-ordination of the upper limbs, heart disease, cerebral palsy or muscular dystrophy.

Today there are many types of wheelchairs available on the market. The number of different types of wheelchairs from which the users may choose have increased enormously in the last two decades. According to Engström (1993), the people who have contributed the most to the development of modern wheelchairs, at least in Sweden, are active users. In fact, in accordance with the core of this thesis, the users and their carers are the best people to say what their needs and views are. The following sections and sub-sections will describe and analyse a survey in which a sample of wheelchair users and their carers expressed their opinions, needs and views about wheelchair design and prescription.

5.2 Survey of wheelchair users

5.2.1 Strategy and design of the field study of wheelchair users

A field study of the wheelchairs users was carried out with the main objectives of: a) finding out the characteristics of wheelchairs the users use; b) obtaining the respondents feelings about their wheelchairs; c) obtaining the users' views about the prescription process; d) finding out the extent to which the wheelchairs issued by the N.H.S. and private companies are considered satisfactory; e) discovering more about the users' views
on wheelchair design and how the wheelchair design could be improved and f) using the results, later in this thesis, to develop a user-centred method for the design of wheelchairs.

The topics covered by the "Questionnaire for Wheelchair Users" were divided into four sections, including a total of 32 questions:

- Questions about the users themselves
- Questions about the wheelchair(s) belonging to the users
- Questions about the prescription process
- Questions about wheelchair design in general.

Taking into account that most of the users had more than one wheelchair, the questionnaire was designed in such a way as to enable the respondent to write down information separately for the two wheelchairs which they used most.

The sample of wheelchair users who took part in this survey was not intended to be representative of the wheelchair population as a whole in this country. This research was essentially exploratory. As such, the answers should be interpreted as impressions of part of a population that may, or may not, represent the views of the whole universe of wheelchair users.

A descriptive analysis of the answers obtained from the sample is outlined in section 5.2.2.

5.2.1.1 Ethical considerations

The survey was in accordance with the Department of Human Sciences' ethical guidelines. Responses were confidential and respondents' anonymity was guaranteed. No names were indicated on the completed questionnaire and results of the research could not be traced to any individual respondent. It was considered unlikely that the nature of the questions in the survey would adversely affect respondents. No other person had access to the completed questionnaires.

5.2.1.2 Survey procedures

The survey was conducted in three stages: a) identifying a number of "key persons" to distribute the questionnaire; b) carrying out the pilot surveys by personal interviews or
sending the questionnaires out by mail and c) the sending out of the final version of the questionnaires by mail to the "key persons".

Identifying the "key persons"

The field study approach was to send out the questionnaire to be distributed by people named here as "key persons". These persons should belong a) mainly to wheelchair user groups; b) to some association dealing with wheelchair issues or c) to any N.H.S. Wheelchair Services. The "key persons" could be either a wheelchair user or an able-bodied person.

The first step was try to identify some wheelchair user groups. The process to identify the wheelchair user groups was:

a) to send out a letter to each N.H.S. Wheelchair Service. The letter was sent for the attention of the Senior Therapist (Appendix 5.1, page 428). It included a form, to be detached and sent back by the therapists, asking if they knew any wheelchair user group and, if the answer was positive, the correspondent address and name of the person to contact. From the 166 letters sent out there were 38 responses.

b) to look at the internet. The site "Disability Net" (http://www.disabilitynet.co.uk/groups/index.html) was identified. It includes the addresses of several user groups throughout the country.

The second step was to make personal contact with each wheelchair user group by telephone or email in the attempt to convince any member of the group to distribute the questionnaires. Thirty persons agreed to distribute the questionnaires to members of their user group (a few of them in the same city, such as London and Birmigham). This covered the following places which represent most areas of the country:

- Birmingham
- Bradford
- Brighton
- Chesterfield
- Truro, Cornwall
- Coventry
- Bridport, Dorset
- Doncaster
- Glasgow
- Grantham
• Greenwich
• Headley Bondon, Hampshire
• Welwyn Garden City
• Newport, Isle of Wight
• Ipswich
• Kings Winford, West Midlands
• Loughborough
• Lincoln
• London
• Maidenhead
• Norwich
• Plymouth
• Scothern, Lincolnshire
• Sharesbury, Shropshire
• Southampton
• Stockport
• Sutton, Surrey
• Wirral

A director of the "Spinal Injuries Scotland" kindly agreed to distribute the questionnaires in some areas of Scotland:

• Aberdeen
• Aviemore
• Dundee
• Edinburgh
• Inverness

Finally, some therapists who work for the N.H.S. Wheelchair Services agreed to distribute the questionnaires in the following areas:

• Ellesmere Port
• Cambridge
• Derby
• London
• Preston
Unfortunately no "key person" was identified in the regions of Northern Ireland and Wales, consequently these areas were not covered by this survey.

**Pilot Survey**

Twelve persons took part in the pilot survey of wheelchair users. Three of them were interviewed face-to-face and had the opportunity to make comments and suggestions about the questions. From the total of 15 questionnaires sent out by mail there were nine responses. A covering letter (Appendix 5.2, page 430) was included to accompany the pilot questionnaires (Appendix 5.3, page 432).

The mailed questionnaires were sent to a manager of a wheelchair user group. The questionnaires were distributed by the manager in one of the wheelchair user group meetings. Each user received a set of two questionnaires: the first to be answered by themselves and the second to be answered by a carer nominated by them. If they did not have a carer, they were asked to ignore the second questionnaire. The questionnaires given to the carers are analysed in the section 5.3.2, page 223.

The following changes were made to the pilot questionnaire to produce the final version of the "Questionnaire for wheelchair users", most of them emerged from the pilot survey:

- The statement regarding questions 4 to 11 was re-written and was placed after question 3.
- A new question was included, after question 5, regarding the time the users had owned their wheelchairs.
- Two new options of accessories, seat cushion and back cushion, were included in question 6.
- In question 7, the option "less often than this" was re-written as "less often than 1 day a week".
- Question 8 was split in two to cover the use of wheelchairs indoors and outdoors and also included the option "none".
- A new question was included, after question 8, regarding the major problems the users had had with their wheelchairs in the last 12 months.
- A new question was included, after question 9, asking if the users had been shown how to use their wheelchairs.
- The word "written" was included in question and sub-question 10: "Have you received written instructions explaining how to use your wheelchairs?" and "If yes, do you consider that these written instructions were satisfactory?".
Chapter 5: Wheelchair Use

- In question 13, the words "broadly speaking" were included in the beginning of the phrase: "Broadly speaking, how important for you are the following characteristics of a wheelchair?".
- In questions 13 and 15, the characteristic "portability" was split into "portability due to size" and "portability due to use".
- In question 13 and 15, the characteristics "cheap to buy", "cheap to maintain" and "cheap to repair" were re-written as "cost to buy", "cost to maintain" and "cost to repair".
- In question 14, a statement asking the user to answer why they chose the three characteristics pointed out by them as the most important was included.
- In question 15, the tables for "chair 1" and "chair 2" were merged to improve the design of the questionnaire.
- In question 15, the statement "the chair you use the most, as stated in question 3" was included in the column headings for both "chair 1" and "chair 2".
- Former question 18, was placed after question 19, re-written and split into questions 20 and 21: a) Is it your impression that, in general, the wheelchairs actually in the NHS market place are designed taking into account the range of needs of disabled people? and b) Is it your impression that, in general, the wheelchairs actually in the private market place are designed taking into account the range of needs of disabled people?
- In question 23, the statement "do you drive your own vehicle" was substituted with "when you go out in a vehicle do you take your wheelchair with you?".
- In sub-question 23, the statement "if no, are you regularly taken out (e.g. for shopping, recreation) in a vehicle and accompanied by your wheelchair?" was replaced by the new question "which forms of public transport have you used in the last twelve months".
- A new question "what is the nature of your disability?" was included after question 23.
- The last question was re-written: "Lastly, is there anything that you can suggest to improve the design of wheelchairs in the market place?"

Although there were some changes made, it was decided to include the twelve pilot questionnaires in the final sample because the changes: a) did not affect the main points in the questionnaire and b) represented less than seven percent of the whole sample. The answers which were different from the pilot to the final version of the questionnaires have received special treatment and will be discussed, when appropriate, in the section regarding the analysis of questionnaires (section 5.2.2).
Chapter 5: Wheelchair Use

Full Survey
After having been revised, a package, including kits with the final version of the "Questionnaire for Wheelchair Users", was sent out to 41 key persons to be distributed amongst wheelchair users. Most of the key persons received 15 questionnaires in the package except a few persons who were willing to distribute only five or ten questionnaires. Another exception was the member of the "Spinal Injuries Scotland" who had agreed to distribute 45 questionnaires amongst the areas of Inverness and Aviemore, Dundee and Aberdeen, and Edinburgh.

The package sent to the key persons included a cover letter to him or herself (Appendix 5.4, page 440) and sets of 5 to 15 kits each one including: a) a cover letter to the wheelchair user; b) a copy of the "Questionnaire for Wheelchair User" (Appendix 5.5, page 442); c) a copy of the "Questionnaire for Personal Assistants (Carers)" and d) a Freepost return envelope to facilitate replies of both questionnaires. A number was given to each questionnaire so as to enable the researcher to monitor which "key person" had distributed the questionnaires. Each "Questionnaire for Wheelchair User" and "Questionnaire for Personal Assistants (Carers)" had the same number to facilitate the correspondence between each user with his or her carer. A reminder letter (Appendix 5.6, page 452) was sent out five weeks after the initial posting. Twenty-one questionnaires were received after the reminder letter had been posted.

5.2.2 Analysis of questionnaires

A total of 618 questionnaires were distributed including the pilot survey. An overall number of 191 users replied. Four responses were considered invalid because: a) there were very few answers and the main questions were left blank or b) they arrived when the questionnaires had already been processed. So, the number of valid response in the sample, including the twelve pilot questionnaires, was 187. This gave a response rate of 30.26%.

Two computer programmes were used for the treatment of the data: the spreadsheet Excel 97 for the data preparation and the software SPSS (Statistical Package for Social Sciences) version 8.0 for the tabulation and data analysis.

From the data tabulation, it could be observed that there were a number of missing data. These fell into two categories: "not applied" and "no answer":
This note is put here to remind the reader of what was written on page 128a. In all figures, unless otherwise explicitly stated, the n give in any figure is the number of respondents on which the percentages are based. Thus, for example, in Fig. 5.1, on page 173, there are 185 respondents who gave their age. 15.7% of 185 respondents were in the age group 25-34.
Chapter 5: Wheelchair Use

The first one occurred when it would have been inappropriate if the subjects had produced an answer (e.g. people who did not have a second chair would not produce answers on it) and the twelve subjects in the pilot sample who did not have some questions which only appeared in the final version of the questionnaires (e.g. question 30: "What is the nature of your disability?").

The second one occurred where no answer was provided even though one should have been (e.g. three people did not answer how long they had used their wheelchairs). In view of this, it was decided to consider only the valid percentage, leaving the missing questions out of the graphical portrayal of the data and analysis. So, although the total sample size was 187, sometimes the total number of valid responses was below 187. The number of valid responses is always given in the graphics or description of answers. With respect to the latter, the value of the percentage is followed by the number of the sample: for example 55.1%, n=187. This means that 55.1% of the sample of size 187. In some cases, when referring to statistics for wheelchairs one and two, the percentage and the number on which that percentage is based are given side-by-side for both chairs 1 and 2. For instance, concerning the accessories that the respondents said their wheelchairs have: seat cushion (84.7% for chair 1, n=176 and 81.4% for chair 2, n=140), back cushion (19.3%, n=176; 20.7%, n=140) and kerb climber (16.2%, n=185; 14.7%, n=143). So, the first percentage is always for chair 1 and the second for chair 2.

In every figure the abscissa gives the percentage of respondents to a particular value on the ordinate. For example, it can be seen, in Figure 5.1, that the age group is given on the left hand side of the graphic and the percentage is given along the bottom. In almost all bar graphs the percentage is given numerically on the top of the bars to enable the figure to be read and interpreted more easily.

5.2.2.1 Questions about the wheelchair users

The sample was comprised of almost equal numbers of men (n=90) and women (n=95). Two respondents did not give their gender.

There was a need to collect information on the ideas, views and feelings of wheelchair users at different stages in their lives, so the questionnaires were carried out with people in all age groups. The age profile of the sample is shown on Figure 5.1. It can be seen that the majority of respondents were over 45 years old and more than one-third of them were over 55 years old. Only one respondent was under 16 years old.
When asked about the nature of their disability, the majority of respondents answered that they suffered from neurological conditions (71.9%, $n=171$) such as Parkinson's disease and spinal muscular dystrophy. 18.7% suffered from arthritis. The remainder suffered from cardiovascular conditions (7%), stroke (6.4%), amputation (6.4%), ageing (6.4%), respiratory condition (5.3%) and other(s) (11.7%) such as diabetic neuropathy and chronic fatigue syndrome. The total is over 100% because some respondents had more than one disability.

The majority of people in the sample lived in a town or suburb (52.2%, $n=182$) or city (13.7%). A significant number lived in a village or hamlet (22.5%) or rural areas (11%). Just one respondent answered lived in an area other than these previously mentioned but did not specify which one.

Almost half of the respondents ($n=177$) answered that they were retired (44.1%). 18.6% answered that they were employed full time or part time. The same number stated that they were unemployed. Amongst those who answered "other" to this question (18.6%), there were eleven respondents who said that they had never worked or were unable to work due to their disability, eight who answered that they are involved in voluntary work, four students and three housewives.

When asked if they took their wheelchairs with them when they went out in a vehicle, only two respondents, out of 172, said not.
Figure 5.2 shows that a large percentage of respondents (40.5%) answered that they had not used any form of public transport in the last twelve months. However, 33.5% had used an airplane. The remainder of the sample are distributed amongst those who had used a mobility bus (19.1%), an intercity train (16.2%), a dial-a-ride service (14.5%), a local train (12.7%), a low floor type bus (7.5%), an other type of bus (4.6%), an underground train (5.8%) and an other (20.2%) which included taxi and ferry. The total is over 100% because some respondents gave more than one answer.

Figure 5.2
Forms of public transport that respondents have used in the last twelve months (n=173)

More than half of the sample (55.1%, n=187) had severe disabilities and were cared for full-time or part-time by personal assistants. It was expected that they would give the attached "Questionnaire for Personal Assistants" to a nominated carer.

5.2.2.2 Questions about user’s wheelchair(s)

As previously expected, Figure 5.3 confirms that the large majority of respondents (79.6%) had more than one wheelchair. The number of those who have three wheelchairs (24.2%) is even larger than those who have only one (20.4%). Almost 6% said they had four or more wheelchairs.
Figure 5.3
Number of wheelchairs (n=186)

<table>
<thead>
<tr>
<th>WHEELCHAIRS OWNED</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four or more</td>
<td>5.4</td>
</tr>
<tr>
<td>Three</td>
<td>24.2</td>
</tr>
<tr>
<td>Two</td>
<td>50</td>
</tr>
<tr>
<td>One</td>
<td>20.4</td>
</tr>
</tbody>
</table>

Figure 5.4
How long have the respondents used their wheelchair(s) (n=184)

<table>
<thead>
<tr>
<th>YEARS</th>
<th>Percentage</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 10 years</td>
<td>54.9</td>
<td>54.9</td>
</tr>
<tr>
<td>6-10 years</td>
<td>23.9</td>
<td>23.9</td>
</tr>
<tr>
<td>3-5 years</td>
<td>15.2</td>
<td>15.2</td>
</tr>
<tr>
<td>1-2 years</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td>&lt; 1 year</td>
<td>1.6</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Figure 5.4 shows that the majority of users in the sample had been using a wheelchair for more than ten years (54.9%). It also illustrates that the number of users increases according to the number of years that the wheelchairs have been used.

The respondents were asked to specify the makes and models of wheelchairs that they use. In the case where the respondents had more than one wheelchair, they were asked to name no more than two: only the most used and the next most used. The answers, with the number of users for both chairs 1 and 2, are shown in Table 5.1.

Some respondents were unable to identify the make or model of wheelchair(s) they used. Others pointed out some unknown makes or models which were included in the table anyway.

The wheelchair makes and models specified by respondents are produced by the following manufacturers which correspond to almost all wheelchair manufacturers in the United Kingdom:
Table 5.1
Makes and Models of wheelchairs used by respondents

<table>
<thead>
<tr>
<th>Make/Model</th>
<th>Ch 1 n</th>
<th>Ch 2 n</th>
<th>Make/Model</th>
<th>Ch 1 n</th>
<th>Ch 2 n</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.C. Model 6</td>
<td>-</td>
<td>1</td>
<td>HNE Explorer</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Aldersley</td>
<td>1</td>
<td>-</td>
<td>HNE Liberty 2 powered</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Barrett</td>
<td>1</td>
<td>1</td>
<td>HNE Whisper Out powerchair</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Kuschall Champ 3000ST1</td>
<td>-</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Le Chair</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lomax Thompson</td>
<td>1</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mangar Freestyle</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meyra Battery</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newton</td>
<td>-</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newton powered</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ortho-Kinetics, Quadra</td>
<td>1</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pride Jazzy Autochair</td>
<td>-</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regal</td>
<td>-</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remploy 8L</td>
<td>1</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remploy Roller</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rgid Edge</td>
<td>1</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ross &amp; Bonnyman</td>
<td>1</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RGK Quattro sportchair</td>
<td>-</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R.G.K. Sprint</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RGK Titanium</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scandinavian Mobility</td>
<td>-</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinner 2000</td>
<td>1</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sungift 400</td>
<td>1</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunrise Quickie</td>
<td>17</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunrise SunTec</td>
<td>28</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunrise Spirit powered</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunrise PowerTec</td>
<td>8</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunrise Top End sport chair</td>
<td>-</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessa Vitesse</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessa Vitesse powered</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volant</td>
<td>1</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8L, 8BL, 8L SP, 8HU</td>
<td>11</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Aldersley
- Barrett
- Bencraft
- B.E.C.
- Carters Invacare
- Chevron
- D.M.A.
- Eadiecare, a division of Ross & Bonnyman
- Etac, Sweden
- Everest Jennings
- Huntleigh Mobility
It can be seen from Table 5.1, that the wheelchairs of very few companies were used by more than five users with only two major exceptions. This perhaps reflects a very competitive market. The two exceptions were used as chair 1 by 28 and 17 people respectively.

Figure 5.5 shows what types of wheelchairs are owned by the users in the sample. The majority of them owned a manual self-propelled wheelchair as the most used wheelchair (63.8%) and the next most used chair (57.5%). The second most used type of wheelchairs, falling well below this level, was the powered indoor/outdoor wheelchair for both chair 1 (16.2%) and chair 2 (20.5%).
The remainder of the sample owned manual attendant propelled wheelchairs (8.6%; 8.2%), powered indoor (5.4%; 4.1%) and outdoor (3.8%; 4.1%) wheelchairs or other kinds of wheelchairs (2.1%; 5.5%) such as a scooter or powered buggy. It is important to call attention to the fact that manual self-propelled wheelchairs correspond to those wheelchairs most issued by the N.H.S.

Figure 5.6 illustrates how the respondents obtained their wheelchairs, whether the most used or the next most used (for those who had more than one wheelchair). It can be seen that the number of users who obtained their wheelchairs via the N.H.S. (60% for chair 1 and 54.1% for chair 2) was larger than the number who obtained them through private companies (33%; 38.5%) or other sources (7%; 7.4%). These figures are true for both chair 1 and chair 2. Those respondents who answered "other" indicated they had received the wheelchairs: a) from a work scheme or employment agency; b) from charity funding; c) on loan from disabled clubs or societies or from the Red Cross; d) from the D.L.A. Mobility; e) as a present and f) from being sponsored by the manufacturer. It is important to mention that from now on it will be considered that people with private wheelchairs are those who have obtained them from a source other than the N.H.S., for instance, by buying one themselves, obtaining one from a friend, relative or social association or having one on loan from an agency, such as the Red Cross.

When respondents were asked about how long they had owned their wheelchairs, it was found that nearly sixty percent of respondents had owned their wheelchairs for less than six years (Figure 5.7). It is important to observe that a significant number of users in the sample had owned their wheelchairs for less than three years (38.7% for chair 1 and 42% for chair 2). A substantial number of them had had their wheelchairs for over 10 years: 20.8% for chair 1 and 15.9% for chair 2. Nineteen respondents did not answer this
question or answered that it did not apply because they did not consider themselves to be owners of their wheelchairs.

In terms of the accessories included with their wheelchairs, almost all respondents answered that they had seat cushion for both wheelchairs (84.7% for chair 1, \(n=176\) and 81.4% for chair 2, \(n=140\)). They also said that they had the following accessories: manual elevating foot rest (21.6%, \(n=185\); 18.9%, \(n=143\)), back cushion (19.3%, \(n=176\); 20.7%, \(n=140\)), specially made seating (15.7%, \(n=185\); 11.9%, \(n=143\)), kerb climber (16.2%, \(n=185\); 14.7%, \(n=143\)) and manual reclining seat (5.4%, \(n=185\); 5.6%, \(n=143\)). Accessories included as "others" (9%, \(n=185\); 6.4%, \(n=143\)) were: headrest, side support, powered elevating foot rest, device to help the user to a standing position, elevating seat and powered reclining seat. Some respondents answered that they did not have any accessories either for chair 1 (9.2%, \(n=185\)) or chair 2 (8.4%, \(n=143\)). The total is over 100% because some respondents had more than one accessory.

Figure 5.7
Length of time the respondents have owned their wheelchairs (chair 1, \(n=168\); chair 2, \(n=138\))

![Figure 5.7](image)

Figure 5.8 shows that chair number one is used by almost all the respondents (85.3%) on a daily basis. Apart from the every day use, it can be seen that the first chair is used very little. The pattern for chair two is different. It seems to fluctuate mainly between being used every day (30.9%) or used infrequently less than one day a week (32.4%).

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Figure 5.8
Number of days per week that the respondents used their wheelchairs (chair 1, \(n=184\); chair 2, \(n=139\))

<table>
<thead>
<tr>
<th>FREQUENCY OF USE</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 day a week</td>
<td>2.7</td>
<td>15.1</td>
</tr>
<tr>
<td>1–2 days p/week</td>
<td>1.1</td>
<td>12.2</td>
</tr>
<tr>
<td>3–4 days p/week</td>
<td>4.9</td>
<td>9.4</td>
</tr>
<tr>
<td>5–6 days p/week</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Every day</td>
<td>32.4</td>
<td>30.9</td>
</tr>
</tbody>
</table>

Almost 76% of respondents said that they used their main wheelchair indoors more than five hours a day (Figure 5.9). The number of those who used their main wheelchair less than five hours a day is less than 10%. Only 14.4% answered that they did not use their wheelchairs indoors. Slightly more than 40% of users said that they did not use their second wheelchair indoors and the same percentage of users (40.9%) affirmed that they used it less than three hours a day inside home.

Figure 5.9
Hours per day that respondents used their wheelchairs indoors (chair 1, \(n=181\); chair 2, \(n=110\))

<table>
<thead>
<tr>
<th>HOURS</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>14.4</td>
<td>19.1</td>
</tr>
<tr>
<td>&lt; 1 hour</td>
<td>1.1</td>
<td>7.7</td>
</tr>
<tr>
<td>2–3 hours</td>
<td>1.8</td>
<td>11.1</td>
</tr>
<tr>
<td>4–5 hours</td>
<td>16.4</td>
<td>75.7</td>
</tr>
</tbody>
</table>

A different picture is shown for the use of wheelchairs outdoors (Figure 5.10). It can be seen that 40% of respondents used the main chair outdoors more than four hours a day (19.4% + 20.6% = 40.3%). A little more than half of respondents (33.3% + 18.2% = 51.5%) said they used chair 1 outside for less than three hours per day. Almost 9% answered that
they did not use their main wheelchair outside their home. For those who owned a second wheelchair, 48.6% (18.3% + 30.3%) said they used it outdoors less than three hours per day and 26.6% did not use it outdoors.

Figure 5.10
Hours per day that respondents used their wheelchairs outdoors (chair 1, n=165; chair 2, n=109)

<table>
<thead>
<tr>
<th>HOURS</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>8.5</td>
<td>26.6</td>
</tr>
<tr>
<td>&lt;1 hour</td>
<td>18.2</td>
<td>30.3</td>
</tr>
<tr>
<td>2-3 hours</td>
<td>13.8</td>
<td>33.3</td>
</tr>
<tr>
<td>4-5 hours</td>
<td>11</td>
<td>20.6</td>
</tr>
<tr>
<td>&gt;5 hours</td>
<td>19.4</td>
<td></td>
</tr>
</tbody>
</table>

The users in the sample were asked to identify the major problems with the wheelchairs they had owned in the last 12 months. Figure 5.11 shows the result. Thirty seven percent of respondents who answered this question concerning their main wheelchair and about 60% who answered in regard to their second wheelchair said they did not have any problem. This means that 63% of respondents had had problems with their main wheelchair in the last 12 months and nearly 40% had had problems with their second wheelchair in the same period. The high percentages of 63% and 40% are a little alarming given that it has already been shown that many wheelchairs were relatively new having been owned less than 5 years (see Figure 5.7).

The main problems identified by the respondents (see Figure 5.11) were punctures (25.4% for chair 1 and 16% for chair 2), electrical failures (12.1%; 4.8%), brake failures (9.2%; 5%), broken footplates (9.2%; 8.4%), broken frames (6.9%; 3.2%) and broken armrests (8.6%; 2.1%). Respectively, 22% and 9.2% of respondents identified other problems occurring with their main wheelchair and their second wheelchair. The other problems identified by the users were: problems with the wheels (e.g. damaged push rims, wheel locking broken, worn tyres, broken castor), problems with arm, seat and back supports (broken armrest, damaged canvas and upholstery, broken back support) and others such as faulty motors, battery failure, battery holder broken and gear box failure. The total is over 100% for the each of the first and second wheelchairs because some users had more than one problem.
Figure 5.11

Major problems occurring with the wheelchairs belonging to the respondents in the last 12 months (chair 1, n=173; chair 2, n=119)

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Others</td>
<td>22.1</td>
<td>9.2</td>
</tr>
<tr>
<td>Broken armrest</td>
<td>9.2</td>
<td>2.1</td>
</tr>
<tr>
<td>Electrical failures</td>
<td>12.1</td>
<td>4.8</td>
</tr>
<tr>
<td>Broken frame</td>
<td>6.9</td>
<td>3.2</td>
</tr>
<tr>
<td>Broken footplate</td>
<td>9.2</td>
<td>8.4</td>
</tr>
<tr>
<td>Brake failure</td>
<td>9.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Punctures</td>
<td>16.0</td>
<td>25.4</td>
</tr>
<tr>
<td>None</td>
<td>37.0</td>
<td>60.5</td>
</tr>
</tbody>
</table>

5.2.2.3 Questions about the prescription of users' wheelchairs

The respondents were asked if they felt that their needs and abilities were taken into consideration during the process of assessment and prescription of their wheelchairs. Seventy four percent (n=180) answered affirmatively and 17% negatively. Nine percent said that they were unsure.

One third of respondents (31.3%, n=163) answered that they were not shown how to use their wheelchairs. From those who answered affirmatively (68.7%), the vast majority of them (84.8%) said that they considered the demonstration satisfactory.

Half of the sample (50%) answered that they had received written instructions explaining how to use their wheelchairs and half said they had not (n=160). The large majority (78.8%) of those who answered positively considered that these written instructions were satisfactory. The remainder considered them unsatisfactory (16.3%) or were unsure (5%).

A vast number of respondents (74.9%, n=179) affirmed that they had not received any follow-up after their wheelchairs had been delivered to check on whether they were satisfactory. Almost two-thirds of respondents (57.3%, n=171) were able to identify some weaknesses in the process by which they were assessed, their wheelchairs prescribed and the follow-up carried out. The problems identified by respondents and the number of people who identified them are shown in Table 5.2. Some people identified more than one
problem. Some quotes provided by respondents reflect a deep dissatisfaction concerning the prescription process:

Table 5.2
Problems identified by respondents concerning the processes of assessment, wheelchair prescription and follow-up

<table>
<thead>
<tr>
<th>Problems related to assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lack of communication between prescriber and users (6)</td>
</tr>
<tr>
<td>• Long wait for assessment (4)</td>
</tr>
<tr>
<td>• Assessment was inadequate (3)</td>
</tr>
<tr>
<td>• Time allowed for assessment was too short (2)</td>
</tr>
<tr>
<td>• Assessment failed to take into consideration some of my problems (2)</td>
</tr>
<tr>
<td>• The people assessing me chose the chair they thought suitable for me (1)</td>
</tr>
<tr>
<td>• Did not take into account my needs in terms of portability, of aesthetics and of ease of transportation (1)</td>
</tr>
<tr>
<td>• Assessment resulted in a wheelchair with some problems (1)</td>
</tr>
<tr>
<td>• Lack of communication between NHS Wheelchair Services and Medical/Surgical Department (1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Problems related to prescription</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Prescribers had insufficient knowledge (4)</td>
</tr>
<tr>
<td>• Wheelchair did not suit my needs (5)</td>
</tr>
<tr>
<td>• Prescribers reluctant to issue any other than a standard chair (2)</td>
</tr>
<tr>
<td>• I had to argue to have the right chair chosen for me (2)</td>
</tr>
<tr>
<td>• Prescriber did not have knowledge about different wheelchairs models and the consequences for users (1)</td>
</tr>
<tr>
<td>• The wheelchairs available on prescription are not suitable for active users (1)</td>
</tr>
<tr>
<td>• Little technical information available about the chair (1)</td>
</tr>
<tr>
<td>• Some recommendations from prescribers were not kept and referred to (1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Problems related to wheelchairs availability and provision</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Too long time before delivery (5)</td>
</tr>
<tr>
<td>• Few options of wheelchairs available (3)</td>
</tr>
<tr>
<td>• Did not have, or had insufficient, types of wheelchairs for user to try (2)</td>
</tr>
<tr>
<td>• Too long to get the right chair (1)</td>
</tr>
<tr>
<td>• Wheelchair which was prescribed was not that which was supplied (1)</td>
</tr>
<tr>
<td>• No demonstration and instruction on how to use the chair for first time users (1)</td>
</tr>
<tr>
<td>• Model available with bad design (1)</td>
</tr>
<tr>
<td>• Chairs available not adequate for my size (1)</td>
</tr>
<tr>
<td>• Special chairs for sport or travel not provided (1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Problems related to follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>• No follow up (13)</td>
</tr>
<tr>
<td>• Poor follow-up (1)</td>
</tr>
</tbody>
</table>
5.2.2.4 Questions about wheelchair design in general

A list of 21 characteristics of wheelchairs was shown to the respondents and they were asked, broadly speaking, to classify such characteristics on a scale of five named as extremely important, very important, important, fairly important and not important. The results are illustrated in the Figures 5.12 to 5.33 and are described in the following paragraphs.

Safety (Figure 5.12)
This is the property of a wheelchair to permit the user to handle it without risk of damage or injury provoked by faults, malfunctions or errors in normal use, or foreseeable misuse, of the wheelchair or its components. This is a vital characteristic, and as a result was considered extremely important or very important by almost all respondents (92.4%=79.5%+13%).

Robustness (Figure 5.13)
This is the quality of a wheelchair to be able to resist fairly demanding use and occasional misuse. It was considered extremely important or very important by the large majority users in the sample (86.5%=60.1%+26.4%).

Stability (Figure 5.14)
This is the property of a wheelchair to remain steady and firm in position and be in good balance. Almost all respondents considered it extremely important or very important (91.2%=71.4%+19.8%).
Suitability (Figure 5.15)
This is the characteristic of a wheelchair to be appropriate to the user's medical and social requirements. Almost 95% (78.4% + 15.9%) of respondents rated it as extremely or very important.

Reliability (Figure 5.16)
This is the probability that a wheelchair will perform a required function under typical conditions for a stated period of time. It was almost unanimously (98.3% = 85.6% + 12.8%) considered as an extremely or very important characteristic.

Figures 5.12 and 5.13
How the respondents rate the design of wheelchairs in terms of some characteristics

Figure 5.12 - Safety (n = 185)

RATING
Not imp 0
Fairly imp 0.6
Imp 12.9
Very imp 26.4
Ext imp 60

Figure 5.13 - Robustness (n = 178)

RATING
Not imp 0
Fairly imp 0.6
Imp 12.9
Very imp 26.4
Ext imp 60

Figures 5.14 and 5.15
How the respondents rate the design of wheelchairs in terms of some characteristics

Figure 5.14 - Stability (n = 176)

RATING
Not imp 0
Fairly imp 1.1
Imp 7.7
Very imp 19.8
Ext imp 71.4

Figure 5.15 - Suitability (n = 176)

RATING
Not imp 0
Fairly imp 0.6
Imp 5.1
Very imp 15.9
Ext imp 78.4
Figures 5.16 to 5.17

How the respondents rate the design of wheelchairs in terms of some characteristics

**Figure 5.16 - Reliability (n=180)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>0</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>0</td>
</tr>
<tr>
<td>Imp</td>
<td>1.7</td>
</tr>
<tr>
<td>Very imp</td>
<td>12.8</td>
</tr>
<tr>
<td>Ext imp</td>
<td>85.6</td>
</tr>
</tbody>
</table>

**Figure 5.17 - Comfort (n=182)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>0</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>1.1</td>
</tr>
<tr>
<td>Imp</td>
<td>5.5</td>
</tr>
<tr>
<td>Very imp</td>
<td>17.6</td>
</tr>
<tr>
<td>Ext imp</td>
<td>85.6</td>
</tr>
</tbody>
</table>

**Comfort** (Figure 5.17)

This is the quality of a wheelchair to produce physical well-being during its use. Almost 94% (75.8%+17.6%) of respondents rated this as extremely or very important.

**Aesthetic appearance** (Figure 5.18)

This is the virtue of a wheelchair to be pleasurable to the user in terms of its visual appearance. The majority of respondents rated it as an important characteristic (35.1%). The number of those who considered it as extremely and very important (33.3%=15.2%+18.1%) was almost the same as those who rated it as fairly or not important (31.6%=22.2%+9.4%).

**Adjustability** (Figure 5.19)

This is the ability of a wheelchair to be altered through a range of options easily and safely. This characteristic was considered extremely or very important for 58.8% (34.1%+24.7%) of respondents and important for 23.5% of them.

**Portability due to size** (Figure 5.20)

This is the property of a wheelchair to be carried or moved easily considering its overall dimension. Almost 80% (57.2%+21.7%) of respondents rated it as extremely or very important and 23.5% as important. The characteristic "portability" in the pilot survey included both "portability due to size" and "portability due to weight".
Figures 5.18 to 5.21

How the respondents rate the design of wheelchairs in terms of some characteristics

**Figure 5.18 - Aesthetic appearance**

*(n = 171)*

<table>
<thead>
<tr>
<th>RATING</th>
<th>Not imp</th>
<th>Imp</th>
<th>Ext imp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.4</td>
<td>22.2</td>
<td>15.2</td>
</tr>
</tbody>
</table>

**Figure 5.19 - Adjustability**

*(n = 170)*

<table>
<thead>
<tr>
<th>RATING</th>
<th>Not imp</th>
<th>Fairly imp</th>
<th>Imp</th>
<th>Very imp</th>
<th>Ext imp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.5</td>
<td>11.2</td>
<td>23.5</td>
<td>24.7</td>
<td>34.1</td>
</tr>
</tbody>
</table>

**Figure 5.20 - Portability due to size**

*(n = 180)*

<table>
<thead>
<tr>
<th>RATING</th>
<th>Not imp</th>
<th>Imp</th>
<th>Ext imp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.8</td>
<td>14.4</td>
<td>21.7</td>
</tr>
</tbody>
</table>

**Figure 5.21 - Portability due to weight**

*(n = 182)*

<table>
<thead>
<tr>
<th>RATING</th>
<th>Not imp</th>
<th>Fairly imp</th>
<th>Imp</th>
<th>Very imp</th>
<th>Ext imp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.3</td>
<td>3.3</td>
<td>8.8</td>
<td>19.2</td>
<td>65.4</td>
</tr>
</tbody>
</table>

**Portability due to weight** (Figure 5.21)

This is the attribute of a wheelchair to be carried or moved easily considering its overall weight. Most respondents (84.6% = 74.2% + 21.4%) rated it as extremely or very important.

**Manoeuvrability** (Figure 5.22)

This is the quality of a wheelchair to permit change of direction. Respondents rated this characteristic almost unanimously (95.6% = 74.2% + 21.4%) as extremely important or very important.

**Ease of use** (Figure 5.23)

This is the attribute of a wheelchair not to demand excessive strength or over-exertion in use. Again, almost all respondents (94.4% = 70.9% + 23.5%) rated this characteristic as extremely important or very important.
The property of a wheelchair to bend, disassemble and/or bring together its components. It was rated as extremely or very important by 72.4% (49.2%+23.2%) of respondents and important by 14.4% of them.

*Ease of storage* (Figure 5.25)
This is the ability a wheelchair to be stored considering its overall dimensions, weight and the space available for storing. Almost 65% (40.1%+24.2%) of respondents rated this feature as extremely important or very important. It was rated by 18.7% as being important.

*Ease of maintenance* (Figure 5.26)
This is the ease with which the user or a repairer can carry out conservation services to the wheelchair's parts and components. It was rated by almost 70% (41.6%+27.5%) of users in the sample rated it as extremely or very important. Almost 25% of them rated it as important.

*Ease of repair* (Figure 5.27)
This is the ease with which the user or a repairer can carry out services on a wheelchair's parts and components. Seventy percent (46.3%+23.7%) of respondents rated it as extremely or very important and 22% as being important.

*Ease of transport in a car* (Figure 5.28)
This is the attribute of a wheelchair to be moved in a car, considering its weight, dimensions, manoeuvrability and whether it can be folded up or dismantled easily. The majority of respondents (86.8%=72.4%+14.4%) rated it as extremely or very important.

*Provision of accessories* (Figure 5.29)
This is the possibility of finding spare parts and components easily available, at a reasonable price, in the market place. Almost half of the respondents considered this feature as extremely or very important (47.4%=28%+19.4%). A number of them (25.1%) rated it as important.
Figures 5.22 to 5.27
How the respondents rate the design of wheelchairs in terms of some characteristics

**Figure 5.22 - Manoeuvrability**
(n=182)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>0</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>0.5</td>
</tr>
<tr>
<td>Imp</td>
<td>3.8</td>
</tr>
<tr>
<td>Very imp</td>
<td>21.4</td>
</tr>
<tr>
<td>Ext imp</td>
<td>74.2</td>
</tr>
</tbody>
</table>

**Figure 5.23 - Ease of use**
(n=179)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>1.7</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>3.9</td>
</tr>
<tr>
<td>Imp</td>
<td>23.5</td>
</tr>
<tr>
<td>Very imp</td>
<td>70.9</td>
</tr>
</tbody>
</table>

**Figure 5.24 - Ease of folding**
(n=181)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>10.4</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>2.8</td>
</tr>
<tr>
<td>Imp</td>
<td>14.4</td>
</tr>
<tr>
<td>Very imp</td>
<td>23.2</td>
</tr>
<tr>
<td>Ext imp</td>
<td>49.2</td>
</tr>
</tbody>
</table>

**Figure 5.25 - Ease of storage**
(n=182)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>11</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>6</td>
</tr>
<tr>
<td>Imp</td>
<td>18.7</td>
</tr>
<tr>
<td>Very imp</td>
<td>24.2</td>
</tr>
<tr>
<td>Ext imp</td>
<td>40.1</td>
</tr>
</tbody>
</table>

**Figure 5.26 - Ease of maintenance**
(n=178)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>2.2</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>4.5</td>
</tr>
<tr>
<td>Imp</td>
<td>24.2</td>
</tr>
<tr>
<td>Very imp</td>
<td>27.5</td>
</tr>
<tr>
<td>Ext imp</td>
<td>41.6</td>
</tr>
</tbody>
</table>

**Figure 5.27 - Ease of repair**
(n=177)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>2.8</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>5.1</td>
</tr>
<tr>
<td>Imp</td>
<td>22</td>
</tr>
<tr>
<td>Very imp</td>
<td>23.7</td>
</tr>
<tr>
<td>Ext imp</td>
<td>46.3</td>
</tr>
</tbody>
</table>
Figures 5.28 and 5.29
How the respondents rate the design of wheelchairs in terms of some characteristics

**Figure 5.28 - Ease of transport in a car (n = 181)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>Not imp</th>
<th>Fairly imp</th>
<th>Imp</th>
<th>Very imp</th>
<th>Ext imp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>1.1</td>
<td>7.2</td>
<td>14.4</td>
<td>72.4</td>
</tr>
</tbody>
</table>

**Figure 5.29 - Provision of accessories (n = 175)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>Not imp</th>
<th>Fairly imp</th>
<th>Imp</th>
<th>Very imp</th>
<th>Ext imp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12.6</td>
<td>6.3</td>
<td>14.9</td>
<td>19.4</td>
<td>28</td>
</tr>
</tbody>
</table>

**Cost to buy, maintain and repair** (Figures 5.30, 5.31 and 5.32)
This is the ability of a wheelchair to offer good value for money at purchase, in maintenance and in the repairing of parts and components. The majority of respondents considered these characteristics extremely or very important and gave them almost the same rate: cost to buy, 66.1% (48.3% + 17.8%); cost to maintain, 65% (43.5% + 21.5%) and cost to repair, 64.8% (43.8% + 21%).

Figures 5.30 and 5.31
How the respondents rate the design of wheelchairs in terms of some characteristics

**Figure 5.30 - Cost to buy (n = 174)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>Not imp</th>
<th>Fairly imp</th>
<th>Imp</th>
<th>Very imp</th>
<th>Ext imp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.2</td>
<td>6.3</td>
<td>18.4</td>
<td>17.8</td>
<td>48.3</td>
</tr>
</tbody>
</table>

**Figure 5.31 - Cost to maintain (n = 177)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>Not imp</th>
<th>Fairly imp</th>
<th>Imp</th>
<th>Very imp</th>
<th>Ext imp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8.5</td>
<td>7.3</td>
<td>19.2</td>
<td>21.5</td>
<td>43.5</td>
</tr>
</tbody>
</table>
Figure 5.32
How the respondents rate the design of wheelchairs in terms of some characteristics

**Figure 5.32 - Cost to repair**  
(*n=176*)

<table>
<thead>
<tr>
<th>RATING</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>8</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>7.4</td>
</tr>
<tr>
<td>Imp</td>
<td>19.9</td>
</tr>
<tr>
<td>Very imp</td>
<td>21</td>
</tr>
<tr>
<td>Ext imp</td>
<td>43.8</td>
</tr>
</tbody>
</table>

The respondents were asked to nominate, in order, the three characteristics which were most important for them from the 21 previously analysed. Their answers are shown in Figure 5.33.

According to this figure, it can be seen that the five most important characteristics in order were: safety (indicated by 50 of them), comfort (27), reliability (23), suitability (20) and portability due to weight (12). These five characteristics represent almost 80% of the answers in the sample. The five characteristics considered the second most important (whether or not they had been previously mentioned as the first most important) were: reliability (32), comfort (27), ease of transport in a car (17), suitability (15) and stability (15). Those rated as the third most important (whether or not they had been previously mentioned as the first and second most important) were: comfort (24), reliability (22), ease of transport in a car (21), manoeuvrability (19) and cost to buy (11).

After having pointed out the characteristics the respondents judged as most important, they were asked why they considered those as the most important. Table 5.3 shows some statements made by respondents for each characteristic (the table occupies pages 193 to 196 and the text of the thesis continues on page 196).
Figure 5.33
Characteristics of wheelchairs rated as the most important for the respondents ($n=171$)

- Safety: 50
- Comfort: 24
- Reliability: 32
- Suitability: 22
- Portability due to weight: 20
- Ease of transport in a car: 17
- Stability: 15
- Robustness: 13
- Maneuvarability: 12
- Cost to buy: 11
- Ease of use: 10
- Portability due to size: 8
- Aesthetic appearance: 9
- Cost to maintain: 7
- Ease of repair: 6
- Ease of maintenance: 5
- Adjustability: 4
- Cost to repair: 3
- Ease of storage: 2
- Ease of folding: 2
- Provision of accessories: 1

Number of respondents

First  Second  Third
Table 5.3
Quotes from respondents about some characteristics of wheelchairs

**Safety**

- Having a safe chair brings peace of mind.
- You will get more use out of your chair if you feel safe using it.
- If you feel safe it gives you more confidence to tackle outside.
- I have to feel safe especially when alone.
- Staying most part of the day in a wheelchair makes me vulnerable, so I need confidence in the equipment.
- Could be life threatening if breaks down whilst crossing the road.
- It is important not to be worried that what you sit in is not going to let you down.
- If a chair is unsafe it could lead to serious injury.
- It is important due to the inability of a disabled person to retrieve him or herself from a difficult situation.
- I don’t need an unsafe chair to add to my current disability.

**Comfort**

- I am in it all day, if I was in pain or positioned wrongly, everything else palls.
- Full time in wheelchair and very prone to pressure sores.
- The chair is me: needs to be comfortable and make you feel good when spend many hours on it.
- I believe a wheelchair must fit like a glove and not create extra problems.
- I am often in pain - right design can alleviate this.
- Posture pains, skin break down and tiredness quickly develop unnecessarily.
- When sitting for a long time you get very uncomfortable in the most comfy of chairs. It makes my pain worse if I am uncomfortable, and it puts me off using it and going out.
- To keep pain levels under control.

**Reliability**

- I cannot move without my chair, so it has to be 100% reliable.
- The chair is a vital component in my ability to cope with day to day living and is useless unless it is reliable.
- I live alone and therefore like to be as independent as possible. If my chair is broken, so am I.
- It is most important to be sure that you have mobility when needed.
- I do not have a spare chair and I need to have total confidence in my chair.
- Because I do a lot of travelling in it.
- To prevent it breaking down in awkward places.
- This applies particularly to an electric model, where a breakdown leaves the user stranded and helpless, with no means of propulsion.
- Because I use it all the time and do not want to stay in bed when it needs repair.
Table 5.3
Quotes from respondents about some characteristics of wheelchairs (cont.)

<table>
<thead>
<tr>
<th>Suitability</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• All disabilities are different and so are peoples' needs, size, weight,</td>
<td>• The more suitable a wheelchair for one's needs the better one</td>
</tr>
<tr>
<td>etc. We need a chair we can use.</td>
<td>can function and less help is required.</td>
</tr>
<tr>
<td>• The more suitable a wheelchair for one's needs the better one can</td>
<td>• The more it meets an individual's needs and requirements the</td>
</tr>
<tr>
<td>function and less help is required.</td>
<td>more freedom it gives to that individual.</td>
</tr>
<tr>
<td>• The chair must be well fitted and suited to everyday need, otherwise</td>
<td>• A wheelchair is the most important item used in my day to day</td>
</tr>
<tr>
<td>independence is hindered.</td>
<td>life and must suit me.</td>
</tr>
<tr>
<td>• If the chair is not suitable it will not enable me to do things I want/</td>
<td>• People have different disabilities which require individual</td>
</tr>
<tr>
<td>need to do.</td>
<td>attention and the chair has to be suitable for its use.</td>
</tr>
<tr>
<td>• The wheelchair is there to suit my abilities, not to disable me further.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Portability due to weight</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• It is important because I have to take it apart and lift it across me</td>
<td>• Chairs must be able to be handled and moved by the user and</td>
</tr>
<tr>
<td>into my car.</td>
<td>not relying on other people.</td>
</tr>
<tr>
<td>• I need to be able to lift to and from car to enable me to go out alone</td>
<td>• It is important because I rely on others to assist in the</td>
</tr>
<tr>
<td>with no carer.</td>
<td>loading/unloading of the chair from my vehicle.</td>
</tr>
<tr>
<td>• My daughters say how heavy and awkward it is, and they are young and</td>
<td>• I have to dismantle and lift into car while sitting in driver's</td>
</tr>
<tr>
<td>fit.</td>
<td>seat.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ease of transport in a car</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• I work so I need to get in and out of a car 5 days a week.</td>
<td>• It is important to try and maintain some semblance of</td>
</tr>
<tr>
<td>• It is important to try and maintain some semblance of independence.</td>
<td>independence.</td>
</tr>
<tr>
<td>• A full-time user with no carer must be able to manage without having</td>
<td>• Unless it can be easily transported in a car, the wheelchair</td>
</tr>
<tr>
<td>to accost passers by!</td>
<td>user is confined to the house and its area and cannot travel</td>
</tr>
<tr>
<td>• Unless it can be easily transported in a car, the wheelchair user is</td>
<td>further afield.</td>
</tr>
<tr>
<td>confined to the house and its area and cannot travel further afield.</td>
<td>• If it is not easy to transport in my car the chair is of no</td>
</tr>
<tr>
<td>• It is important not only for cars but occasional transport.</td>
<td>real use to me.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ease of transport in a car (cont.)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Although my wheelchair comes apart, the weight of the parts make it</td>
<td>• I need to put the chair behind the driver's seat therefore it</td>
</tr>
<tr>
<td>difficult for older people to consider car transportation.</td>
<td>needs to be light and easy to fold.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stability</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• I am unable to help myself if the wheelchair tips and you don't want</td>
<td>• A stable sitting position is vital for me to work.</td>
</tr>
<tr>
<td>to feel like it might overturn.</td>
<td>• I have to manage myself in and out of chair, so it has to be</td>
</tr>
<tr>
<td>• A stable sitting position is vital for me to work.</td>
<td>stable when I use it to lever myself in and out.</td>
</tr>
</tbody>
</table>
Table 5.3
Quotes from respondents about some characteristics of wheelchairs (cont.)

<table>
<thead>
<tr>
<th>Robustness</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Used frequently for local shopping involving lots of pavement climbs, many not adequate.</td>
<td></td>
</tr>
<tr>
<td>Needs to be robust due to everyday use.</td>
<td></td>
</tr>
<tr>
<td>I am big and it has to take my size and support my weight.</td>
<td></td>
</tr>
<tr>
<td>I have a very busy life and travel a lot.</td>
<td></td>
</tr>
<tr>
<td>They are very expensive to buy so they need to last.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manoeuvrability</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I think this is important to crowded locations, lifts, boarding trains.</td>
<td></td>
</tr>
<tr>
<td>Independence is a priority so must be able to turn in small environments, i.e. shops, restaurants, toilets, lifts, etc.</td>
<td></td>
</tr>
<tr>
<td>As I live alone I have to manage the chair around the house (including tight corners) myself.</td>
<td></td>
</tr>
<tr>
<td>I use the chair indoors/outdoors so ability to move on soft and hard surface is important.</td>
<td></td>
</tr>
<tr>
<td>To move around in restricted access, doorways, inside inappropriately designed shops.</td>
<td></td>
</tr>
<tr>
<td>Have you tried shopping in a chair that behaves like a tank?</td>
<td></td>
</tr>
<tr>
<td>As a teacher classroom space can be very tight when moving around.</td>
<td></td>
</tr>
<tr>
<td>The environment is not wheelchair friendly so we need to be able to fit into funny spaces.</td>
<td></td>
</tr>
<tr>
<td>I must feel that my chair is able to do the things that I expect of it.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost to buy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sometimes the most suitable chair is the most expensive.</td>
<td></td>
</tr>
<tr>
<td>Lightweight chairs are vastly over priced considering the quality of construction.</td>
<td></td>
</tr>
<tr>
<td>I believe they could be made cheaper, disabled people seem to have to pay over the top for everything.</td>
<td></td>
</tr>
<tr>
<td>As a person who needs a chair, the provision of N.H.S. chair is totally inadequate and to purchase one at the moment privately is too expensive.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ease of use</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>It is important to prevent exhaustion.</td>
<td></td>
</tr>
<tr>
<td>The easier it is the more I will do in it and the more able it will make me.</td>
<td></td>
</tr>
<tr>
<td>It is important to be able to propel myself around so I do not have to rely on other people.</td>
<td></td>
</tr>
<tr>
<td>Chairs must be easy to use, well built and safe to encourage confidence of user.</td>
<td></td>
</tr>
<tr>
<td>This makes a great deal of difference to the amount of energy one has to expend using the wheelchair.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Portability due to size</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>It must fit into the boot of my car.</td>
<td></td>
</tr>
<tr>
<td>I need to be able to get it in and out of my car several times a day.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aesthetic appearance</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>It is important because most wheelchairs look like torture implements: ugly, not colourful, old, badly designed.</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.3 - Quotes from respondents about some characteristics of wheelchairs (cont.)

**Aesthetic appearance (cont.)**

- I may be disabled but I don’t need to emphasise the fact by using an outdated N.H.S. chair and looking gaga.
- My wheelchair is not only an enabler, it is an extension of how I feel about myself and how people see me.
- I do not want to appear as a wheelchair with a person in it!
- As a woman I am aware of my appearance and the wheelchair is part of it.
- It is important because if my chair looks good I feel good when in it.
- My wheelchair is an extension of me. So if I look good I want my chair to look good too.
- I take a pride in my appearance and therefore wish to look smart. No N.H.S. chair can achieve this.
- Because a chair is almost clothes and everyone wants to look good.

**Cost to maintain**

- It is important because being on benefits, there is not much money and often I have to wait months to save for repairs.

**Ease of repair**

- I am totally dependent on my chair and can’t stand up, so can’t afford to be without it.
- Often manufactures can keep you waiting up to a month for repairs so it needs to be local.

**Ease of maintenance**

- It is important because we repair it ourselves after we get the parts from the supplier.
- I can’t pump up the tyres or mend the brakes.
- Powered chairs need charging points to be at the most accessible place possible on the chair.

**Adjustability**

- Being able to adjust a wheelchair (e.g. centre of gravity) makes chairs easier to use and improve posture.

**Ease of folding**

- I need to take it apart and lift across me into my car.

In spite of the latter two questions having produced a picture of the respondents views of the main characteristics which wheelchairs should have, it was considered important to ask them how they classified the design of their own wheelchair(s) in the light of the characteristics to which they had previously attributed levels of importance. Their own wheelchairs could be rated in terms of specific characteristics as very good, good, average, poor and very poor. Results were sorted into three kinds of responses: a) the first category of response was a high number of "goods" and "very goods"; b) the second category comprised a large number of "averages"; and c) the third category included a significant number of responses given as "poor" and "very poor".
Figures 5.34 and 5.35 show that a very large number of respondents judged the design of their own wheelchairs as being "very good" and "good" in terms of safety, ease of use, stability, suitability, manoeuvrability, reliability and robustness. Observing these figures, it can be seen that although respondents judged the design of their wheelchairs favourably, as being "very good" and "good" for some important characteristics, the percentage who attributed this level of satisfaction never exceeded 78%, which is less than the level of 80%-90% which might be hoped for. Typically, the best results were between 60 and 78%. It can be said, really, that there is no characteristic which got a satisfactorily high percentage of "very good" and "good". At the other end of the spectrum, there are a number of characteristics for which the percentage of "poor" and "very poor" responses are worryingly high.

According to Figure 5.34, the three design characteristics rated most highly as "very good" or "good" for chair 1 were: safety (78.5%), ease of use (77.2%) and stability (76.2%). Although safety reached the highest level (almost 80%), it did not obtain a rate that undoubtedly could be classify it as being of the highest class. Suitability (76.2%) and manoeuvrability (75%) were, respectively, rated as the fourth and fifth most important category for the most used chair. There was also a number of characteristics which did not exceed 50% in terms of being "very good" or "good", such as aesthetic appearance (48%), ease of repair (45.9%) and adjustability (42%).

A number greater than or equal to 20% of respondents, rated the design of their own wheelchair as being "poor" or "very poor" for almost half of the characteristics. The five characteristics which reached the highest level of "poor" or "very poor" for chair 1 were: cost to buy (30%), cost to repair (28.5%), portability due to weight (28.1%), provision of accessories (27.1%) and ease of folding (24.4%).

An impressive number of respondents rated their own wheelchairs as being "average" for a high number of characteristics such as cost to repair (48%), cost to maintain (47.2%) and cost to buy (44.7%). In terms of the most used wheelchair, considering some vital characteristics, such as safety, reliability, suitability, manoeuvrability and comfort, it can be seen that the number of respondents who rated them as "average" added to those who rated them as "poor" and "very poor" appears to be somewhat worrying: safety (21.6%), reliability (28.3%), suitability (23.9%), manoeuvrability (25%), comfort (36.6%) and stability (23.8%).
Figure 5.34
How the respondents rated the design of their own wheelchairs in terms of particular characteristics (chair 1)
Figure 5.35
How the respondents rated the design of their own wheelchairs in terms of particular characteristics (chair 2)
Figure 5.35 shows the responses for chair 2. In terms of what was regarded as "very good" or "good", it can be seen that the percentage for safety (76.1%) is almost the same that was given for the most used chair. There is a marginal change in the order for the rest of characteristics but the picture is almost the same for chair 1 in Figure 3.34. The five characteristics rated as being "very good" or "good" by respondents for the design of their second most used chair, except the already mentioned safety, were: reliability (73.9%), robustness (69.9%), stability (69.2%) and ease of use (64.4%).

The five characteristics with the highest level of "poor" or "very poor" for chair 2 were: portability due to weight (30.5%), cost to buy (27.7%), ease of transport in a car (27.3%), provision of accessories (25.4%) and portability due to size (24.8%). The five which obtained the highest rate of "average" were: cost to maintain (57.6%), cost to repair (57.1%), cost to buy (51.1%), ease of repair (50.4%) and ease of maintenance (46.6%).

The users in the sample were asked if it was their impression that, in general, the N.H.S. and privately acquired wheelchairs were designed taking into account the range of needs of disabled people and why they thought this.

Figure 5.36 shows that the number of respondents who thought that privately acquired wheelchairs were designed taking into consideration the needs of disabled people was more than the double those who thought the same for the wheelchairs provided by the N.H.S. (63.3% against 24.9%).

Figure 5.36
User's views on whether or not wheelchairs in the N.H.S. and private sectors are designed taking into account the needs of disabled people (NHS, n=169; Private market, n=166)
A considerable number of respondents answered "I do not know" for either N.H.S. or private provision. Although the question asked for an impression about both markets, some respondents did not answer, stating, for example, that as they were a user of only one of these markets they did not know about the design of the wheelchairs provided by the other.

Table 5.4 summarises why respondents believed or did not believe that the wheelchairs in either the N.H.S. or private market place were designed taking into account the range of needs of disabled people (Table 5.4 occupies pages 202 to 208, the text of the thesis continues on page 209). The answers were organised into categories of responses in terms of: cost, quality of design and standardisation, comfort, suitability and user needs and availability.

Only seven respondents in the sample (n=183) answered that they had ever been involved in wheelchair design with a company that mass produced wheelchairs for a large market. They said their main contributions were:

- Test driving wheelchairs and contributing to a design focus group.
- Discussion with a manufacturer about the introduction of a new sport chair and helping to design a racing wheelchair with students of a local college.
- Testing a prototype and giving comments about controls, ease of transfer and comfort.

The respondents were asked if they would like to be involved, or continue to be involved, in wheelchair design with companies that mass produced wheelchairs for a large market. 47.1% of them (n=180) answered positively and 51.1% negatively. Few of them (3.7%) did not answer. Some respondents answered negatively alleging that they had no time. Those who answered positively were asked what kind of contribution to wheelchair design they thought they could provide. Most of them said "to contribute with personal experience and the point-of-view of a disabled person". Others provided the following answers:

- Experience as a long-time user enables me to provide contributions to identify some understanding of the requirements of users with severe condition, and their carers.
- I know the problems users face and I have certain needs which seem to be after-thoughts to designers.
- I would be able to give direct feedback on design highlighting problems of reliability, cost, comfort, safety, etc.
- As a very active sports person my needs are quite different to the average and are not usually considered.
Table 5.4
Respondents' explanation of why they think wheelchairs in the N.H.S. and private market place were or were not designed taking into account the needs of disabled people

<table>
<thead>
<tr>
<th>Wheelchairs in the N.H.S. market place</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, considering the coverage required both for patients and monetary restrictions in the service, I feel it is adequate.</td>
<td>Yes, people who can afford to buy get what they want.</td>
</tr>
<tr>
<td>No, NHS wheelchairs tend to be produced as cheaply as possible, are usually heavy and difficult to self propel, and are not designed to enable user to sit properly.</td>
<td>Yes, you get more choice and better features, if you pay for it.</td>
</tr>
<tr>
<td>No, they are designed much more for cheapness than the needs of user and carer.</td>
<td>Yes, there are no cost restrictions therefore: a) suitable designs are offered; b) comfort is taken into account; c) reliability/safety is ensured; d) suitable materials are used during manufacture; e) overall cost effectiveness is ensured; f) value for money over lifetime of chair is given and g) choice for disabled people is given.</td>
</tr>
<tr>
<td>No, cost dictates the design, materials and suitability of N.H.S. wheelchair provision.</td>
<td>Yes, they seem to have more understanding and time. The only trouble is they are far too expensive to buy, repair and to obtain spare parts.</td>
</tr>
<tr>
<td>No, I believe most wheelchairs are designed to a price. Profit is more important than usage.</td>
<td>Yes, because in the private sector you are paying for what you get and it is my impression that if you pay you tend to be listened to.</td>
</tr>
<tr>
<td></td>
<td>Yes, but many disabled people cannot afford what they need, although if only a manufacturer was brave enough to go into mass production the prices would come down and more people could be properly equipped.</td>
</tr>
</tbody>
</table>
Table 5.4
Respondents' explanation of why they think wheelchairs in the N.H.S. and private market place were or were not designed taking into account the needs of disabled people (cont.)

<table>
<thead>
<tr>
<th>In terms of quality of design and standardisation:</th>
<th>Wheelchairs in the N.H.S. market place</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, the design of N.H.S. wheelchairs has greatly improved in recent years thanks to increased pressure by disabled groups.</td>
<td>Yes, they are usually lightweight, have more adjustments, are more manoeuvrable, better looking and more comfortable.</td>
<td></td>
</tr>
<tr>
<td>No, wheelchairs produced by manufacturers from abroad are better designed than those provided by UK manufacturers.</td>
<td>Yes, very lightweight, easy to manoeuvre, comfortable, wide choice, lots of different colours available, better made, less repairs to be made.</td>
<td></td>
</tr>
<tr>
<td>No, many of the N.H.S. wheelchairs are designed to many standards considered obsolete.</td>
<td>Yes, as a paying customer you dictate the design requirements.</td>
<td></td>
</tr>
<tr>
<td>No, most of the wheelchairs available on the N.H.S. are very heavy, ageing design, dull colours and cheap. No thought is given to what the disabled person wants from a wheelchair. Some of them were designed more than 20 years ago and not a lot has change since then.</td>
<td>Yes, because of the market demand. The sales rely on good design in all aspects of the wheelchair.</td>
<td></td>
</tr>
<tr>
<td>No, standard issue chairs are 1950's design. Do not allow sufficient adjustment and use of accessories. The finish is poor, with projections of clips that can be dangerous or cause injury. Paint finish is poor. Far too heavy. Special purpose, indoor/outdoor electric, custom built are usually more suitable but very rarely available. Do not utilise advanced materials and technology generally available. Base design is not flexible, modular, capable of wide range of variance.</td>
<td>Yes, some designers have personal experience of disability and design for a specific market: e.g. sport, electric powered. Manufacturers are prepared to innovate and take risks to satisfy perceived needs and create demand. Use of new materials is common. Many chairs are custom-built to order. Different configurations and accessories are possible to accommodate a range of users or variance in individual's functioning. It is possible to refurbish and upgrade the basic equipment. Modular design concepts, particularly seating, are beginning to be used, allowing quick interchange and adjustment.</td>
<td></td>
</tr>
<tr>
<td>Yes, but particularly powered wheelchairs needs to be more portable.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Respondents' explanation of why they think wheelchairs in the N.H.S. and private market place were or were not designed taking into account the needs of disabled people (cont.)

<table>
<thead>
<tr>
<th><strong>In terms of quality of design and standardisation (cont.):</strong></th>
<th><strong>Wheelchairs in the N.H.S. market place</strong></th>
<th><strong>Wheelchairs in the private market place</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wheelchairs in the N.H.S. market place</strong></td>
<td>No, most wheelchairs seem to be designed to be exactly the same and have to be adapted to suit one's disability at the assessment stage.</td>
<td>Yes, although the lack of standardisation in components is a problem, e.g. battery chargers are not interchangeable which means we can't travel lightly. Our charger must be carried everywhere.</td>
</tr>
<tr>
<td></td>
<td>No, they are usually standard models, extremely heavy, ugly, but they don't break too often.</td>
<td>Yes, to compete in this market they have to offer features and benefits on their chairs. All disabilities have to be catered for and retailers have to offer a good and comprehensive range to make chair sales a viable position.</td>
</tr>
<tr>
<td></td>
<td>No, the weight of the metal used in N.H.S. chairs makes the chair very difficult to lift or fold/unfold by the disabled person.</td>
<td>No, they still very ugly, heavy, expensive and uncomfortable. No bright seat covers, hideous navy accessories, I want bright pink leopard skin, I see wheelchair part of me, should reflect me, not the company's ideas.</td>
</tr>
<tr>
<td></td>
<td>No, basically the design is unchanged from decades ago.</td>
<td>No, designers do not take account of carriage of goods, books, handbags which all alter the weight and stability of the chair.</td>
</tr>
<tr>
<td></td>
<td>No, it seems that not much effort has gone into design features. Postural support accessories supplied by N.H.S. are completely inadequate. Reclining chairs are not available.</td>
<td>No, they are designed by engineers who do not know the market. I have used electric wheelchairs for seventeen years and except for getting faster, they are still extremely poorly designed, over-priced and tend to fail at the most inconvenient times.</td>
</tr>
<tr>
<td></td>
<td>No, N.H.S. issued 8L wheelchairs will be lucky to last one year if give to an active user. 8L and 9L chairs are also far too heavy for the elderly and their carers, poorly designed and constructed.</td>
<td>No, they are as good and as bad as each other.</td>
</tr>
</tbody>
</table>
Table 5.4
Respondents' explanation of why they think wheelchairs in the N.H.S. and private market place were or were not designed taking into account the needs of disabled people (cont.)

<table>
<thead>
<tr>
<th>In terms of quality of design and standardisation (cont.):</th>
<th>Wheelchairs in the N.H.S. market place</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>No, as far as manufacturers of wheelchairs in the private market place are concerned their priority is to make a profit. They design chairs which will suit many people and can be easily constructed and mass produced. A minority of individuals lose out and wheelchairs to meet their special needs are not readily available.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In terms of comfort:</th>
<th>Wheelchairs in the N.H.S. market place</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-one who answered &quot;yes&quot; explained why.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No, The comfort of standard issued chairs even for permanent users does not seem to be considered by designers.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No, design for basic needs, not for people who lead an active life. They are basic wheelchairs, no thought of comfort.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, they are more comfortable.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, they are far superior in comfort and design and do usually take account of a wider range of user needs.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In terms of suitability and user needs</th>
<th>Wheelchairs in the N.H.S. market place</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, they can be modified to suit user's needs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, due to the vast range of different disabilities the N.H.S. would have to make many compromises to accommodate everyone.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, a range of needs are taken into account but because of cost, in general N.H.S. chairs are heavy and do not have enough adjustments to make them easy to use and more comfortable.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, they take into account the various needs of disablement.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, they employ some disabled people who have a greater understanding of others' needs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, they produce chairs specifically designed for people's needs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, they are personalised for you own needs, more comfortable, sturdy and look good. You feel more confident and less conspicuous.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5.4
Respondents' explanation of why they think wheelchairs in the N.H.S. and private market place were or were not designed taking into account the needs of disabled people (cont.)

<table>
<thead>
<tr>
<th>Wheelchairs in the N.H.S. market place</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, I feel that the range of chairs should cover the needs of the majority of disabled people, especially if adaptations are made to suit specific problems.</td>
<td>Yes, many manufacturers are actual users. They seem to have an understanding and sympathy towards your needs. As the customer is paying they will take time and effort to choose the wheelchair which most suits their needs. The consultation process is more appropriate to both clinical needs and 'street credibility' combined.</td>
</tr>
<tr>
<td>Yes, the disabled needs are taken into account by therapists during assessment and, if circumstances change, they are willing to reassess the situation and, if necessary, change the chair to suit the new requirement.</td>
<td>Yes, but purchasers need input from another more experienced user when making a choice, rather than simply being swayed by a convincing salesman. Sometimes another user is a better judge of a chair than the professional therapist.</td>
</tr>
<tr>
<td>Yes, more care is now taken to ensure chair is compatible with use required.</td>
<td>Yes, the wheelchairs in the private market are custom built to your own personal needs and you can choose from a wide range of models and colours.</td>
</tr>
<tr>
<td>Yes, they are designed for all people and therefore do not cater for individual needs</td>
<td>Yes, satisfied customers are their future.</td>
</tr>
<tr>
<td>No, do not take into account how active the user is.</td>
<td>No, because the private market place just wants to make a sale. They don't take into account the fact that the chair may be totally unsuitable for the user's needs.</td>
</tr>
<tr>
<td>No, there is too much emphasis on clinical needs and less on user's everyday needs. The chairs are selected against budgetary availability, are not aesthetically pleasing and do not have good brakes.</td>
<td>No, with the odd exception, their suitability in providing adequate support and encouraging correct posture seems to be almost ignored by manufacturers.</td>
</tr>
<tr>
<td>No, each chair is very individual and often people are given chairs that are not correct for their disability because it is the closest they have in stock.</td>
<td>No, the majority of manufacturers have no disabled personnel on the work force and only disabled users can fully understand their needs.</td>
</tr>
<tr>
<td>No, too much standardisation. People are sometimes made to sit in a wheelchair rather than a wheelchair that is truly suitable for a person.</td>
<td>No, they do not always have the chair that suits your needs.</td>
</tr>
<tr>
<td>No, there was nothing taken into account about my needs. The chairs are ugly, cumbersome, weighty and uncomfortable.</td>
<td>206</td>
</tr>
</tbody>
</table>
Table 5.4

Respondents' explanation of why they think wheelchairs in the N.H.S. and private market place were or were not designed taking into account the needs of disabled people (cont.)

<table>
<thead>
<tr>
<th>In terms of suitability and user needs (cont.):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wheelchairs in the N.H.S. market place</strong></td>
<td><strong>Wheelchairs in the private market place</strong></td>
</tr>
<tr>
<td>No, if you need anything 'different' there is a long waiting list. Also the waiting list for assessment and delivery is ridiculously long.</td>
<td>No, in general, I have found that if you go to purchase a chair privately the sales staff will sell you any chair regardless of the user's requirements.</td>
</tr>
<tr>
<td>No, There are no full time wheelchair users who do not have a private lightweight wheelchair because the N.H.S. wheelchairs are usually not appropriate.</td>
<td>No, able bodied people usually think they know what disabled people need and nine times out of ten get it wrong.</td>
</tr>
<tr>
<td>No, the range of disabilities and requirements are so vast that is impossible to cater exactly for all individual needs.</td>
<td>No, persons with special needs are probably served best by the N.H.S.</td>
</tr>
<tr>
<td>No, privately bought wheelchairs are always, according to the salesmen, wonderful, the best in the world. Unfortunately, they do not always live up to the salesman's opinion.</td>
<td>No, there is not enough consideration of the needs of the individual disabled person at the one when the assessment is done. You have to take the wheelchair you are offered and it is not always the most suitable.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In terms of availability</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wheelchairs in the N.H.S. market place</strong></td>
<td><strong>Wheelchairs in the private market place</strong></td>
</tr>
<tr>
<td>Yes, there are a wide range of wheelchairs now available and the facility of voucher scheme to reward the cost of a private chair if this would suit the person better. The voucher scheme may allow those who can afford the extra cost to purchase a more expensive and more suitable chair than that offered by the N.H.S.</td>
<td>Yes, there is a reasonable choice and most are adaptable.</td>
</tr>
<tr>
<td>No, there is not enough consideration of the needs of the individual disabled person at the one when the assessment is done. You have to take the wheelchair you are offered and it is not always the most suitable.</td>
<td>Yes, there is a good range of chairs available which can be adapted to suit most requirements.</td>
</tr>
<tr>
<td>Yes, I think it is getting better, but in the rural areas it is hard to get much choice.</td>
<td>Yes, I think it is getting better, but in the rural areas it is hard to get much choice.</td>
</tr>
<tr>
<td>Yes, there are many different models available. Every chair is slightly different meaning a better choice for the consumer and they have a lot of additional equipment and accessories available.</td>
<td>Yes, there are many different models available. Every chair is slightly different meaning a better choice for the consumer and they have a lot of additional equipment and accessories available.</td>
</tr>
<tr>
<td>No, there are only about four basic designs for manual chairs and about five basic designs for powered chairs.</td>
<td>No, there are only about four basic designs for manual chairs and about five basic designs for powered chairs.</td>
</tr>
</tbody>
</table>
Table 5.4
Respondents' explanation of why they think wheelchairs in the N.H.S. and private market place were or were not designed taking into account the needs of disabled people (cont.)

<table>
<thead>
<tr>
<th>In terms of availability (cont.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wheelchairs in the N.H.S. market place</strong></td>
</tr>
<tr>
<td>No, the N.H.S. chairs are, with few exceptions, budget chairs with very poor adjustment. They cause posture problems for those in them for any length of time because of poor backrests that encourage hunched shoulders.</td>
</tr>
<tr>
<td>No, chairs under the new scheme for indoor/outdoor powerchairs are not available to all who need them.</td>
</tr>
<tr>
<td>No, people do not have many choices. It is able bodied people who decide which chairs are to be issued by the N.H.S.</td>
</tr>
<tr>
<td>No, the N.H.S. has limited resources and to make the most of them it bulk buys from a limited range of wheelchairs from the cheaper end of the market.</td>
</tr>
<tr>
<td>No, the N.H.S. wheelchair is issued on a 'take it or leave it' basis.</td>
</tr>
<tr>
<td>No, the staff are not very helpful and do not show you what is available, they only show you the basics. Nobody gives you a choice. Wheelchairs are cumbersome and causes problems getting through doors.</td>
</tr>
<tr>
<td>No, the OT's attitudes are dictatorial, they do not seem to want to listen to a client's point of view.</td>
</tr>
<tr>
<td>No, there still seems to be an attitude that they are the experts, so they know what is best for you and not enough attention is paid to the individuals need. It could appear that there is an effort to get you to agree to one that is 'normal' stock and if your need differs, then pressure is applied to get you to accept what they think you should have.</td>
</tr>
</tbody>
</table>
• Taking part in focus groups and finding a balance between business needs and user preferences.
• To give a better view of the needs of the user, what is suitable to a wider range of users and is truly cost effective.
• Provide information about chairs that are suitable for children and their parents, i.e. transport, size, storage and aesthetics.
• Contributions to improve aesthetics and produce better design.
• I have a range of needs, so I could advise on a chair that would take various adaptations.
• Being a large person they need to cater for people of 18/20 stones.
• As an advisor for the disabled, I am in contact with people whose needs and disabilities range from minor to severe, and listen to what they have to say.
• As a wheelchair user I am more likely to know what is needed unlike someone who is doing it purely and simply as a job of work.
• I have extensive experience of my own customised modifications and could advise on adaptations and accessories.
• I have an understanding of the specific needs of the female market and needs of 'cold climate' users (Scotland).

Lastly, the users in the sample were asked if there was anything that they could suggest to improve the design of wheelchairs in the market place. Their answers are shown on Table 5.5 (the table occupies pages 210 to 212, the text of the thesis continues on page 213). To gain a better understanding, the answers were grouped into the subjects to which they were related. The number of respondents who gave the same suggestion is in brackets. They fell into categories of responses related to:

• Design and the design process
• Weight, portability and foldability
• Frame and supports
• Wheels, tyres and castors
• Pushing rims and handles
• Brakes
• Footrests and headrests
• Seat and back system
• Canvas and upholstery
• Battery and power system
• Others.
Table 5.5
Respondent' suggestions for improving the design of wheelchairs

**Design and the design process**

- Consult/involve disabled people or wheelchair user groups and carers in the design process (21).
- Improve appearance of chairs (6).
- Produce wheelchairs with standardisation of sizes and interchangeable parts to enable quick repair, simple adjustment and reduce costs, i.e. universal spindle diameter, universal drop out for castor forks, axle diameter, bearing sizes and wheels (3).
- Look at new materials to produce lightweight wheelchairs (3).
- Provide possibility to assemble basic components to suit individual needs (2).
- Electric/powered wheelchairs seem to be just manual chairs with bits bolted on (1).
- It would be better if powered chairs were designed from scratch with the powered aspect more integrated into the basic design (e.g. motor usually dangle down below the chair, lots of bolts, screws, all add weight to the chair (1).
- Test the products for extensive periods indoors and outdoors in all weather conditions before launch in the market (1).
- Make sure that sharp edges are smoothed off and protruding nuts and boles are covered to protect legs (1).
- Designers, ergonomists and engineers should work together to produce better wheelchairs and they should use themselves the product for at least three days before delivery to the market place (1).

**Weight, portability and foldability**

- Reduce weight of chairs (11).
- Produce chairs which can be folded to small size for easy transportation (4).
- Produce chairs which could be light to lift and push, modular and portable (2).
- Investigate the weight/strength ratio involving modern materials (1).

**Frame and supports**

- Use lighter materials especially in framework (4).
- Chairs capable of being fitted, where necessary, with thoracic support (1).
- Make frame able to absorb impact or 'suspension' system (1).

**Wheels, tyres and castors**

- Tyres that won't puncture but give a more comfortable ride than solid tyres (2).
- The front steering wheels could be pneumatised (1).
- Wheels that can turn freely (1).
- Removable wheels (1).
- Provide faster tyres (in sport you get tyres which are mainly for indoors but if used outside and punctured the inner tube can be repaired. This is different from other indoors tyres that don't have inner tubes and must be replaced) (1).
Table 5.5
Respondent's suggestions for improving the design of wheelchairs (cont.)

<table>
<thead>
<tr>
<th>Wheels, tyres and castors (cont.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Use solid tyres (1).</td>
</tr>
<tr>
<td>• Front castor should be stronger (1).</td>
</tr>
<tr>
<td>• Companies should use wheels on the more popular 559 rim diameter and abandon the old 24&quot; size. 559 rims can accommodate a wider choice of tube as available to mountain bikes from any outlet tyre widths range from 20mm to 50mm off road tyres (1).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pushing rims and handles</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Removable push handles to save space in small halls, bathrooms, etc (3).</td>
</tr>
<tr>
<td>• Adjustable height push handles to suit taller person (1).</td>
</tr>
<tr>
<td>• Improve the design of pusher rims, i.e. shape and material (1).</td>
</tr>
<tr>
<td>• Avoid cut pushrims which damage hands (1).</td>
</tr>
<tr>
<td>• The hand driving rim is covered by a smooth plastic moulded cover. If this was rigid it would give a much more positive hand hold to drive (1).</td>
</tr>
<tr>
<td>• Providing rubber lining on the push bars (on the wheels) would help as the metal gets very cold; all scratched up and you may cut up your hands (1).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Brakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Brakes more efficient (1).</td>
</tr>
<tr>
<td>• Brakes that can be reached and are secure (1).</td>
</tr>
<tr>
<td>• Improve braking system for arthritic people (1).</td>
</tr>
<tr>
<td>• Put on hand brakes like bicycles (1).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Footrests and headrests</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Footplates adjustable (3).</td>
</tr>
<tr>
<td>• Longer footplates (1).</td>
</tr>
<tr>
<td>• Wider option of footplates for standard model chairs (1).</td>
</tr>
<tr>
<td>• Provide optional light leg extension that does not make it difficult to propel (1).</td>
</tr>
<tr>
<td>• Foot rest which could retract under seat between front wheels (1).</td>
</tr>
<tr>
<td>• Improve the design of leg rests and headrests (1).</td>
</tr>
<tr>
<td>• Provide standard headrests (1).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Seat and back system</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Adjustment to the height of the backrest (3).</td>
</tr>
<tr>
<td>• Seat height adjustable (2).</td>
</tr>
<tr>
<td>• Seats and backs should be made to stop stretching and sagging (1).</td>
</tr>
<tr>
<td>• Possibility to move seat and seat back to adjust position (1).</td>
</tr>
<tr>
<td>• Make the back of the seat recline like on a normal reclining chair (1).</td>
</tr>
</tbody>
</table>
Table 5.5
Respondent suggestions for improving the design of wheelchairs (cont.)

<table>
<thead>
<tr>
<th>Seat and back system (cont.)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Produce better back support (1).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Canvas and upholstery</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Further cushion on seat back and armrest (2).</td>
<td></td>
</tr>
<tr>
<td>• Washable and easily removable upholstery (1).</td>
<td></td>
</tr>
<tr>
<td>• Availability of durable and colourful upholstery (1).</td>
<td></td>
</tr>
<tr>
<td>• Strong seat canvas (1).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Battery and power system</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Improve battery technology to develop lighter and smaller batteries (2).</td>
<td></td>
</tr>
<tr>
<td>• Reduce batteries' weight (1).</td>
<td></td>
</tr>
<tr>
<td>• Provide cheaper batteries (1).</td>
<td></td>
</tr>
<tr>
<td>• I would like to see in the manual self-propelled wheelchair some sort of power pack that could help on steep hills (1).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Others</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Bring pricing of private chairs down (5).</td>
<td></td>
</tr>
<tr>
<td>• Make wheelchairs easy to adjust (5).</td>
<td></td>
</tr>
<tr>
<td>• Consideration for a safe place to carry bags and some shopping (3).</td>
<td></td>
</tr>
<tr>
<td>• Make them strong (2).</td>
<td></td>
</tr>
<tr>
<td>• Rubber bumpers particularly on electric wheelchairs to avoid damage to furniture, doors, etc. (1).</td>
<td></td>
</tr>
<tr>
<td>• Mobile wheel rims that do not chip after two days of use (1).</td>
<td></td>
</tr>
<tr>
<td>• Fixing space for weather cover (1).</td>
<td></td>
</tr>
<tr>
<td>• Fixing space for a tray (1).</td>
<td></td>
</tr>
<tr>
<td>• A bell to warn of approach (1).</td>
<td></td>
</tr>
<tr>
<td>• There should be &quot;clamping/anchorage&quot; points for safety when travelling in vehicles (1).</td>
<td></td>
</tr>
<tr>
<td>• Strong camber bars (1).</td>
<td></td>
</tr>
<tr>
<td>• Ability to climb kerbs and steps easier (1).</td>
<td></td>
</tr>
<tr>
<td>• Consideration to standardise clamping areas for additional components(1).</td>
<td></td>
</tr>
<tr>
<td>• Charging point should be easily accessible (1).</td>
<td></td>
</tr>
<tr>
<td>• Avoid angular corners (1).</td>
<td></td>
</tr>
<tr>
<td>• Avoid some metal parts which touch legs and are cold (1).</td>
<td></td>
</tr>
<tr>
<td>• More stainless steel rims instead of the plastic coating which peels off (1).</td>
<td></td>
</tr>
<tr>
<td>• Chip proof paint/finish as chairs tend to look very tatty quickly (1).</td>
<td></td>
</tr>
<tr>
<td>• Possibility to add a motorised unit in self propelled chairs (1).</td>
<td></td>
</tr>
<tr>
<td>• More electrical controls (1).</td>
<td></td>
</tr>
<tr>
<td>• Use of 'smart' microprocessors in electric chairs and buggies (1).</td>
<td></td>
</tr>
</tbody>
</table>
It can be observed that some suggestions made by the respondents to improve the design of wheelchairs are already found in many wheelchairs available in the market place. This shows that some of them had little information about the range of equipment currently available.

5.2.3 Major features of data, comments and lessons learned

Although this survey may not be statistically representative of the whole population of wheelchair users in the United Kingdom, comments, concerns and suggestions emerged from the questionnaires which can certainly be considered as a rich input for the improvement of the quality of design, prescription and supply of wheelchairs in this country.

Forty-one people agreed to distribute the questionnaires, but nine did not distribute any or just sent one questionnaire back from the kit of 15 questionnaires posted to them. In spite of this, the use of "key persons" in the distribution of the questionnaires seemed to be a useful and effective approach to finding wheelchair users willing to answer the questionnaires.

The survey has produced some findings, in terms of answers given by the majority of respondents, which will contribute to the establishment of design requirements for the production of wheelchairs on a large scale. Summarising these findings, they reveal that the majority of users in the sample:

- were over 45 years old and more than one-third of them were over 55 years old
- suffered from neurological conditions
- lived in an urban area: town or city
- took their wheelchair with them when they went out in a vehicle
- had used some form of public transport in the last twelve months
- had more than one wheelchair
- had been using a wheelchair for more than ten years
- owned a manual self-propelled wheelchair as the most used and the next most used wheelchair
- obtained their wheelchairs through the N.H.S. for both the most used and the next most used wheelchair
- had owned their current wheelchair(s) for less than five years
- had a seat cushion for both wheelchairs (the most used and the next most used wheelchair)
- used their main wheelchair every day
Chapter 5: Wheelchair Use

- used their main wheelchair indoors for more than five hours a day
- had had problems with their main wheelchair in the last 12 months
- considered safety, comfort, reliability, suitability and portability due to weight as the five most important design characteristics of wheelchairs
- judged the design of their own wheelchairs as being "very good" or "good" in terms of safety, ease of use, stability, manoeuvrability, suitability and reliability although this level of satisfaction was not achieved as consistently as might be hoped for
- judged the design of their own wheelchairs as being "average", "poor" or "very poor" in terms of cost to buy, cost to repair, provision of accessories, cost to maintain, adjustability, ease of repair, aesthetic appearance and portability due to weight
- had the views that privately acquired wheelchairs were designed taking into consideration the needs of disabled people and those issued by the N.H.S. were not
- had never been involved in wheelchair design with a company that mass produced wheelchairs for a large market.

The range of findings revealed by the questionnaires of wheelchair users gives an immediate indication of the varied demands that a wheelchair, with a user-centred design, needs to meet. The findings mentioned immediately above and other findings from the survey of wheelchair users will be commented upon in the following paragraphs.

The claim that the majority of wheelchair users are elderly, made by Goldsmith (1992) and the Royal College of Physicians of London (1995), was not confirmed in this sample where only 10.3% were 65 years old or more. Apart from the users' age, a crucial point to be considered in the design of wheelchairs is the users' strength. A large number of wheelchair users have poor strength and require wheelchairs that should be light to lift and propel. The lack of this property, mainly for wheelchairs issued by the N.H.S., was pointed out by a significant number of respondents.

Most of respondents suffered from neurological conditions and had been using a wheelchair for more than ten years. Stewart (1992) pointed out in a review of Edinburgh-based patients that more than half of the wheelchair users had neurological problems. Also, almost one-third of respondents in a survey reported by Smith, McCreadle and Unsworth (1995) suffered from neurological disorders. This seems to be one of the most frequent causes of disability amongst wheelchair users.

As a number of the respondents worked full or part-time outside the home, and most users lived in a town or city, took their wheelchairs with them when they went out in a vehicle, and had used some form of public transport in the last twelve months, it is important to consider
not only the provision of wheelchair friendly environments but also some specific requirements for the design of wheelchairs to be used in urban areas. According to Ohras, Yelding and Mitchell (1997), if the environment were perfectly accessible, wheelchairs would not be as far from meeting the basic needs of their users as they are now. In fact, the provision of some requirements, such as an adequate kerb climber and the capacity of manoeuvrability in crowded locations and small spaces, e.g. shops, offices, restaurants, toilets and lifts, may represent an increase in independence and an improvement in the quality of life of wheelchair users.

The survey shows that the majority of users in the sample had more than one wheelchair. This may occur because: a) one wheelchair alone did not meet the user's different range of demands; b) the users needed a spare one in the case of the other breaking down and/or c) the first wheelchair had broken down or was not more suitable for the user's needs and the user had decided to keep both anyway. The number of wheelchair users who had more than three wheelchairs, about one-third of the sample, strongly suggests that one wheelchair alone was unable to meet the user's different demands.

The makes and models of wheelchairs used by respondents in the sample were provided by almost 20 different manufacturers. However, very few makes and models were used by more than five users. This may be a sign of a very competitive market. As far as the most used wheelchairs are concerned, two makes are exceptions to this statement - the Sunrise SunTec and the Sunrise Quickie - because they were used respectively by 28 and 17 respondents. These numbers are several times bigger than the number provided by their competitors. This may represent a leadership in the market place. Another important point to consider is the number of respondents using 8L, 8BL, 8L SP and 8HU wheelchairs, all issued mainly by the N.H.S. The number was 11 for the most important chair and 21 for the next most important chair. The figure of 21 given for the second chair may be interpreted as being a function of their inadequacy to fulfil users' basic needs. In view of this, these wheelchairs, which have the N.H.S as the main provider, were replaced by the user by another chair more able to meet their needs and were being considered at the time of the survey as the second most used chair.

The majority of users owned a manual self-propelled chair issued by the N.H.S. for both the most important chair and the second most important chair. Although a significant number of these wheelchairs had been owned for less than three years (almost 40% for chair 1 and 42% for chair 2), it was found that 63% of respondents in the sample had had problems with their main wheelchair in the last 12 months and nearly 40% had had problems with their second wheelchair in the same period. This is a high percentage bearing in mind that most wheelchairs had been owned by respondents for less than 5 years and many of them for less than three.
The main wheelchair, those which are supposed better to meet the users' needs, were used indoors more than five hours on a daily basis by the respondents. The use of the second chair, mainly outdoors, was divided between use every day and infrequent use, less than one day a week. Most of the users had seat cushion on their wheelchairs. Almost one-third of respondents in the sample answered that their wheelchair tyres had had punctures in the last twelve months.

A large majority of respondents answered that they felt that their needs and abilities were taken into consideration during the process of assessment and prescription of their wheelchairs. It is important to draw attention to the fact that, according to the literature, many patients were reluctant to criticise hospital services and products they had received, sometimes because they felt they were in a vulnerable position and sometimes because they did not wish to appear ungrateful (Barber, 1996 and Haran, Knopft and Eardley, 1983).

Although the majority of respondents answered that they felt that their needs and abilities were taken into consideration during the process of assessment and prescription of their wheelchairs, almost two-thirds of them were able to identify some weaknesses in the process by which they were assessed, their wheelchairs prescribed and the follow-up carried out. Among the problems identified by respondents was the long delay between assessment by prescribers and subsequent delivery. This may cause problems for the design process because some user requirements could have changed over this period of time. Other problems identified by respondents concerning the process of assessment and prescription of their wheelchairs refer to the lack of communication between prescribers and users and the wheelchair not suiting the users' needs. The latter may have been caused by the criteria for choosing the wheelchair having been focused mainly, if not solely, on whether it fulfilled the user's physical and medical needs and not considering the user's lifestyle and expectations in terms of the product's characteristics including, for example, aesthetics. Although the consideration by designers and manufacturers of some elements such as intended lifestyle, image, status and identification are ingredients essential for the success of any product, the design of most wheelchairs, mainly those available through the N.H.S., seems to be produced exclusively to solve problems based on the physical and medical requirements of the person who will use it.

Two-thirds of respondents answered that they were shown how to use their wheelchairs, and half of the sample answered that they had received written instructions explaining how to use their wheelchairs. The instructions were considered satisfactory by most of them. In a national survey of wheelchair users in England carried out in 1990, it was found that about two-thirds of all respondents (n=3082) had received standard written instructions explaining how to use
their wheelchair and a similar proportion of respondents received no practical demonstration of their wheelchair (Kettle, Rowley and Chamberlain, 1992). The differences observed in the two surveys may represent some improvements in the prescription process.

The majority of respondents said that they had not received any follow-up after their wheelchair had been delivered to check on whether they were satisfied. The follow-up seems to be extremely important to check the adequacy of the wheelchair in fulfilling user's needs and obtaining feedback regarding satisfaction with the design of the product.

Respondents were asked to rate the level of importance of 21 characteristics of wheelchairs. The majority of them rated almost all characteristics as being "extremely important" or "very important" but when asked which characteristics were more important for them they made a distinction pointing out that safety, comfort, reliability, suitability and portability due to weight were the most important. A number of very interesting quotes were provided by the respondents to justify their answers (Table 5.3, pages 193 to 196). Some of them clearly represent important design requirements such as:

- Full time in wheelchair and very prone to pressure sores (comfort).
- I live alone and therefore like to be as independent as possible. If my chair is broken, so am I (reliability).
- The chair must be well fitted and suited to everyday need, otherwise independence is hindered (suitability).
- I have to dismantle and lift into car while sitting in driver's seat (portability due to weight).
- If it is not easy to transport in my car the chair is of no real use to me (ease of transport in a car).
- It is important because most wheelchairs look like torture implements: ugly, not colourful, old, badly designed (aesthetic appearance).
- My wheelchair is not only an enabler, it is an extension of how I feel about myself and how people see me (aesthetic appearance).

The respondents were asked to classify their own wheelchairs in the light of the characteristics to which they had previously attributed levels of importance. The five characteristics which reached the best level of satisfaction were: a) for chair 1: safety, ease of use, stability, suitability and manoeuvrability and b) for chair 2: safety, reliability, robustness, stability and ease of use. Comparing these characteristics with those listed by the respondents when asked about the main characteristics wheelchairs should have, it can be found that two - comfort and portability due to weight, out of the five main important characteristics which wheelchairs should have, were not included. Reliability, which is only listed under the characteristics for
chair 2 was in fact, according to the respondents, the third most important characteristic of a wheelchair.

Broadly speaking, the 21 characteristics of design of the respondents' own wheelchair(s) did not receive good rates in terms of level of satisfaction, mainly for the second most used wheelchair. Figures 5.34 and 5.35 (pages 198 and 199) showed clearly an impressive number of respondents who rated their own wheelchairs as being "average" and "poor and very poor". If the number of characteristics rated as "average" are added to those rated as "poor" and "very poor" the final figure is somewhat worrying. For instance, safety got 21.6% and 23.9% respectively for chair 1 and chair 2. Comparing this with other kinds of products, it would be a reason for a high level of concern if such percentages occurred in the evaluation of customers' satisfaction, for example for safety in cars. Another point to consider was that a great number of respondents emphasised the high cost of wheelchairs, the characteristic which got the highest rate for "average" added to "poor" and "very poor". One of the respondents answer may summarise the general feeling: "I believe they could be made cheaper, disabled people seem to have to pay over the top for everything".

More than twice as many respondents thought that the privately acquired wheelchairs were designed taking into consideration the range of needs of disabled people than thought the same in terms of the wheelchairs issued by the N.H.S. Respondents justified their views saying for instance that:

a) Wheelchairs in the private market place were or were not designed taking into account the needs of disabled people because:

In terms of costs:

- People have more choice and better features if they pay for it.

In terms of quality of design and standardisation:

- They are very lightweight, easy to manoeuvre, better made, less repairs to be made, comfortable, there is a wide choice and lots of different colours available.
- To compete in this market they have to offer features and benefits on their chairs. All disabilities have to be catered for and retailers have to offer a good and comprehensive range to make chair sales viable.

In terms of comfort:

- They are far superior in comfort and design and do usually take account of a wider range of user needs.
In terms of suitability and user needs:

- The wheelchairs in the private market are custom built to users personal needs and they can choose from a wide range of models and colours.

In terms of availability:

- There is a good range of chairs available which can be adapted to suit most requirements.

b) Wheelchairs in the N.H.S market place were or were not designed taking into account the needs of disabled people because:

In terms of costs:

- They are designed much more for cheapness than the needs of the user and carer. Cost dictates the design, materials and suitability of N.H.S. wheelchair provision.

In terms of quality of design and standardisation:

- Most of the wheelchairs available on the N.H.S. are very heavy, ageing design, dull colours and cheap. No thought is given to what the disabled person wants from a wheelchair. Some of them were designed more than 20 years ago and not a lot has changed since then.
- The weight of the metal used in N.H.S. chairs makes the chair very difficult to lift or fold/unfold by the disabled person.
- They are usually standard models, extremely heavy, ugly, but they don't break too often.

In terms of comfort:

- They are designed for basic needs, not for people who lead an active life. They are basic wheelchairs, no thought of comfort.

In terms of suitability and user needs:

- There is too much emphasis on clinical needs and less on user's everyday needs. The chairs are selected against budgetary availability, are not aesthetically pleasing and do not have good brakes.
- Each chair is very individual and often people are given chairs that are not correct for their disability because it is the closest they have in stock.

In terms of availability:

- The N.H.S. chairs are, with few exceptions, budget chairs with very poor adjustment. They cause posture problems for those in them for any length of time because of poor backrests that encourage hunched shoulders.
- The N.H.S. wheelchair is issued on a 'take it or leave it' basis.
Generally speaking, it may be concluded that most respondents with privately bought wheelchairs had a level of satisfaction superior to those who had N.H.S.-supplied wheelchairs. It could be because those privately brought wheelchairs were chosen carefully, from a range of options, by the user him or herself to meet specific needs.

A large number of suggestions to improve the design of wheelchairs in the market place were given by users in the sample (Table 5.5, pages 210 to 212). The suggestions were related to several aspects of the wheelchair, for instance, design and the design process; weight, portability and foldability; frame and support; wheels, tyres and castors. Although a number of suggestions provided by respondents were already incorporated in some models currently available in the market place, they should certainly be considered in the phase of identifying user needs in the design process for the production of new models.

Although a large number of respondents stressed the need to involve users in the design of wheelchairs, only seven users in the sample had ever been involved in wheelchair design with companies that mass produced wheelchairs for a large market. Almost half of the sample answered that they would like to be involved, or continue to be involved, in wheelchair design. This number would probably have been greater if a considerable number of users in the sample did not have limitations in terms of condition of health and age. Most of the users who answered that they would be willing to be involved in wheelchair design said that their main contribution would be in terms of the provision of personal experience and the point-of-view of a disabled person in the design process. Undoubtedly these contributions are indispensable for the design of wheelchairs which are intended to fulfil user requirements and needs for an independent life. All wheelchair characteristics including safety, comfort, adjustability and reliability may be evaluated by users. Taking part in user trials, focus groups and other techniques to gather user opinions would help to achieve a balance between the various requirements of the product such as suitability, ergonomics, aesthetics, structure, costs and manufacturing. As is exhaustively repeated in this thesis, users are the best people to point out what their needs are. A quotation provided by Barber (1996, p. 564) reinforces the importance of designing products for the disabled which are focused on their needs:

"If the consumers of disability products do not demand that designers accept the challenge to design products that emphasises activity instead of passivity, interests rather than lack of interests, going to restaurants, theatres and night clubs rather than staying in watching television, more people may be less reluctant to use a product that has been prescribed by the medical and therapy professionals, and people who develop a physical impairment in adulthood may find it easier to accept their new situation."
A user-centred method describing the phases of wheelchair design and the involvement of users will be given in the next chapter.

Finally, as was previously mentioned, the improvement of dialogue between all the stakeholders involved in the design and prescription of wheelchairs and their participation in the design process should contribute to a better quality of wheelchairs in the market place, allowing the consumers to find better options of wheelchair to fit their needs and overcome barriers that impede independent mobility and function.

5.3 Survey of personal assistants (carers)

5.3.1 Strategy and design of the field study of carers

A field study of the wheelchair users' personal assistants, also called carers, helpers or facilitators, was carried out with the main objectives of: a) obtaining the respondents' feelings about the design of the wheelchair belonging to the person whom they assisted; b) obtaining the carers' views about the prescription process; c) finding out the extent to which the wheelchairs issued by the N.H.S. and private companies are considered satisfactory; d) discovering more about the carers' views on wheelchair design and how the wheelchair design could be improved and e) using the results, later in this thesis, to develop a user-centred method for the design of wheelchairs. The terms "personal assistants" and "carers" are used synonymously in this thesis.

The "Questionnaire for Personal Assistants" comprised 18 questions divided into three parts:

- Questions about the carers themselves
- Questions about wheelchair prescription
- Questions about wheelchair design in general

This sample, similar to that used in the survey of wheelchair users, was also essentially exploratory and was not intended to be statistically representative of the population of carers in the United Kingdom.
5.3.1.1 Ethical considerations

The survey was in accordance with the Department of Human Sciences' ethical guidelines. Responses were confidential and respondents' anonymity was guaranteed. No names were indicated on the completed questionnaire and results of the research could not be traced to any individual respondent. It was considered unlikely that the nature of the questions in the survey would adversely affect respondents. No other person than the author had access to the completed questionnaires.

5.3.1.2 Survey procedures

The survey procedure was almost identical to the survey of wheelchair users described in the sub-section 5.2.1.2. It was conducted in three stages: a) identifying a number of "key persons" to distribute the questionnaire; b) carrying out the pilot surveys by personal interviews or sending the questionnaires out by mail together with the questionnaires of wheelchair users and c) the sending the final version of the questionnaires out by mail to the "key persons" together with the questionnaires for wheelchair users.

Identifying the "key persons"

This phase was identical to the previous survey of wheelchair users and was described in section 5.2.1.2. To avoid repetition, it is not described again here.

Pilot Survey

The same approach used with the pilot survey of wheelchair users was again used to carry out the pilot survey of carers: face-to-face interviews and questionnaires sent by post. Ten persons took part in this pilot survey. Two persons were interviewed and had the opportunity to make comments and suggestions about the questions. Eight, out of the 15 originally delivered, sent their questionnaires back by post together with the questionnaires of wheelchair users. An example of the pilot questionnaire is included in Appendix 5.7 (p. 453).

The following changes were made to the pilot questionnaire to produce the final version of the "Questionnaire for Personal Assistants (Carers)":

- In questions 3 and 5, the characteristic "portability" was split into "portability due to size" and "portability due to use".
- In questions 3 and 5, the characteristics "cheap to buy", "cheap to maintain" and "cheap to repair" were re-written as "cost to buy", "cost to maintain" and "cost to repair".
In question 4, a statement asking the carer to answer why they had chosen the three characteristics pointed out by them as the most important was included.

Question 8 was re-written and split into questions 8 and 9: a) Is it your impression that, in general, the wheelchairs actually in the NHS market place are designed taking into account the range of needs of carers? and b) Is it your impression that, in general, the wheelchairs actually in the private market place are designed taking into account the range of needs of carers?

A new question was included after question 16: "Please list, in order of severity, the three tasks which cause you the most difficulty when assisting the user with the wheelchair".

In view of the few and relatively minor changes, the ten pilot questionnaires were included in the final sample. The answers which were different from the pilot to the final version of the questionnaires have received special treatment and will be discussed, when appropriate, in the section regarding the analysis of questionnaires (section 5.3.2).

**Full Survey**

A final version of the "Questionnaires for Personal Assistants" (Appendix 5.8, page 459) was part of the package sent to "key persons" to be distributed amongst wheelchair users. The package included sets of 5 to 15 kits each one including: a) a cover letter to the wheelchair user; b) a copy of the "Questionnaire for Wheelchair User"; c) a copy of the "Questionnaire for Personal Assistants (Carers)" and d) a Freepost envelope to facilitate return of both questionnaires. As part of the kit, wheelchair users were asked to give to a nominated carer a copy of the "Questionnaires for Personal Assistants", if they were being cared for full-time or part-time by a personal assistant. If they did not have a carer, they were asked to ignore this questionnaire.

A number was assigned to each questionnaire so as to enable the researcher to monitor which "key person" had distributed the questionnaires. Each "Questionnaire for Wheelchair Users" and "Questionnaire for Personal Assistants" had the same number to facilitate the correspondence between each user and his or her carer. A reminder letter to the wheelchair user (Appendix 5.6, page 452) was sent out five weeks after the initial posting. Thirteen "Questionnaires for Personal Assistants" were received after the reminder letter had been posted.

**5.3.2 Analysis of questionnaires**

A total of 618 questionnaires was initially distributed, including the pilot survey, as part of the set delivered to wheelchair users. An overall number of 105 carers replied. Six responses were considered invalid because: a) there were very few answers and the main questions were left
blank or b) they arrived when the questionnaires had already been processed. So, the number of valid responses in the sample, including the ten pilot questionnaires, was 99. One hundred and three wheelchair users answered in the previous survey that they had a personal assistant. Four did not answer this question. This meant that the rate of responses for the survey of personal assistants was a remarkable 100%: all wheelchair users who answered that they had a carer delivered the questionnaire to them and they replied.

The same computer programmes used to analyse the questionnaires of wheelchair users, were used for the carers' questionnaires: Excel 97 and SPPS version 8.0.

A number of missing data were found, as in the questionnaire of wheelchair users. They also fell into the two categories of "not applied" and "no answer". An explanation about these missing data was given in section 5.2.1.2. The way in which the information is shown is also similar to the previous survey and is described in the same section.

5.3.2.1 Questions about the carers themselves

The number of female respondents in the sample (n=53) was slightly greater than the number of male (n=42). Four respondents did not give their gender.

Figure 5.37 shows the age profile of the sample. The large majority of them (83.3%) were over 35 years old. Almost one quarter of the sample (21.9%=14.6%+7.3%) were over 65 years old.

Figure 5.37
Age group (n=96)
Figure 5.38
Relationship between the carers and the wheelchair users whom they assist (n=97)

Figure 5.38 shows that more than half of the sample (57.7%, n=97) answered that the relationship between them and the wheelchair user whom they assisted was that of spouse. Almost 22% were the parents of the users. The remainder of the sample were paid carer, brother or sister, friend or other. The respondents who answered "other" said they were partners (3), son and daughter and an "unpaid slave".

According to Figure 5.39, when asked about how many days per week they assisted users in using the wheelchair, most of the carers in the sample (70.1%) answered that they assisted them on a daily basis. A few more than 11% answered to have assisted the users over four days per week. Almost 16% answered that they assisted them less than four days per week.
The remainder of the respondents helped the user with their wheelchairs less than once a week (3.1%).

The respondents who answered that they assisted the user with their wheelchair every day were asked to say how long per day this assistance was given. Figure 5.40 shows that many (40.5%) respondents answered that they assisted the wheelchair user for the whole day. About 16% said they helped them for more than five hours a day. Almost 13% said that they helped them between two and five hours and almost 15% answered for less than two hours per day.

Figure 5.40
Hours per day that carers assisted the user in using the wheelchair (n=96)

<table>
<thead>
<tr>
<th>RATING</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2 hours a day</td>
<td>14.5</td>
</tr>
<tr>
<td>Between 2-5 hours</td>
<td>12.7</td>
</tr>
<tr>
<td>&gt; 5 hours</td>
<td>16.2</td>
</tr>
<tr>
<td>All day long</td>
<td>40.5</td>
</tr>
</tbody>
</table>

The carers were asked to rate their health at the time they answered the questionnaire (Figure 5.41). The sample was divided between those who rated their health as being "very good" and "good" (47.5%=15.5%+32%) and those who rated their health as "average", "poor" and "very poor" (52.5%=30.9%+18.6%+3.1%). An important point to be considered in the design of wheelchairs is that they are usually pushed and lifted by a considerable number of persons with relatively poor health.
After having rated their health, the carers were asked, considering just the period when they assisted the user with the wheelchair, to rate the pain (if any) they felt in each region of their body. The results are shown in two figures: Figure 5.42 and 5.43. Although almost all respondents answered this question, some of them failed to give an answer for some regions of the body.

Figure 5.42 shows a graphic comparing respondents who answered that they felt no pain at all when they assisted the user with the wheelchair and those who felt some pain in various regions of their body. It can be seen that more than thirty percent of the carers in the sample answered that they experienced pain in at least one region of their bodies. There were six regions stated as the most painful by more than or about half of the respondents: the regions of lower back (75.4%), buttocks (54.1%), mid back (53.2%), right shoulder (51.6%), left shoulder (49.5%) and neck (47.3%). A significant number of respondents also answered that they felt pain in other regions of their bodies such as hands and lower arms.

The distribution of discomfort in the carer's body was evaluated using a body map, divided into segments, as suggested by Corlett and Bishop (1976). A figure representing the human body was provided in the questionnaire and the respondents were asked to rate the pain in each region of their body using a scale. The scale had four categories: 0 = "I feel no pain at all", 1 = "I feel a just noticeable pain", 2 = "I feel a moderate pain" and 3 = "I feel an intolerable pain".
Figure 5.42
Percentage of respondents who felt no pain at all in specific regions of their body compared with those who felt some pain when they assisted the user with the wheelchair.

The respondents were asked to indicate the level of pain in each of the boxes in the body map provided and not to leave any blank. Respondents were also advised that although the figure was drawn solely from the back, their responses should relate to the region of their body whether at the front or the back.
Figure 5.43 shows the map of body discomfort with the answers provided by the respondents. It should be noted that the graphics do not include those who did not feel any pain at all because they were already included in Figure 5.42. According to Figure 5.43, the number of respondents who rated the lower back as the most painful part of their body were distributed as follows: 40% answered that they felt a moderate pain in this region; 25% who said they felt a just noticeable pain and 11% who felt an intolerable pain. The second and third regions rated as the most painful by the carers in the sample were respectively the mid back and the buttocks. These were the most painful regions in the carers' bodies may be because of poor postures assumed by them when pushing the user's wheelchair and the amount of effort they usually put in when lifting the wheelchair and/or the user and positioning the user in the wheelchair. Certainly, such pain could be minimised by the provision of good design in the wheelchair and some of its components, e.g. handles, taking into account the carers' specific needs and requirements in addition to the users'.

The carers in the sample were asked to list the three tasks which caused them the most difficulty when assisting the user with the wheelchair. Table 5.6 shows their answers including the number of people who identified them in brackets. The tasks were organised into the following categories of responses for both indoor and outdoor activities: lifting, lowering and moving; manoeuvring; transferring; pushing; adjusting and removing the wheelchair's components; adjusting the person, dressing, bathing and toileting; and others. Some outdoor activities were considered the most demanding by the carers.

The table shows that half of the sample pointed out that going up/down steps, stairs, kerbs and hills were the most difficult outdoor tasks they performed. Getting the wheelchair into and out of the car was the second most difficult outdoor activity (indicated by 28 respondents) and manoeuvring through doorways the third (indicated by 9 respondents). In terms of indoor activities, getting/lifting into and out of the wheelchair was considered the most difficult activity (19 persons indicated it). Manoeuvring the wheelchair with the user through doorways, indicated by 15 respondents, was considered the second most difficult indoor task. The third most difficult activity, manoeuvring in tight spaces, e.g. toilets and bathrooms, was indicated by ten carers in the sample. Consideration of the tasks performed by carers when assisting the user in the wheelchair during the design process, certainly constitutes one important contribution to the success of a wheelchair in the market place.
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Figure 5.43
The map of body discomfort with the answers given by the carers

1 = "I feel a just noticeable pain"
2 = "I feel a moderate pain"
3 = "I feel an intolerable pain"
Table 5.6
The most difficult tasks indicated by the carers when assisting the user with the wheelchair

<table>
<thead>
<tr>
<th>Lifting, lowering and moving</th>
<th>Outdoor tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indoor tasks</strong></td>
<td><strong>Outdoor tasks</strong></td>
</tr>
<tr>
<td>• Lifting up stairs (5)</td>
<td>• Going up/down steps, stairs, kerbs and hills (49)</td>
</tr>
<tr>
<td>• Lifting the front when needed (1)</td>
<td>• Getting the wheelchair into and out of a car (28)</td>
</tr>
<tr>
<td>• Putting on and removing from hoist sling (1)</td>
<td>• Lifting the wheelchair in general (8)</td>
</tr>
<tr>
<td>• Taking the chair in and out of the home (1)</td>
<td>• Lifting chair into boot of car (2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indoor tasks</th>
<th>Outdoor tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Manoeuvring through doorways (15)</td>
<td>• Manoeuvring through doorways (9)</td>
</tr>
<tr>
<td>• Manoeuvring in tight spaces, e. g. toilets and bathrooms (10)</td>
<td>• Manoeuvring in tight and crowded spaces, e. g. shops, unfriendly buildings and inappropriate toilets (8)</td>
</tr>
<tr>
<td>• Manoeuvring around house, furniture, corners, etc. (5)</td>
<td>• Manoeuvring in general (2)</td>
</tr>
<tr>
<td>• Manoeuvring in general (5)</td>
<td>• Manoeuvring through small gaps (1)</td>
</tr>
<tr>
<td>• Manoeuvring to get under table (4)</td>
<td>• Manoeuvring to get under tables in restaurants (1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indoor tasks</th>
<th>Outdoor tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Getting/lifting into and out of chair (19)</td>
<td>• Transferring into and out of chair (4)</td>
</tr>
<tr>
<td>• Transferring from wheelchair to bed, bath, toilet, lounge chair and sofa (8)</td>
<td>• Transfer to car seat (1)</td>
</tr>
<tr>
<td>• Transferring from one wheelchair to another (1)</td>
<td></td>
</tr>
</tbody>
</table>

| Outdoor tasks |
|----------------|---------------|
| • Pushing (4) | • Pushing on uneven surfaces, difficult pavements and rough terrain such as across rough and/or soft ground, over gravel, up gradients, sand beach (13) |
| • Difficulty with pushing on carpet (1) | • Pushing in general (5) |
| | • Pushing for long periods and distances (2) |
Table 5.6
The most difficult tasks indicated by the carers when assisting the user with the wheelchair (cont.)

<table>
<thead>
<tr>
<th>Adjusting and removing the wheelchair’s components</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indoor tasks</strong></td>
<td><strong>Outdoor tasks</strong></td>
</tr>
<tr>
<td>Adjusting/removing armrest and footrest (5)</td>
<td>Mounting and dismounting (4)</td>
</tr>
<tr>
<td>Adjusting cushion (1)</td>
<td>Replacing and taking wheels on/off (4)</td>
</tr>
<tr>
<td>Adjusting user position (1)</td>
<td>Replacing armrests (1)</td>
</tr>
<tr>
<td>Aligning front wheels (1)</td>
<td>Releasing backrest (1)</td>
</tr>
<tr>
<td>Mounting and dismounting (1)</td>
<td>Replacing failure motors and batteries (1)</td>
</tr>
<tr>
<td></td>
<td>Clamping wheelchair in car (1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adjusting the person, dressing, bathing and toiletries</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indoor tasks</strong></td>
<td><strong>Outdoor tasks</strong></td>
</tr>
<tr>
<td>Bathing and toiletries (7)</td>
<td>-</td>
</tr>
<tr>
<td>Dressing (2)</td>
<td></td>
</tr>
<tr>
<td>Positioning the person in wheelchair (1)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Others</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indoor tasks</strong></td>
<td><strong>Outdoor tasks</strong></td>
</tr>
<tr>
<td>Folding the wheelchair (2)</td>
<td>Folding the wheelchair (2)</td>
</tr>
<tr>
<td>Coping with bending (1)</td>
<td>Coping when raining (1)</td>
</tr>
<tr>
<td>Running over carers’ feet (1)</td>
<td>Catching feet on rear of wheelchair (1)</td>
</tr>
<tr>
<td>Charging the battery (1)</td>
<td>Accessing taxis and cars (1)</td>
</tr>
<tr>
<td>Living with the &quot;click&quot; of the battery chair (1)</td>
<td>Finding a place to put luggage (1)</td>
</tr>
<tr>
<td>Difficulty of cleaning seat in &quot;patterned grooves&quot; (1)</td>
<td>Finding access point in the community (1)</td>
</tr>
</tbody>
</table>

5.3.2.2 Questions about wheelchair prescription

Almost half the carers in the sample (44.4%, n=99) answered that they did not attend the assessment with the wheelchair user. From those who had attended the assessment, 31% answered that they felt that their needs and abilities were not taken into consideration during the process of assessment. A little more than nine percent said they were unsure.

Forty-two percent of the respondents (n=86) answered that they were able to identify weaknesses in the process by which the wheelchair belonging to the wheelchair user, whom they assisted, was prescribed. The problems identified by the carers and the number of people who identified them are summarised in Table 5.7.
Table 5.7
Problems identified by carers concerning the prescription of the wheelchair belonging to the wheelchair user whom they assisted

- Provision of a wheelchair with poor design: too heavy, cumbersome, difficult to push, etc. (16).
- Prescription process did not take into account the comfort of the carer, his or her height or physical capabilities to lift or manoeuvre the wheelchair (11).
- Insufficient information given regarding available range of alternatives (3).
- The N.H.S. issues wheelchairs on a cost-saving basis (3).
- No explanation of the issues surrounding wheelchairs, e.g. transport, sport, size, manoeuvrability, etc. (2).
- Waiting times to assessment were quite long (1).
- There wasn't enough time for the assessment (1).
- Long time to process appointments and prepare the chair (1).
- No account of seating difficulties was taken (1).

The following quotations provided by respondents illustrate the weaknesses identified by them concerning the prescription of the wheelchair belonging to the user whom they assisted.

- "Waiting times to be assessed were quite long. I feel the personal assistant should attend as people don't know assistant's height, capabilities and physical illnesses. These requirements were not taken into account."
- "The carer's needs were not taken into account: use of indoor/outdoor wheelchairs is approved on evidence of manoeuvrability in a hospital corridor, not the confines of home and the need for pushing handles for the helper was not foreseen."
- "Prescribers did not take into account the comfort of the carer and whether she had to push the wheelchair for long periods on distances."
- "I was excluded!"
- "Provision of a wheelchair which was too heavy, cumbersome, difficult to push, had sharp parts and jamming front wheels. Brakes need to be easier to reach."
- "The wheelchair provided had problems with the height of pusher: handles not adjustable. You have to "fit" whatever the outcome."
- "There are no adjustment to make them suit the user and carer. So it's take it or leave it."
- "I am very tall and have health problems, my problems were not discussed."
- "Not all the options described were available, cheapness came first."
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- "No explanation of the issues surrounding wheelchairs, e.g. transport, sport, size, manoeuvrability, etc."

5.3.2.3 Questions about wheelchair design in general

The carers in the sample were shown a list of 21 characteristics of a wheelchair and asked to classify such characteristics on a scale of five levels of importance: extremely important, very important, important, fairly important and not important. The characteristics were the same as those analysed for the wheelchair users in the previous survey. The meaning of each characteristic was described in sub-section 5.2.2.4. Figures 5.44 to 5.62 show the level of importance attributed by the carers to each category. The following paragraphs comment on their answers.

Safety (Figure 5.44)
This essential characteristic was considered extremely important or very important almost unanimously by the respondents (95.9% = 86.7% + 9.2%).

Robustness (Figure 5.45)
The majority of respondents (58.7%) rated robustness as extremely important. Almost 30% considered it as being very important and 12% as being important.

Stability (Figure 5.46)
A large percentage of respondents (90.5% = 74.7% + 15.8%) rated this characteristic as extremely or very important.

Suitability (Figure 5.47)
Almost all carers in the sample (95.8% = 73.7% + 22.1%) rated suitability as being extremely or very important.

Reliability (Figure 5.48)
Again, almost all carers in the sample (97.9% = 75.8% + 22.1%) rated this property as being extremely or very important.

Comfort (Figure 5.49)
This property of a wheelchair was considered extremely important by 68.4% of respondents and very important for 22.1% of them. Almost 10% of the sample rated it as being important.
Figures 5.44 to 5.49

How the carers rated the design of wheelchairs in terms of some characteristics

**Figure 5.44 - Safety (n = 98)**

- Not imp: 0
- Fairly imp: 1
- Imp: 3.1
- Very imp: 9.2
- Ext imp: 86.7

**Figure 5.45 - Robustness (n = 92)**

- Not imp: 0
- Fairly imp: 12
- Imp: 29.3
- Very imp: 58.7
- Ext imp: 80

**Figure 5.46 - Stability (n = 95)**

- Not imp: 1.1
- Fairly imp: 2.1
- Imp: 6.3
- Very imp: 15.8
- Ext imp: 73.7

**Figure 5.47 - Suitability (n = 95)**

- Not imp: 0.6
- Fairly imp: 1.1
- Imp: 3.2
- Very imp: 22.1
- Ext imp: 73.7

**Figure 5.48 - Reliability (n = 95)**

- Not imp: 0
- Fairly imp: 0
- Imp: 2.1
- Very imp: 22.1
- Ext imp: 75.8

**Figure 5.49 - Comfort (n = 95)**

- Not imp: 0
- Fairly imp: 9.5
- Imp: 22.1
- Very imp: 68.4
- Ext imp: 80
**Aesthetic appearance** (Figure 5.50)
This characteristic was rated as being important and very important by a significant number of respondents (42.5% and 27.6%, respectively). The remainder in the sample rated it as being extremely important (9.2%), fairly important (11.5%) or not important (9.2%).

**Adjustability** (Figure 5.51)
Almost 70% of the respondents (34.4%+32.3%) rated adjustability as being extremely or very important. Twenty-two percent considered it as being important.

**Portability due to size** (Figure 5.52)
The large majority of respondents (85.4%=59.4%+36%) rated portability due to size as an extremely or very important characteristic. The characteristic "portability" in the pilot survey included both "portability due to size" and "portability due to weight".

**Portability due to weight** (Figure 5.53)
Almost all respondents (89.6%=67.7%+21.9%) rated this characteristic as extremely or very important.

**Manoeuvrability** (Figure 5.54)
This was considered as being extremely or very important by a little more than 90% (66.3%+24.2%) of carers in the sample.

**Ease of use** (Figure 5.55)
Almost 93% of respondents (62.8%+29.8%) considered this characteristic as extremely important or very important.

**Ease of folding** (Figure 5.56)
The large majority of respondents (81.8%=53.2%+28.7%) rated ease of folding as being extremely or very important.

**Ease of storage** (Figure 5.57)
The majority of respondents (63%=44.6%+18.5%) rated this property as being extremely or very important. In addition, a little over 20% rated it as being important.

**Ease of maintenance** (Figure 5.58)
The majority of respondents (72.8%=43.5%+20.3%) rated ease of maintenance as being extremely or very important. A few more than 20% rated it as important.
Figures 5.50 to 5.55
How the carers rated the design of wheelchairs in terms of some characteristics

Figure 5.50 - Aesthetic appearance (n=87)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>9.2</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>11.5</td>
</tr>
<tr>
<td>Imp</td>
<td>42.5</td>
</tr>
<tr>
<td>Very imp</td>
<td>27.6</td>
</tr>
<tr>
<td>Ext imp</td>
<td>9.2</td>
</tr>
</tbody>
</table>

Figure 5.51 - Adjustability (n=90)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>4.4</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>6.7</td>
</tr>
<tr>
<td>Imp</td>
<td>22.2</td>
</tr>
<tr>
<td>Very imp</td>
<td>32.2</td>
</tr>
<tr>
<td>Ext imp</td>
<td>34.4</td>
</tr>
</tbody>
</table>

Figure 5.52 - Portability due to size (n=96)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>0</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>5.2</td>
</tr>
<tr>
<td>Imp</td>
<td>9.4</td>
</tr>
<tr>
<td>Very imp</td>
<td>26</td>
</tr>
<tr>
<td>Ext imp</td>
<td>59.4</td>
</tr>
</tbody>
</table>

Figure 5.53 - Portability due to weight (n=96)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>1</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>2.1</td>
</tr>
<tr>
<td>Imp</td>
<td>7.3</td>
</tr>
<tr>
<td>Very imp</td>
<td>21.9</td>
</tr>
<tr>
<td>Ext imp</td>
<td>67.7</td>
</tr>
</tbody>
</table>

Figure 5.54 - Manoeuvrability (n=95)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>0</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>0</td>
</tr>
<tr>
<td>Imp</td>
<td>9.5</td>
</tr>
<tr>
<td>Very imp</td>
<td>24.2</td>
</tr>
<tr>
<td>Ext imp</td>
<td>66.3</td>
</tr>
</tbody>
</table>

Figure 5.55 - Ease of use (n=94)

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>0</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>0</td>
</tr>
<tr>
<td>Imp</td>
<td>7.4</td>
</tr>
<tr>
<td>Very imp</td>
<td>29.8</td>
</tr>
<tr>
<td>Ext imp</td>
<td>62.8</td>
</tr>
</tbody>
</table>
Figures 5.56 to 5.61

How the carers rated the design of wheelchairs in terms of some characteristics

**Figure 5.56 - Ease of folding (n=94)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>2.1</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>2.1</td>
</tr>
<tr>
<td>Imp</td>
<td>13.8</td>
</tr>
<tr>
<td>Very imp</td>
<td>28.7</td>
</tr>
<tr>
<td>Ext imp</td>
<td>53.2</td>
</tr>
</tbody>
</table>

**Figure 5.57 - Ease of storage (n=94)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>5.4</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>10.9</td>
</tr>
<tr>
<td>Imp</td>
<td>20.7</td>
</tr>
<tr>
<td>Very imp</td>
<td>18.5</td>
</tr>
<tr>
<td>Ext imp</td>
<td>44.6</td>
</tr>
</tbody>
</table>

**Figure 5.58 - Ease of maintenance (n=92)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>1.1</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>5.4</td>
</tr>
<tr>
<td>Imp</td>
<td>20.7</td>
</tr>
<tr>
<td>Very imp</td>
<td>29.3</td>
</tr>
<tr>
<td>Ext imp</td>
<td>43.5</td>
</tr>
</tbody>
</table>

**Figure 5.59 - Ease of repair (n=91)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>1.1</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>4.4</td>
</tr>
<tr>
<td>Imp</td>
<td>18.7</td>
</tr>
<tr>
<td>Very imp</td>
<td>34.1</td>
</tr>
<tr>
<td>Ext imp</td>
<td>41.8</td>
</tr>
</tbody>
</table>

**Figure 5.60 - Ease of transport in a car (n=95)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>0</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>0</td>
</tr>
<tr>
<td>Imp</td>
<td>5.3</td>
</tr>
<tr>
<td>Very imp</td>
<td>20</td>
</tr>
<tr>
<td>Ext imp</td>
<td>74.7</td>
</tr>
</tbody>
</table>

**Figure 5.61 - Provision of accessories (n=85)**

<table>
<thead>
<tr>
<th>RATING</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not imp</td>
<td>7.1</td>
</tr>
<tr>
<td>Fairly imp</td>
<td>9.4</td>
</tr>
<tr>
<td>Imp</td>
<td>25.9</td>
</tr>
<tr>
<td>Very imp</td>
<td>32.9</td>
</tr>
<tr>
<td>Ext imp</td>
<td>24.7</td>
</tr>
</tbody>
</table>
**Ease of repair (Figure 5.59)**
The majority of respondents (75.8%=41.8%+34.1%) rated ease of repair as being extremely or very important. Almost 19% rated this characteristic as important.

**Ease of transport in a car (Figure 5.60)**
Respondents considered this characteristic almost unanimously (94.7%=74.7%+20%) as being extremely or very important.

**Provision of accessories (Figure 5.61)**
A few more than half of the sample (57.6%=24.7%+32.9%) rated this characteristic as being extremely or very important. Almost 26% of them rated it as being important. Almost 17% of the carers in the sample rated it as being fairly or not important.

Figures 5.62 to 5.64
How the carers rated the design of wheelchairs in terms of some characteristics

![Figure 5.62 - Cost to buy (n=81)](image)

![Figure 5.63 - Cost to maintain (n=81)](image)

![Figure 5.64 - Cost to repair (n=79)](image)
Cost to buy, cost to maintain and cost to repair (Figure 5.62, 5.63 and 5.64)
The majority of respondents considered these three characteristics as being extremely or very important and gave them almost the same rate: cost to buy, 67.9% (48.1%+19.8%); cost to maintain, 66.7% (37%+29.6%) and cost to repair, 70.9% (40.5%+30.4%).

The carers were asked to nominate, in order, the three characteristics which were most important for them from the 21 previously analysed. Almost all respondents answered this question: 96 answered for the first characteristic, 92 for the second and 91 for the third. Two characteristics - cost to maintain and provision of accessories - were not mentioned by any respondent. The answers of the carers in the sample are shown on Figure 5.65. According to this figure, two characteristics were considered as the most important for the respondents (both corresponding to more than 10% of the sample): safety (indicated by 41 of them) and portability due to weight (16). Almost 60% of the answers given by the respondents concentrated on these two characteristics. In terms of the second most important characteristic, the answers concentrated on three characteristics (whether or not they had been previously mentioned as the first most important, and all of them corresponding to more than 10% of the sample): comfort (15), manoeuvrability (12) and portability due to weight (11). The third most mentioned characteristic (whether or not they had been previously mentioned as the first most important, and all of them corresponding to more than 10% of the sample) were: ease of transport in a car (16) and manoeuvrability (10).

As in the survey of wheelchair users, after the carers had indicated the characteristics they judged to be most important, they were asked why they considered those as the most important. Some statements provided by the respondents for each characteristic are shown in Table 5.8 (text of the thesis continues on page 246). Three characteristics were not included by the respondents: ease of maintenance, cost to repair, cost to maintain and provision of accessories.
Figure 5.65
Characteristics of wheelchairs rated as the most important by the carers in the sample

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>First</th>
<th>Second</th>
<th>Third</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portability due to weight</td>
<td></td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Reliability</td>
<td>4</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Suitability</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Ease of transport in a car</td>
<td>6</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>Manoeuvrability</td>
<td></td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Stability</td>
<td>4</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Portability due to size</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robustness</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comfort</td>
<td>6</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Ease of use</td>
<td>4</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Adjustability</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of folding</td>
<td>6</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Aesthetic appearance</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of storage</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of maintenance</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to repair</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to buy</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of repair</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Number of respondents
Table 5.8
Quotes from carers about some characteristics of wheelchairs

<table>
<thead>
<tr>
<th>Safety</th>
</tr>
</thead>
</table>

- Safety is the first rule not only for the person who is disabled but for the carer as well.
- Obviously the prime concern is that the wheelchair is carried safely and in a way that does not lead to further injury.
- I need to know that when I leave the brakes on the chair will not move.
- Because this is the only way a disabled person can get about, it should be the safest and easiest way.
- If my patient is not safe in his chair, I don’t feel safe myself.
- This is in use full time. A slight risk will lead to a high probability of an accident.
- Modern chairs go quite fast and could crash into something.
- I need to feel at ease knowing that when I assist the user he feels comfortable with me pushing him them and feel safe if anything were to happen.
- As the chair user is a child he relies on us to protect him more.
- I know my wife is safe when I’m not around.

<table>
<thead>
<tr>
<th>Portability due to weight</th>
</tr>
</thead>
</table>

- Light weight is essential for outside use.
- Because I have to lift the chair up from the ground and over the boot lip into the boot.
- The weight of the chair makes a great deal of difference to the ease with which a chair can be stowed or pushed up hill.
- I am only 5ft tall and weight is of importance to me.
- Carers are often elderly and frail.
- Although staff at premises (e.g. restaurants) would after be willing to lift my husband up stairs, etc, the chairs’ bulk and weight preclude this.
- Because of my wife’s size I find it very difficult to push her. This prevents us going out as much as we would like.
- The carer should not risk injury lifting the equipment in and out of a car.
- It is very tiring to push someone in a chair. Lighter chair would give user more mobility and independence.
Table 5.8
Quotes from carers about some characteristics of wheelchairs (cont.)

<table>
<thead>
<tr>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Because of daily usage</td>
</tr>
<tr>
<td>• Otherwise the wheelchair is useless.</td>
</tr>
<tr>
<td>• With the chair being in such frequent use it needs to be reliable if it is not to impinge on the user’s freedom.</td>
</tr>
<tr>
<td>• To give confidence to wheelchair user.</td>
</tr>
<tr>
<td>• My partner depends 100% on wheelchair indoors and outdoors.</td>
</tr>
<tr>
<td>• It makes my job much harder without a wheelchair.</td>
</tr>
<tr>
<td>• The pusher needs to know that the user is in a reliable chair.</td>
</tr>
<tr>
<td>• Nothing is more boring than a wheelchair not working properly.</td>
</tr>
<tr>
<td>• Must be reliable and not fall apart at the first kerb it hits.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Must meet needs of user first but not be totally unmanageable for carers.</td>
</tr>
<tr>
<td>• Suitable for the carer in terms of their physical needs.</td>
</tr>
<tr>
<td>• Because there are different levels of disabilities.</td>
</tr>
<tr>
<td>• Far too often a wheelchair is not designed to be adjustable for individual needs.</td>
</tr>
<tr>
<td>• Each chair should be tailored to the user and carer.</td>
</tr>
<tr>
<td>• To maintain my son’s health. He spends a lot of time in the chair and an unsuitable one could prove detrimental to his health.</td>
</tr>
<tr>
<td>• An inappropriate vehicle would be dangerous to the user and could put more work on the carer.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ease of transport in a car</th>
</tr>
</thead>
<tbody>
<tr>
<td>• To be able to fold it and lift it into and out of the car boot.</td>
</tr>
<tr>
<td>• I need to get the chair in and out easily, without twisting, without handling heavy items, without assembling lots of bits and pieces.</td>
</tr>
<tr>
<td>• Need to get the patient to and from easily.</td>
</tr>
<tr>
<td>• So we can go out.</td>
</tr>
<tr>
<td>• So that the disabled person can be as independent as possible and have a better quality of life.</td>
</tr>
<tr>
<td>• Because of carer’s age and health.</td>
</tr>
<tr>
<td>• It is important when loading in bad weather.</td>
</tr>
<tr>
<td>• Ability to transport the chair is vital to our lifestyle.</td>
</tr>
<tr>
<td>• To make it easy to get from A to B.</td>
</tr>
</tbody>
</table>
Table 5.8
Quotes from carers about some characteristics of wheelchairs (cont.)

<table>
<thead>
<tr>
<th>Manoeuvrability</th>
<th>Stability</th>
<th>Portability due to size</th>
<th>Robustness</th>
</tr>
</thead>
<tbody>
<tr>
<td>For long walks, etc it makes pushing and turning harder if manoeuvrability isn't there.</td>
<td>To obviate fear of overturning</td>
<td>We can go out.</td>
<td>If it is not strong enough you will get broken parts which makes the chair unsafe.</td>
</tr>
<tr>
<td>To allow freedom of access and not tax the ability of either the individual or carer to propel the chair.</td>
<td>I don't want the chair tipping when I am manoeuvring because I used it on uneven surfaces - cobbles, gravel, gross, etc.</td>
<td>It is important for storage in a car boot.</td>
<td>Something that may hold someone of great weight has to have the strength to cope with this.</td>
</tr>
<tr>
<td>I push the chair out of doors and have to negotiate kerbs, steps, inclines, doorways, lifts, shops...</td>
<td>To ensure the person being wheeled is safe so as the chair does not turn over.</td>
<td>If the chair is too large and heavy we cannot go out because I can't lift it.</td>
<td>Dealing with breakdowns is time-consuming and their frequency has a bearing on my husband's independence.</td>
</tr>
<tr>
<td>Because I have arthritis and I need it to be easy to handle.</td>
<td>When pushing a wheelchair I am seldom in a good position to prevent the chair from tipping on an uneven surface, which in turn could lead to an injury to the pusher.</td>
<td></td>
<td>A well built, solid chair is easier to control.</td>
</tr>
<tr>
<td>Wheelchairs are heavy, so you have lack of movement and it is also difficult to get up kerbs and in and out of cars.</td>
<td>As my husband is a bilateral amputee, I must be sure he won't tip when I leave the chair.</td>
<td></td>
<td>Because my son loves to go camping and goes over some rough terrain.</td>
</tr>
<tr>
<td>As a manual chair needs an assistant, it has to be made so anyone of any size can manoeuvre it.</td>
<td></td>
<td></td>
<td>Mechanical failure could lead to my daughter being stranded.</td>
</tr>
</tbody>
</table>
Table 5.8
Quotes from carers about some characteristics of wheelchairs (cont.)

<table>
<thead>
<tr>
<th>Comfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Essential to prevent pressure sores.</td>
</tr>
<tr>
<td>• Assistants need comfort when pushing the wheelchair.</td>
</tr>
<tr>
<td>• Why should the user be in any more discomfort?</td>
</tr>
<tr>
<td>• With the frequency of use, comfort must be considered a necessity.</td>
</tr>
<tr>
<td>• If my son is comfortable in his wheelchair, hopefully there is no fear of his skin being broken.</td>
</tr>
<tr>
<td>• Provision of good posture and lack of pressure points, with long term consequences.</td>
</tr>
<tr>
<td>• The user needs to be comfortable and the pusher needs handles at the correct height.</td>
</tr>
<tr>
<td>• My husband is in a great deal of pain if there is a problem with the wheelchair which affects his back.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ease of use</th>
</tr>
</thead>
<tbody>
<tr>
<td>• It should assemble, manoeuvre, fold, store and be easy to maintain for the user.</td>
</tr>
<tr>
<td>• Needs to be able to make my life and my patient's easy.</td>
</tr>
<tr>
<td>• I'm not a young person also I suffer with arthritis, holding on to the wheelchair is a big help.</td>
</tr>
<tr>
<td>• No-one should be condemned to fighting a permanent battle with a poor piece of equipment: repetitive strain can have long term consequences.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adjustability</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Everybody is different in health and body structure, e.g. height, so there needs to be adjustments made.</td>
</tr>
<tr>
<td>• The adjustable add-ons we had made for the chair are fiddly and cause problems for inexperienced carers.</td>
</tr>
<tr>
<td>• If adjustable features were professionally designed and come with the wheelchair as bought, they would be of a higher standard and easier to use.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ease of folding</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Must be easy to fold to fit into the car boot. Size of chair and car boots not taken into account in design calculations.</td>
</tr>
<tr>
<td>• All my joints are arthritic and painful, simple pushing and folding of parts is hard and on some days impossible.</td>
</tr>
<tr>
<td>• As time is important when weather is bad.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aesthetic appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Disability is damaging to self esteem and nice looking equipment is important.</td>
</tr>
<tr>
<td>• I don't like the name &quot;Invacare&quot; for example or chairs that somehow emphasise an invalid quality.</td>
</tr>
<tr>
<td>• My husband is not sick, he just can't walk.</td>
</tr>
</tbody>
</table>
Table 5.8
Quotes from carers about some characteristics of wheelchairs (cont.)

<table>
<thead>
<tr>
<th>Ease of storage</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Because of confined space.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ease of repair</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Do not want chair in the workshop for 2/3 weeks while minor repairs are carried out.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost to buy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• On a limited income it is of great importance.</td>
<td></td>
</tr>
<tr>
<td>• You have to get the best deal to suit your pocket.</td>
<td></td>
</tr>
</tbody>
</table>

In addition to pointing out characteristics which wheelchairs should have, the carers were asked to classify the design of the wheelchairs belonging to the wheelchair user whom they assisted. If the person who the carer assisted had more than one wheelchair, he or she was asked to answer the question in relation to the wheelchair which was used the most. The wheelchairs could be rated in terms of specific characteristics as very good, good, average, poor and very poor. In the same way as with the wheelchair users' survey, results were sorted into three kinds of responses: a) the first category of response was a high number of "goods" and "very goods"; b) the second category comprised a large number of "averages"; and c) the third category included a significant number of responses given as "poor" and "very poor".

Responses are shown in Figure 5.66. It can be seen that the results are similar to those found in Figures 5.34 and 5.35, which shows the rates given by wheelchair users when judging their own wheelchairs. According to Figure 5.66, the majority of carers in the sample judged the design of the wheelchair belonging to the person whom they assisted as "very good" and "good" in terms of safety (76.6%), ease of use (73.6%), stability (72.5%), reliability (72.2%), robustness (71.6%) and suitability (71.4%). As in the survey of wheelchair users, although the carers judged the design of the wheelchair as being "very good" and "good" for some important characteristics, the percentage who attributed this level of satisfaction never exceeded 77%, which is less than the high level, say 90%, which might be hoped for. Again, the best results were, typically, between 60 and 77%. There were a worryingly high number of responses with characteristics rated as being "poor" and "very poor".

Figure 5.66 also shows that about 15% of the sample rated the design of the wheelchair belonging to the user whom they helped as being "poor" or "very poor" for about half of the characteristics.
The five characteristics which reached the highest level of "poor" and "very poor" ratings were: cost to buy (31.3%), provision of accessories (25.8%), portability due to weight (23.7%), adjustability (21.6%) and ease of transport in a car (19.4%). The five which obtained the highest level of "average" ratings were: cost to repair (46.9%), cost to maintain (44.4%), aesthetic appearance (41.4%), ease of maintenance (40%) and provision of accessories (38.5%).

The respondents were asked if they thought that, in general, the N.H.S. and privately acquired wheelchairs were designed taking into account the range of needs of carers and why they thought this. Their answers are shown in Figure 5.67 and Table 5.9.

In terms of the wheelchairs issued by the N.H.S, Figure 5.67 shows that more than half of the sample were of the view that the wheelchairs belonging to the users whom they assisted were not designed taking into consideration the needs of carers. Almost 20% of the remainder of the sample answered affirmatively to this question and 23% said that they did not know.

As far as the privately acquired wheelchairs are concerned, the figures are different from those previously described. Forty-three percent of respondents answered that they did not know whether or not the wheelchairs issued in this way were designed taking the needs of carers into account. A few more than 37% answered positively and almost 20% answered negatively.

Figure 5.67
Carers' view on whether or not wheelchairs in the N.H.S. and private sectors are designed taking into account the needs of disabled people (N.H.S., n=87; Private market, n=86)
Some of respondents who answered 'do not know' stated, for example, that the wheelchair belonging to the user whom they cared for was issued by only one of these markets, they did not know about the design of the wheelchairs provided by the other.

Table 5.9 shows the carers' explanation of why they believed or did not believe that the wheelchairs in either the N.H.S. or private market place were designed taking into consideration the needs of carers (Table 5.9 is on pages 250 to 254, the text of the thesis continues on page 254). As in the survey of wheelchair users, the answers are organised into categories of responses in terms of: cost, quality of design and standardisation, suitability and carer needs, and availability.

Only one respondent in the sample (n=94) answered that he or she had ever been involved in wheelchair design with a company that mass produced wheelchairs for a large market. The respondent did not explain what his or her contribution was.

The majority of carers in the sample (66.3%, n=95) answered negatively when asked if they would like to be involved, or continue to be involved, in wheelchair design with companies that mass produced wheelchairs for a large market. The remainder, who answered positively, were asked what kind of contribution to wheelchair design they thought they could provide. Most of them said "to contribute from personal experience and the point-of-view of carers". Others provided the following answers:

- Give the views of the carer, what they need in order to help the user. Helping in the improvement of the wheelchair, including appearance.
- Give the user's parent views. Chairs are not designed for young children's needs. No facilities for sun canopies, rain hoods or space to cover child with blankets.
- I have repaired many chairs and I can recognise design faults both from a user's and carer's point of view.
- Take part in practical testing followed by suggestions to improve user and carer comfort in use.
- Give advice on design faults and daily usability for carer and user.
- Give advice about comfort, weight, manoeuvrability, transport, safety and storage.
- Give advice about compactness, anchor points, proper back support, stabiliser wheels that don't leave drive wheels spinning in mid air when climbing or dismounting a kerb and better handle height when chair requires lifting from behind.
- As a person who pushes a wheelchair on a regular basis, I could explain what features I would like to see incorporated.
Table 5.9
Carers’ explanation of why they think wheelchairs in the N.H.S. and private market place were or were not designed taking into account the needs of disabled people

<table>
<thead>
<tr>
<th>In terms of costs:</th>
<th>Wheelchairs in the N.H.S. market place</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Yes, I think the N.H.S has made a genuine effort to meet the needs of patients but is limited by costs in the choice of materials.</td>
<td>• Yes, you have greater choice but they are prohibitively expensive.</td>
<td></td>
</tr>
<tr>
<td>• No, made at a low cost and no thought of the weight the carer has to lift or push.</td>
<td>• Yes, they are better but are very expensive.</td>
<td></td>
</tr>
<tr>
<td>• No, done as cheaply as can be for the N.H.S. budget, not for the needs of user or taking account of carers.</td>
<td>Ridiculous that it depends on persons financial position as to whether they have a good wheelchair or not.</td>
<td></td>
</tr>
<tr>
<td>• No, the wheelchairs in the N.H.S. market seem to be designed to the lowest price possible, rather than suitability to the users.</td>
<td>• No, because they cost too much.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In terms of quality of design and standardisation:</th>
<th>Wheelchairs in the N.H.S. market place</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Yes, basically for getting up and down kerbs.</td>
<td>• Yes, because private purchasers are offered a far wider choice of both design and materials.</td>
<td></td>
</tr>
<tr>
<td>• Yes, they are stronger than I expected and fairly easy to push, but I wish the handles were different.</td>
<td>• Yes, they seem to be lighter and more modern than the N.H.S., but beggars cannot be choosers.</td>
<td></td>
</tr>
<tr>
<td>• Yes, the technology is very up to date</td>
<td>• Yes, they are all made from lightweight materials making transporting easier for the carer.</td>
<td></td>
</tr>
<tr>
<td>• No, they are heavy and do not break down for transport purposes into small enough or light enough sections.</td>
<td>• Yes, they are easy to push, to open/close, lighter to transport and easier to lift.</td>
<td></td>
</tr>
<tr>
<td>• No, most manual wheelchairs are too heavy to transport easily. I believe that a majority of carers have health problems themselves.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5.9
Carers' explanation of why they think wheelchairs in the N.H.S. and private market place were or were not designed taking into account the needs of disabled people (cont.)

<table>
<thead>
<tr>
<th>In terms of quality of design and standardisation (cont.):</th>
<th>Wheelchairs in the N.H.S. marketplace</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>• No, they are heavy, cumbersome, with non-removable handles, cheap stitching so they require frequent repair.</td>
<td></td>
<td>Yes, because they are lighter and more stable. There is also more manoeuvrability with them.</td>
</tr>
<tr>
<td>• No, when pushing outdoors it is hard to keep them straight, they always want to go left.</td>
<td></td>
<td>Yes, much more flexibility in private market. The chairs are generally lighter, dismantle easier, adjustable and are padded for greater comfort.</td>
</tr>
<tr>
<td>• No, handles are not adjustable and have an awkward angle, wheelchairs are also cumbersome, hard to fold, heavy to lift and pull to the left.</td>
<td></td>
<td>Yes, yes, you get what you pay for. Design can be changed if you can pay.</td>
</tr>
<tr>
<td>• No, they don’t provide adjustable handles: they are too low.</td>
<td></td>
<td>Yes, they can easily be adapted to the user’s and carer’s needs.</td>
</tr>
<tr>
<td>• No, because they don’t take into account of the height of the pusher.</td>
<td></td>
<td>Yes, they are lighter, much easier to push, much easier for the user to handle on their own and therefore give greater independence.</td>
</tr>
<tr>
<td>• No, because they are not easy to push over high kerbs and put on public transport.</td>
<td></td>
<td>Yes, the design in this area is better with wider use of light-weight materials.</td>
</tr>
<tr>
<td>• No, carer’s hands are not free for anything else except pushing. I have two young children and shopping doors etc to cope with too.</td>
<td></td>
<td>Yes, because the technology is very up to date.</td>
</tr>
<tr>
<td>• No, they don’t have height adjustable handles, are cumbersome and heavy to load and unload to car boot.</td>
<td></td>
<td>No, they are too big for modern homes, have a lack of standardisation on anchor points for adapted transport and chair back design is awfully inadequate for all day use.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No, they are of poor quality plus money making objectives.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No, try and take one apart in a hurry!</td>
</tr>
</tbody>
</table>
Table 5.9
Carers’ explanation of why they think wheelchairs in the N.H.S. and private market place were or were not designed taking into account the needs of disabled people (cont.)

<table>
<thead>
<tr>
<th>In terms of quality of design and standardisation (cont.):</th>
<th>Wheelchairs in the N.H.S. market place</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>• No, not all chairs are designed to suit the height of the carer and sometimes the weight does not help, i.e. when lifting into a boot of a car.</td>
<td>• No, they are awkward to fit into a modern car. Heavy, they require a lift, causing difficulties with manual handling and possible health and safety risk.</td>
<td></td>
</tr>
<tr>
<td>• No, too much standardisation not made to fit individual needs.</td>
<td>• No, because I have seen very few for the carer at recent exhibitions. Unless the user is unable to make any decision for themselves, political correctness of dealing with user precludes carer.</td>
<td></td>
</tr>
<tr>
<td>• No, the chairs often go to one side when you are pushing it which is painful for your arms, back and neck.</td>
<td>• No, because powered wheelchairs are bulky, not manoeuvrable, have bits of metal sticking out of them. Accessories are not usually designed well for ease of access to the user. Handles come off too easily. Wheelchairs disassemble in the hands of well intentioned members of the public trying to help - have observed this often.</td>
<td></td>
</tr>
<tr>
<td>• No, don’t fold away small enough and are not light.</td>
<td>• No, private market place merely seeks to make a large profit by pretending to design more appropriate wheelchairs and over charging for that privilege.</td>
<td></td>
</tr>
<tr>
<td>• No, my husband chair is blow suck. It has two batteries, he is 6' 2&quot; approximately and weights about 20 stones without chair. If batteries fail judge for yourselves. I have arthritis and other problems so I need something light and easy to manoeuvre.</td>
<td>• No, although this is a subject to my limited knowledge, my employer’s current chair is primarily designed for basketball and as such is more designed to needs of the user than the carer.</td>
<td></td>
</tr>
<tr>
<td>• No, the wheelchair my mum has is very unsuitable for me. As I am tall, I get a lot of backache using the wheelchair due to me bending over to reach the handles. Also it is very heavy. I’m only 16 but think that would apply to most people.</td>
<td>• No, the wheels at the front of wheelchair need to be wider, to save the wheelchair user being jarred, when outside, with all the holes and cracks in pavements and roads.</td>
<td></td>
</tr>
</tbody>
</table>
### In terms of quality of design and standardisation (cont.):

<table>
<thead>
<tr>
<th>Wheelchairs in the N.H.S. market place</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>No, they are of poor quality, no individuality: rubbish!</td>
<td>-</td>
</tr>
<tr>
<td>No, I was not present at the assessment. the height of handles was wrong.</td>
<td>-</td>
</tr>
</tbody>
</table>

### In terms of suitability and carers' needs:

<table>
<thead>
<tr>
<th>Wheelchairs in the N.H.S. market place</th>
<th>Wheelchairs in the private market place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, wheelchairs are designed to suit various disabilities.</td>
<td>Yes, wheelchairs are designed to suit various disabilities.</td>
</tr>
<tr>
<td>Yes, much more attention is paid to individual disabilities.</td>
<td>Yes, because height, physical condition, etc. are taken into account when dealing with the user.</td>
</tr>
<tr>
<td>Yes, more consideration is being given. In some parts of the country things have improved a little over many years.</td>
<td>Yes, because private chairs are more suitable to the users' needs, therefore making it easier for the carer.</td>
</tr>
<tr>
<td>No, disabled people and their carers are not consulted.</td>
<td>Yes, when the wheelchair was purchased, great care was taken by the supplier to provide the correct equipment.</td>
</tr>
<tr>
<td>No, I wasn't consulted when they interviewed my wife.</td>
<td>No, simply because I have not yet come across a really suitable chair for our needs.</td>
</tr>
<tr>
<td>No, don't take into account carers with difficulties.</td>
<td>No, they do not seem to consider the needs of those who use the chair, particularly elderly carers.</td>
</tr>
<tr>
<td>No, because age and health are not taken into account.</td>
<td>No, because N.H.S. chairs are prescribed for patients' needs, so private chairs could be just another sale.</td>
</tr>
<tr>
<td>No, some do have features taking carers into account but there are still those whose features make them difficult for carers and sometimes users.</td>
<td>No, mainly concerned with ability to suit a wide range of users, the adaptation for special needs made chair less ideal for carers. The more specialised adaptations for the user, the more problematic the chair is for the carer.</td>
</tr>
</tbody>
</table>
Table 5.9
Carers' explanation of why they think wheelchairs in the N.H.S. and private market place were or were not designed taking into account the needs of disabled people (cont.)

<table>
<thead>
<tr>
<th>In terms of suitability of and carers needs (cont.):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheelchairs in the N.H.S. market place</td>
<td>Wheelchairs in the private market place</td>
</tr>
<tr>
<td>• No, some carers are frail themselves and cannot</td>
<td>-</td>
</tr>
<tr>
<td>lift, assemble or manoeuvre N.H.S. wheelchairs.</td>
<td></td>
</tr>
<tr>
<td>I have injured my lower back lifting an N.H.S.</td>
<td></td>
</tr>
<tr>
<td>chair when I was 26 years old.</td>
<td></td>
</tr>
<tr>
<td>• Wheelchairs in the N.H.S. market place</td>
<td>Wheelchairs in the private market place</td>
</tr>
<tr>
<td>• No, the range of models available is limited. The</td>
<td>• Yes, there is more choice if you go private, so</td>
</tr>
<tr>
<td>primary consideration is cost, rather than need.</td>
<td>we can choose a chair that suits all our needs.</td>
</tr>
<tr>
<td>• No, because salesmen are only interested in selling</td>
<td>• No, because salesmen are only interested in</td>
</tr>
<tr>
<td>the chair to an unfortunate person.</td>
<td>selling the chair to an unfortunate person.</td>
</tr>
<tr>
<td>After that no one wants to know.</td>
<td>After that no one wants to know.</td>
</tr>
</tbody>
</table>

• I have access to considerable expertise in materials joining technology.
• As my wife uses a wheelchair and I have to push/store/place in car etc, my experience would be useful.
• I can provide ideas on folding requirements and general safety.
• Naturally the contribution of potential users would be more important, but in a sense I am a user myself and from the point of view of the chair I currently use my needs could be considered more. For example, the positioning of the handles at the back is too low.

Finally, the carers in the sample were asked if there was anything that they could suggest to improve the design of wheelchairs in the market place. Their answers are shown in Table 5.10 (the text of the thesis continues on page 257). As in the survey of wheelchair users, the answers were grouped into the subjects to which they were related. The number of responses making the same suggestion is in brackets.
Table 5.10
Carer's suggestion for improving the design of wheelchairs

<table>
<thead>
<tr>
<th>Design and the design process</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Consult the carers and users in the design process (11).</td>
<td></td>
</tr>
<tr>
<td>Use more lightweight and softer materials in the wheelchair design (6).</td>
<td></td>
</tr>
<tr>
<td>Make them more colourful and with better appearance (3).</td>
<td></td>
</tr>
<tr>
<td>Produce wheelchairs which are more manoeuvrable (3).</td>
<td></td>
</tr>
<tr>
<td>Taking into account carers' height, health and personal capabilities (2).</td>
<td></td>
</tr>
<tr>
<td>Improve the stability of the wheelchairs (2).</td>
<td></td>
</tr>
<tr>
<td>Make them stronger (2).</td>
<td></td>
</tr>
</tbody>
</table>

Design and the design process (cont.)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Make the design less bulky and more socially acceptable in public (1).</td>
<td></td>
</tr>
<tr>
<td>Produce wheelchairs which are easy to use for larger persons (1).</td>
<td></td>
</tr>
<tr>
<td>Make designers live in the wheelchairs for one week (1).</td>
<td></td>
</tr>
<tr>
<td>Improve the simplicity of operation (1)</td>
<td></td>
</tr>
<tr>
<td>Make them easy to fold, handle and lift (1).</td>
<td></td>
</tr>
<tr>
<td>Test the wheelchair with elderly users (1).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weight, portability and foldability</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Make chairs lighter weight (21)</td>
<td></td>
</tr>
<tr>
<td>Produce chairs which are easier for folding (4)</td>
<td></td>
</tr>
<tr>
<td>Provide chairs easier to dismantle (3)</td>
<td></td>
</tr>
<tr>
<td>Make any joints or clips for the purpose of folding the chair more secure when the chair is in use (1).</td>
<td></td>
</tr>
</tbody>
</table>

Frame and support

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce sharp parts (4).</td>
<td></td>
</tr>
<tr>
<td>Improve suspension (2).</td>
<td></td>
</tr>
<tr>
<td>Produce an independent suspension on medium sized electric chairs - not just on large ones (1).</td>
<td></td>
</tr>
</tbody>
</table>

Wheels, tyres and castors

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide wider wheels for the front of the wheelchair as they go in the cracks and holes in pavements and roads (2)</td>
<td></td>
</tr>
<tr>
<td>Make removing and replacing wheels easier (2).</td>
<td></td>
</tr>
<tr>
<td>Enable kerb to be climbed smoothly (1).</td>
<td></td>
</tr>
<tr>
<td>Produce puncture proof tyres (1).</td>
<td></td>
</tr>
<tr>
<td>Provide front wheels interchangeable with castors for pushing outdoors (1).</td>
<td></td>
</tr>
<tr>
<td>Front castors that don't stick in uneven surfaces (1).</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.10
Carer's suggestion for improving the design of wheelchairs (cont.)

<table>
<thead>
<tr>
<th>Pushing rims and handles</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Produce wheelchairs with adjustable handles (10)</td>
<td></td>
</tr>
<tr>
<td>• Handles could be a better designed, more comfortable to hold and push (5).</td>
<td></td>
</tr>
<tr>
<td>• Get rigid pushing handles (1).</td>
<td></td>
</tr>
<tr>
<td>• The handles and grips should always stay in place (1).</td>
<td></td>
</tr>
<tr>
<td>• Produce a pram-type bar handle (1).</td>
<td></td>
</tr>
<tr>
<td><strong>Brakes</strong></td>
<td></td>
</tr>
<tr>
<td>• Produce a good braking system (1).</td>
<td></td>
</tr>
<tr>
<td>• Rethink brake design (1).</td>
<td></td>
</tr>
<tr>
<td>• Present brakes frequently lose holding power (1).</td>
<td></td>
</tr>
<tr>
<td>• Provide carer-operated brakes (1).</td>
<td></td>
</tr>
<tr>
<td>• Put brakes on push handles as well as on wheels (1).</td>
<td></td>
</tr>
<tr>
<td><strong>Canvas and upholstery</strong></td>
<td></td>
</tr>
<tr>
<td>• Design canvas able to assist in transferring (1).</td>
<td></td>
</tr>
<tr>
<td>• Design of pattern in canvas should be aware of possible soiling and the difficulty of cleaning if the pattern is narrow and/or deep (1).</td>
<td></td>
</tr>
<tr>
<td>• Improve the quality of the pads because wear occurs to arm rests and this fades the colour and makes the chair look scruffy (1).</td>
<td></td>
</tr>
<tr>
<td><strong>Battery and power system</strong></td>
<td></td>
</tr>
<tr>
<td>• Improve battery technology to design lighter batteries (1).</td>
<td></td>
</tr>
<tr>
<td>• Place batteries so that they do not lift front of chair when going up ramps (1).</td>
<td></td>
</tr>
<tr>
<td>• Provide easier conversion from electrical to manual control (1).</td>
<td></td>
</tr>
<tr>
<td>• Make the battery charger connection easier (1).</td>
<td></td>
</tr>
<tr>
<td>• Produce removable battery cases (1).</td>
<td></td>
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<tr>
<td>• Produce more reliable electrical systems (1).</td>
<td></td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
</tr>
<tr>
<td>• Good support (straps or similar) to enable shopping bags to be hung on back of chair or handlebars (3)</td>
<td></td>
</tr>
<tr>
<td>• Produce protection for the carer's feet (1).</td>
<td></td>
</tr>
<tr>
<td>• Produce wheelchairs which transmit less vibration to carer's arms (1).</td>
<td></td>
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<tr>
<td>• Provide chairs that don't need so many repairs (1).</td>
<td></td>
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<tr>
<td>• Provide more adjustment (1).</td>
<td></td>
</tr>
<tr>
<td>• Produce some kind of help (gears?) for uphill pushing (1).</td>
<td></td>
</tr>
<tr>
<td>• Produce a safe method of lifting chair complete with occupant when necessary (1).</td>
<td></td>
</tr>
<tr>
<td>• A bell to warn someone to move out the way (1).</td>
<td></td>
</tr>
<tr>
<td>• Provide a step on the back of electric chair and buggies for the carer to ride on (1).</td>
<td></td>
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</tbody>
</table>
Chapter 5: Wheelchair Use

They fell into categories of responses related to:

- Wheels, tyres and castors
- Pushing rims and handles
- Brakes
- Canvas and upholstery
- Battery and power system
- Others.

As in the survey of wheelchair users, some suggestions made by carers to improve the design of wheelchairs are already found in many wheelchairs available in the market place. This may means that the carers had not enough information about the range of equipment currently available.

5.3.3 Major features of data, comments and lessons learned

A number of lessons have been learnt from the survey of carers. It is important to draw attention to the fact that although the survey of carers was somewhat limited in terms of number of respondents, as with the previous surveys, a number of carers mentioned concerns which need to be taken into account by those involved in wheelchair design, prescription and supply.

With regard to the number of questionnaires, a remarkable rate of 100% of the wheelchair users who answered that they had a carer in their survey, delivered the questionnaire to their carers and all of the latter replied.

Findings provided by the carers in the sample cast an interesting light on design requirements for the production of wheelchairs on a large scale. According to these findings, the majority of respondents:

- were over 35 years old and almost one quarter of them were over 65 years old
- had the relationship of spouse with the wheelchair user whom they assisted
- assisted users in using the wheelchair every day
- rated their own health at the time they answered the questionnaire as "average", "poor" or "very poor"
- suffered from pain in the regions of lower back, buttocks, mid back and right shoulder as a consequence of assisting the user with the wheelchair
• considered safety and portability due to weight as the most important design characteristics of wheelchairs
• judged the design of the wheelchairs belonging to the wheelchair user who they assisted as being "very good" or "good" in terms of safety, ease of use, stability, reliability, robustness and suitability although this level of satisfaction was not achieved as consistently as might be hoped for
• judged the design of the wheelchairs belonging to the wheelchair user whom they assisted as being "average", "poor" or "very poor" in terms of cost to buy, cost to repair, provision of accessories, cost to maintain and aesthetic appearance
• had the view that the wheelchairs issued by the N.H.S. were not designed to take into consideration the needs of disabled people and their carers
• had never been involved in wheelchair design with a company that mass produced wheelchairs for a large market

In addition, half of the sample considered that going up/down steps, stairs, kerbs and hills were the most difficult outdoor tasks they performed.

The findings described above provide an indication of the several demands that a wheelchair needs to meet in terms of fulfilling a carer's requirements. A user-centred designed wheelchair needs to focus not only on user's needs but also on the carer's requirements. The next paragraphs will comment on the findings mentioned above and others from the survey of personal assistants.

As expected, there were a large number of responses by carers which were similar to those given by the wheelchair users. These responses will be discussed below.

Almost half of the sample were over 55 years old and rated their health as "average", "poor" or "very poor". In a survey of personal assistants (n=80) in three District Wheelchair Services, carried out by Smith, McCreadle and Unsworth (1995), it was found that the majority of respondents were over 50 years old. These results confirm that many carers are elderly and frail, and require wheelchairs that should be light to lift and easy to propel. Also, the relationship of the carer to the wheelchair user was examined and, similarly to the previously mentioned survey, it was found to be the spouse.

Carers in the sample stated that they assisted the user with the wheelchair on a daily basis and for the whole day. Assisting the user with the wheelchair, they felt pain mainly in the regions of lower back, buttocks, mid back and right shoulder. This can represent excessive effort in that region of the spine and is probably caused by the excessive load transmitted to the carer's
back or resulting from the forward curvature of the spine due to the inadequate height of the wheelchair push handles.

Table 5.6 showed that the most difficult activities performed by carers were going up/down steps, stairs, kerbs and hills; getting the wheelchair into and out of a car; pushing on uneven surfaces, difficult pavements and rough terrain; getting/lifting the user into and out of the wheelchair; manoeuvring with the user through doorways; and manoeuvring in tight spaces. It can be observed that most of these very demanding activities are related to wheelchair weight which can be minimised with the use of appropriate materials in the manufacture process.

A few more than half of the carers in the sample answered that they attended the assessment with the wheelchair user. Although about 70% of carers answered that they felt that their needs were taken into consideration during the process by which the wheelchair belonging to the wheelchair user whom they assisted was prescribed, almost half of them were able to identify weaknesses in this process. Only some of those who identified weaknesses could clearly identify them. The identified weaknesses included "provision of wheelchair with poor design" and "prescription did not take into account the comfort of the carer". This result is similar to that found in the survey of wheelchair users concerning the same issue: the majority of wheelchair users answered that they felt that their needs and abilities were taken into consideration during the process of assessment and prescription of their wheelchairs and almost two-thirds of them mentioned some weaknesses in the process.

The carers were asked to rate the level of importance of 21 characteristics of wheelchairs. Similarly to the wheelchair users in the previous survey, the carers rated almost all characteristics as being "extremely important" or "very important". Although this result seemed not to be very useful, it clearly indicates the feeling of respondents that the design of wheelchair needs to take all of those characteristics into account. When the carers were asked which characteristics were more important for them, they made a distinction pointing out safety and portability due to weight as the most important. They also considered comfort and manoeuvrability, and ease of transport in a car, as respectively, the second and third more important characteristics a wheelchair should have. They provided a number of very interesting quotes to justify their answers (Table 5.8) which clearly represent valuable design requirements such as:

- I need to know that when I leave the brakes on the chair will not move (safety).
- Because I have to lift the chair up from the ground and over the boot lip into the boot (portability due to weight).
- Carers are often elderly and frail (portability due to weight).
Chapter 5: Wheelchair Use

- Must be reliable and not fall apart at the first kerb it hits (reliability).
- Each chair should be tailored to the user and carer (suitability).
- To be able to fold it and lift it into and out of the car boot (ease of transport in a car).
- I need to be able to turn tight corners without lifting the chair (manoeuvrability).
- The user needs to be comfortable and the pusher needs handles at the correct height (comfort).
- Disability is damaging to self esteem and nice looking equipment is important (aesthetic appearance).

It is important to observe that in a number of quotations provided by the carers the comments seem to be more the voice of the users than the carers. For instance, when they stated that comfort is an important characteristic that a wheelchair should have, the carers are speaking more on behalf of the users than themselves.

The carers were asked to rate the design of the wheelchairs belonging to the wheelchair user whom they assisted in the light of the characteristics to which they had previously attributed levels of importance. The five characteristics which reached the highest level for carers (being judged as "very good" or "good") were safety, ease of use, stability, reliability, robustness and suitability. Comparing these characteristics with those listed by the carers when they were asked about the main characteristics that wheelchairs should have (safety, portability due to weight, comfort, manoeuvrability and ease of transport in a car), it can be seen that only one characteristic, safety, was common to the two lists. In fact, portability due to weight, the characteristic pointed out by the carers as the second most important characteristic a wheelchair should have, was judged as the third characteristic which reached the highest level of "poor" and "very poor" when respondents rated the design of the wheelchair belonging to the users whom they assisted.

Comparing the five characteristics pointed out by the carers as the most important (safety, portability due to weight, comfort, manoeuvrability and ease of transport in a car) with those indicated by the wheelchair users (safety, comfort, reliability, suitability and portability due to weight) it can be seen that they are very similar. The wheelchair characteristics themselves and the order of importance pointed out by carers and wheelchair users certainly reflect the specific needs of each population and their requirements in terms of design of the product.

The number of carers who rated the design of the wheelchair belonging to the users whom they assisted in terms of particular characteristics as being "average" and "poor and very poor" was unfortunately high. Thirteen, out of the 21 characteristics, have received these
ratings by at least 43% of respondents. If the number of characteristics rated as "average" are added to those rated as "poor" and "very poor" the final figure is somewhat worrying. More than half of the sample of carers had the impression that the wheelchairs supplied by the N.H.S. to the users whom they assisted, were not designed taking into consideration the needs of carers. In terms of the privately acquired wheelchairs, the sample was divided between those who did not know whether or not the wheelchairs issued in this way were designed taking the needs of carers into account and those who affirmed that they did. The respondents who answered negatively corresponded to almost 20% of the sample. Respondents justified their views saying for instance that:

a) Wheelchairs in the N.H.S market place were or were not designed taking into account the needs of disabled people because:

In terms of costs:
- I think the N.H.S has made a genuine effort to meet the needs of patients but is limited by costs in the choice of materials.
- They are done as cheaply as can be for the N.H.S. budget, not for the needs of user or taking account of carers.

In terms of quality of design and standardisation:
- They are heavy, cumbersome, with non removable handles, cheap stitching so they require frequent repair.
- They don't provide adjustable handles: they are too low.

In terms of suitability and carers needs:
- More consideration is being given. In some parts of the country things have improved a little over many years.
- Disabled people and their carers are not consulted.

In terms of availability:
- The range of models available is limited. The primary consideration is cost, rather than need.

b) Wheelchairs in the private market place were or were not designed taking into account the needs of disabled people because:

In terms of costs:
- You have greater choice but they are prohibitively expensive.

In terms of quality of design and standardisation:
- They are lighter and more stable. There is also more manoeuvrability with them.
- You get what you pay for. Design can be changed if you can pay.
In terms of suitability and carers needs:
- Private chairs are more suitable to the users needs, therefore making it easier for the carer.
- Private chairs could be just another sale.

In terms of availability:
- There is more choice if you go private, so we can choose a chair that suits all our needs.

Broadly speaking, contrary to the results from the survey of wheelchair users, it can not be concluded that the carers expressed a high level of satisfaction with the wheelchairs issued by the private market. However, the high level of dissatisfaction with the N.H.S.-supplied wheelchairs was found to be similar to that expressed by the wheelchair users in their survey.

Only one respondent in the sample answered that he or she had ever been involved in wheelchair design with a company that mass produced wheelchairs for a large market. Although a number of carers stressed the need to involve them in wheelchair design, the majority of them answered negatively when asked if they would like to be involved in wheelchair design with companies that mass produced wheelchairs for a large market. The number of those who would like to be involved (about 35%) was smaller than the percentage of wheelchair users who said that would like to be involved in the wheelchair design (almost half of the sample in the survey of wheelchair users). The number of users and carers who answered affirmatively to this question might have been greater if a considerable number of them were not elderly and in poor health. Most of the carers said that they would be able to "contribute from personal experience and the point-of-view of carers" when they were asked what kind of contribution to wheelchair design they thought they could provide.

Finally, it is important to mention that the surveys of wheelchair users and their carers have revealed a number of complaints, wishes and requirements that undoubtedly will contribute towards successful wheelchair design. The respondents' answers and a number of weaknesses identified clearly point to the need to involve both the users and their carers in the process of wheelchair design and prescription. The information from both groups will provide feedback to designers on how they can improve the product in order to meet the needs of the wheelchair user and carer. A user-centred method for the design of wheelchairs, incorporating the user and carer in several phases of the design process, will be described in the next chapter.
Part 3:

A DESIGN METHOD FOR WHEELCHAIR PRODUCTION

- A user-centred method for wheelchair design
- Investigating the suitability of the proposed methodology
Chapter 6: A user-centred method for wheelchair design

6.1 General consideration

The previous chapters have revealed some important findings that indicate the need for a user-centred method for wheelchair design. It was mainly found that there were some important discrepancies between what designers said, indicated by the design of current wheelchairs available through both the N.H.S. and private market places, and what therapists, rehabilitation engineers, users and carers said, indicated by their verbalisation on a series of deficiencies found in the wheelchairs in both market places.

Thus, it is important to bring together the major features of the results of the field studies carried out with the stakeholders involved in the processes of wheelchair design, supply, prescription and use, in an attempt to highlight the deficiencies to be overcome by the user-centred method. The features described below are only those which may provide some kind of contribution to the production of the method for wheelchair design on a mass-production scale.

Major features of the results of the survey of designers

- Almost all the designers who participated in the survey carried out the design process based on their assumptions about users' expectations. The majority of the wheelchair design processes found in the sample can be considered traditional. Furthermore, by not using systematic methods, predictions of the product's usage and performance may not match users' expectations.

- The survey has revealed that several phases of the design methods carried out by the respondents vary significantly from one company to another: some are systematic, some not. The vast majority of design practitioners in the survey do not have an appropriate background involving industrial design qualifications.

- Although respondents regard ergonomics as important in contributing to wheelchair design, its truly effective use in wheelchair development process has yet to happen.
Two broad types of error were identified in the analysis of the design process: "errors of omission" and "errors of commission".

Generally speaking, the main errors of omission were a) lack of a systematic approach in the design process and b) not considering the users' requirements in the various design phases. Errors of omission were also identified when small companies that took care of very severely disabled people did not try to overcome communication problems by involving other professionals in the health area.

Within the topic of design specifications some companies failed to carry out part or whole phases of the design specification - such as identifying users' needs, evaluating competitive products, establishing user profiles, defining product performance requirements and determining design constraints.

It was found that, unfortunately, anthropometric data available in the literature to define the body sizes and shapes of disabled people is almost non-existent. Designers are destined to fail even if they are actively searching for this information. This is one of the reasons given by the respondents for the low use of information from the ergonomics literature.

The main error of commission identified in the analysis was the fact that managers, technical personnel and designers made decisions without any involvement of users.

Consulting only technical personnel on behalf of users with slightly or severely limited communication abilities may be considered an error of commission in the design process of small companies. The ideal process would involve the designer, technical personnel and health professional to overcome communication problems. Of course there may be some situations in which this kind of approach would be difficult to adopt.

Very few manufacturers in the survey were involved in the process of developing and producing entirely new wheelchairs. Broadly speaking, most of the manufacturers preferred to redesign existing wheelchairs rather than to design new products.

All the respondents stressed the importance of costs in the design process.

**Major features of the results of the survey of therapists**

- Most of the therapists in the sample thought that ergonomics is important in the design of wheelchairs in helping users: a) to achieve a high level of functional efficiency, conserving energy and minimising effort, b) to ensure that the characteristics of the wheelchair meet individual needs and lifestyle and c) to improve posture, movement and comfort for both users and carers.

- The majority of the respondents identified weaknesses in the process by which clients are assessed and wheelchair prescribed such as: budgetary constraints do not permit clients to be given what they ideally require, or limit the range of wheelchairs available for prescription; limitation of equipment provided by the statutory service; the user's
condition may change during a long waiting time between prescription and delivery; standard wheelchair do not fit client's needs; carers are not considered in the process; the more sophisticated systems are out of the price range of the majority of users; and poor design of wheelchairs causes rejection by the users.

- They stated that the weaknesses in the process by which clients were assessed and wheelchairs prescribed had some implications for the design of wheelchairs such as the lack of adaptability, interchangeability and adjustability in a number of wheelchairs available.
- A few more than half of the therapists in the sample said that they did not formally collect the views of the users about the wheelchairs which had been prescribed for them when they have been delivered.
- Amongst those respondents who had collected the views of users about the wheelchairs which had been prescribed, the vast majority of them stated that these views were fed back to designers and manufacturers, for instance difficulty the users had in use of headrest, the need to improve the armrest design, the lack of adjustability of various components.
- The majority of therapists in the sample said that they had, at least once, been in contact with manufacturers about problems connected with wheelchairs. Two-thirds of them answered that they were either unsure or certain that the manufacturers did not take notice of what they said or that they had, as a consequence, carried out any modification in the wheelchair.
- The majority of them said that although they had never been involved in wheelchair design with a company that mass produced wheelchairs for a large market, they would like to be involved. They said that they could provide contributions such as: reporting experience of clients needs in their everyday use, home and workplace; providing feedback from users comments and problems; specifying clinical needs such as activity analysis, functional abilities, posture, seating function; and commenting on technical issues and design features.
- Almost one-third of the respondents thought that, in general, the wheelchairs actually in the market place were not designed to take the range of needs of disabled people into account. They argued that the wheelchairs available are: expensive, heavy and bulky, old-fashioned and unattractive, dimensional incompatible, not user-friendly, do not use the technology currently available, and have limited features, variety and flexibility.
- Generally speaking, the majority of therapist viewed manual wheelchairs provided by private companies as structurally equal, and ergonomically and aesthetically superior to those provided by the N.H.S.
• In terms of powered wheelchairs, the majority of therapists rated the wheelchairs provided by private companies as being structurally and ergonomically equal and aesthetically superior to those provided by the N.H.S.

• When asked how they rated, broadly speaking, the design of wheelchairs provided by the N.H.S. and by private companies in terms of meeting the needs of disabled people, the majority of therapists in the sample rated both manual and powered wheelchairs provided by private companies as being "very good" or "good", and manual and powered wheelchairs provided by the N.H.S as being "average", "poor" or "very poor".

**Major features of the results of the survey of rehabilitation engineers**

• The majority of the respondents identified weaknesses in the process by which clients are assessed and wheelchairs prescribed, such as budget constraints, insufficient time to evaluate users, limitations of equipment available, staff without experience or with no formal training to prescribe wheelchairs, and long time lapse before the delivery of the wheelchairs.

• The weaknesses in the process by which clients were assessed and wheelchairs prescribed had some implications for the design of wheelchairs, such as the lack of adaptability, interchangeability and adjustability in a number of wheelchairs available.

• Almost half of the sample of rehabilitation engineers answered that they did not formally collect the views of the users about the wheelchairs which had been prescribed for them after delivery.

• Although the communication between rehabilitation engineers and manufacturers has already being established, most of the respondents were not at that stage aware of the need to report users' views to the designers and manufacturers.

• One-third of respondents affirmed that the manufacturers did not take any notice or were unsure if the manufacturers took any notice of what they said and consequently carried out any modification to the wheelchairs.

• The vast majority of respondents had never been involved in wheelchair design with a company that produces wheelchairs for a large market but would like to be involved. They thought that their main contributions may include: providing information gained from practical experience with users and their requirements; providing technical contribution, including seating, posture management and ergonomics; providing feedback on the problems users have, including design solutions; advising on design suitability; and taking part in product evaluation and trials of prototypes.

• Almost half of the respondents thought that, in general, the wheelchairs actually in the market place were not designed to take the range of needs of disabled people into account. They argued that there is a lack of knowledge about users' needs or the disabled are not asked for their opinions; the wheelchairs are generally designed for
those who are least demanding or to suit an average person; the price of the chairs is high; there is a lack of adjustability in standard models; there are not enough field trials to iron out the design faults; they are only aimed at the young active user; they are very heavy; and few of the wheelchairs available are crash tested.

* Broadly speaking, the majority of rehabilitation engineers view manual wheelchairs provided by private companies structurally equal, and ergonomically and aesthetically superior to those provided by the N.H.S.

* In terms of powered wheelchairs, the majority of respondents rated the wheelchairs provided by private companies as being structurally and ergonomically equal, and aesthetically superior to those provided by the N.H.S.

* The sample of rehabilitation engineers was divided when asked to rate the design of manual wheelchairs provided by the N.H.S. in terms of meeting the needs of disabled people, with almost half of them rating those wheelchairs as being "good" and almost half as being "average". The answers regarding those manual wheelchairs provided by private companies were more positive: the majority answered as being "good" and almost all of the remaining rated them as being "average". In terms of powered wheelchairs, the majority of the respondents rated them as being good for both the N.H.S. and private market place.

**Major features of the results of the survey of users**

The majority of wheelchair users in the survey:

* were over 45 years old and more than one-third of them were over 55 years old
* suffered from neurological conditions
* lived in an urban area: town or city
* took their wheelchair with them when they went out in a vehicle
* had used some form of public transport in the last twelve months such as airplane, intercity and local train, taxi and low floor bus.
* had two or more wheelchairs
* had been using a wheelchair for more than ten years
* owned a manual self-propelled wheelchair as the most used and the next most used wheelchair.
* obtained their wheelchairs through the N.H.S. for both the most used and the next most used wheelchair
* had owned their current wheelchair(s) for less than five years
* had a seat cushion for both wheelchairs (the most used and the next most used wheelchair)
* used their main wheelchair every day
* used their main wheelchair indoors for more than five hours a day
had had problems with their main wheelchair in the last 12 months such as punctures, electrical failures, brake failure or broken armrest

considered safety, comfort, reliability, suitability and portability due to weight as the five most important design characteristics of wheelchairs

judged the design of their own wheelchairs as being "very good" or "good" in terms of safety, ease of use, stability, manoeuvrability, suitability and reliability although this level of satisfaction was not achieved as consistently as might be hoped for

judged the design of their own wheelchairs as being "average", "poor" or "very poor" in terms of cost to buy, cost to repair, provision of accessories, cost to maintain, adjustability, ease of repair, aesthetic appearance and portability due to weight

had the view that privately acquired wheelchairs were designed taking into consideration the needs of disabled people and those issued by the N.H.S. were not

had never been involved in wheelchair design with a company that mass produced wheelchairs for a large market.

Major features of the results of the survey of carers

The majority of carers in the survey:

- were over 35 years old and almost one quarter of them were over 65 years old
- assisted users in using the wheelchair every day
- rated their own health at the time they answered the questionnaire as "average", "poor" or "very poor"
- suffered from pain in the regions of lower back, buttocks, mid back and right shoulder as a consequence of assisting the user with the wheelchair
- considered safety and portability due to weight as the most important design characteristics of wheelchairs
- judged the design of the wheelchairs belonging to the wheelchair user who they assisted as being "very good" or "good" in terms of safety, ease of use, stability, reliability, robustness and suitability, although this level of satisfaction was not achieved as consistently as might be hoped for
- judged the design of the wheelchairs belonging to the wheelchair user whom they assisted as being "average", "poor" or "very poor" in terms of cost to buy, cost to repair, provision of accessories, cost to maintain and aesthetic appearance
- had the view that the wheelchairs issued by the N.H.S. were not designed to take into consideration the needs of disabled people and their carers
- had never been involved in wheelchair design with a company that mass produced wheelchairs for a large market.
The method discussed in the next section has the objective to overcome the discrepancies highlighted above. It is important to draw attention to the fact that some aspects, such as costs and the manufacturing process are not presented in depth. When this occurs, attention will be drawn to this fact. The method will focus mainly on aspects related to ergonomics and product usability developed to match wheelchair user needs and capabilities.

6.2 A user-centred design method

The proposed methodology is intended to be used for the design of wheelchairs produced on a large industrial scale which means a high-volume of manufacture and the adoption of techniques of mass marketing in its commercialisation. This means that the wheelchair should cover the widest range of users possible and be able to be adapted to specific users’ needs.

It is also the intention of this method to provide a step-by-step guide to be used by the designer of wheelchairs in a way to assist him/her in: a) making decisions about the several design dilemmas throughout the distinct design phases, reducing the possibility of moving forward with unsupported decisions and allowing the other members of the team to understand the decision rationale; b) obtaining information on the use of a variety of data gathering techniques; c) taking a series of key steps assuring that relevant design issues have been considered in the design process; and d) organising a documentation of the various design phases in order to facilitate the decision-making process, to be used for future reference and for educating new members of the design team. In this method the design team includes industrial designers and ergonomists. Other professionals such as mechanical, manufacturing and production engineers; finance, marketing and sales personnel and the management team should interact with the design team in the several phases of product development.

The proposed method must be viewed as a dynamic entity, able to be modified and to accept continuous improvement. This means that it may have some of its components adapted and modified to meet the organisational characteristics of the company in which it is intended to be used.

It will take a powered wheelchair for indoors and outdoors use as an example to be used throughout the method. The example and the project situation are fictional with the unique purpose of illustrating the various steps of the methodology and situations faced by the designers. Although a number of appropriate techniques to assist the designers in different
phases of the design cycle are shown, a range of others may be applicable and can be alternatively chosen for a specific situation. This will be mentioned when appropriate. Also, it is important to draw attention to the fact that although the method is intended to be used for the purpose of wheelchair design, its use for other products for the disabled, or even some consumer products, is not excluded, but will depend, of course, on being adapted to the intended situation.

Wheelchairs can be understood in the context of the current method as a "system". According to Chapanis (1996), "a system is an interacting combination, at any level of complexity, of people, materials, tools, machines, software, facilities, and procedures designed to work together for some common purpose". Thus, wheelchairs are systems which include the product itself, the wheelchair users and their carers. The "system wheelchair" is divided into "subsystems", for instance "subsystem of seating", "subsystem backing", "subsystem of movement", "subsystem of braking". In its turn, the "subsystems" may be made up of still smaller units here called "components". So, in the "subsystem of movement", for example, there are a number of identifiable components such as the wheels, the frame, the engine, the connections. Some of the subsystems and their components are part of the industrial designer intervention, others are related to the activities of mechanical or electrical engineers.

The User-centred method for wheelchair design comprises a set of eleven phases presented in the next sub-sections. Figure 6.1 shows a flowchart illustrating the main phases of the method. A number of parties are involved in the Preliminary Strategic Planning including the designers. Industrial designers are directly involved in the following five phases including Approaching the Users, Investigating the Problem, Product Planning, Concept Design, Prototyping and Testing and Verification. As part of the design activities, these phases are analysed in detail in the current methodology. The remainder, concerning the processes of Product Production, Manufacture and Assembly, Market Product and Customer Support, will not be discussed in this thesis.

6.2.1 Preliminary strategic planning

This first phase of the product development method usually involves a series of decisions taken by the company directors which start the whole process. This early stage usually has a very limited direct involvement of the designers and will, therefore, only be briefly described in this thesis.
Figure 6.1

The User-centred method for wheelchair design

Preliminary Strategic Planning
- Define overall budget
- Lay down outline timetables
- Establish preliminary guidelines for innovation
- Define applicable technologies
- Define market segments
- Identify competitive products

Approaching the Users
- Establishing user's needs
- Select users for the User Panel

Investigating the Problem
- Recognising the Problem
- Delimiting of the Problem
- Formulating the Problem

Product Planning
- Carrying out Task Analysis
- Refining User Needs
- Reviewing the State of the Art
- Applying QFD to Wheelchair Development
- Elaborating the Wheelchair Design Specification Document

Approaching the Users
- Establishing user's needs
- Select users for the User Panel

Investigating the Problem
- Recognising the Problem
- Delimiting of the Problem
- Formulating the Problem

Product Planning
- Carrying out Task Analysis
- Refining User Needs
- Reviewing the State of the Art
- Applying QFD to Wheelchair Development
- Elaborating the Wheelchair Design Specification Document

Product Production
- Production development
  - Select manufacture methods and process parameters
  - Select materials
  - Select suppliers
  - State expected costs
  - Select assembly needs and procedures
  - Execute production design documentation
  - Design technical trials
  - Conduct technical tests
  - Appraise the results of trials and modify design if necessary
- Production planning
  - Prepare marketing plans
  - Prepare production plans
  - Design jigs and tools

Manufacture and Assembly
- Meeting product design specification
- Meeting production schedule

Market Product
- Producing product advertising
- Giving training to the sales personnel
- Distributing the product

Testing and Verification
- Prototype evaluation including user manual
- Prototype modification and retesting
- User manual revised
- Promotional material

Concept design
- Generating concepts
- Evaluating concepts
- Selecting concepts
- Refining concepts
- Detailing design
- Designing the user manual
- Designing promotional material

Prototyping
- Building the prototype

Customer Support
- Giving training to users
- Providing product maintenance
- Providing repair service
- Monitoring product's performance
- Carrying out user surveys
- Carrying out product review
This phase comprises a number of strategic decisions including:

- The definition of a business plan for the new wheelchair, indicating that the new product will, for instance, present a good business opportunity and sell in sufficient numbers to exceed its development costs and yield other economic benefits.
- The identification of the relation between the new wheelchair and the company's other products, indicating that the new wheelchair will, for instance, offer wheelchair users a clear benefit over existing products and that there will be significant product differentiation between the new wheelchair and its competitors.
- The definition of the costs associated with the expenses of the product development programme.
- The establishment of a timetable for the product development process defined by the time between the instant the first person starts to work on the product development programme and the instant the final product is available to the user.
- The establishment of preliminary guidelines for innovation, as a result of a decision involving the company's business plan and the wheelchairs intended position in the marketplace in relation to competitors.
- The definition of applicable technologies, taking into account the current technology available in the company and the need to identify relevant and emerging technologies responsible for product innovation.
- The identification of the target market for the product meaning the analysis of the business opportunity in terms of which market segment the wheelchair is aimed to capture and a preliminary planning for its future commercialisation inside and outside the country.
- The identification of competitive wheelchairs representing the discovery of which wheelchairs and their features with similar characteristics are currently in the market place. This will provide data for a further analysis and evaluation of the competitive wheelchairs. This phase may be carried out by designers themselves and/or the marketing personnel. It includes the collection of promotional materials launched by competitors and maybe the acquisition of competitor wheelchairs for future analysis and evaluation.
- The selection of users for the User Panel is a step carried out simultaneously with the next phase of the design process. It has the strong participation of designers and, in view of this, will be explained and discussed in detail in the next sub-section.

6.2.2 Approaching users and other stakeholders

One of the most important aspects of the product development cycle is to understand and learn from the user. Understanding the needs of users is absolutely fundamental to identifying,
specifying and justifying a feasible design of the product. The users, in this case, comprise direct users (the wheelchair users themselves) and indirect users (the carers). Although consulting therapists and rehabilitation engineers are important in the design process, they are not the main stakeholders in the enterprise.

This phase of approaching users will be divided into the following steps:

- investigating existing information about wheelchair users and their carers
- developing profiles of wheelchair users and other stakeholders
- contacting wheelchair users and carers
- selecting wheelchair users and carers to participate in the consulting process
- carrying out focus groups with wheelchair users and carers and
- selecting members to take part in the User Panel.

Additionally this phase will include special session(s) of focus groups with therapists and rehabilitation engineers involved in the process of wheelchair assessment and prescription.

6.2.2.1 Investigating existing information about wheelchair users

As previously mentioned, this method is intended to be used in the development of a mass-produced wheelchair. Consequently, it can be assumed that it involves a company with reasonable experience and some time in running the business in the market place. Thus, the first step in surveying wheelchair users should be the design team investigating existing information about the users inside the own company such as:

- the company sales records, including repair and replacement parts
- the register of complaints
- warranty data
- list of former and current company's customer and their carers.

This will help designers to have an overview of the wheelchairs produced by his/her company, develop a profile of the actual and potential users of the product, and produce a preliminary list of wheelchair users and their carers who could be contacted.
6.2.2.2 Developing profiles of wheelchair users and other stakeholders

An ideal scenario for the participation of users and their carers in the design of products should be to involve in the design process everyone who uses or is going to use the product. This will help to ensure that the product will attend to everyone’s needs. Of course, apart from those products that will be manufactured for an individual or a small number of people, this approach is impractical. In terms of products that are to be mass marketed, it is necessary to choose a sample of participants whose profile is representative of those of the intended end-user population.

Ideally the company will have developed a profile of the actual and potential users of the product long before the time for the development of the new wheelchair. However, if it has not been done yet, the design and/or marketing team will have to do it as one of the first steps in the development of the new product.

Profiles of wheelchair users

As far as indoor/outdoor wheelchairs are concerned, the end-user population comprises a large range of users with diverse shapes, sizes and disabilities. In developing a profile of users, the design and/or marketing team should capture a number of different characteristics including:

- age
- gender
- ethnic origin
- education level
- nature of disability (e.g. arthritic condition, amputation, respiratory condition, ageing)
- physical limitation (e.g. lower and/or upper limbs)
- other(s) limitation(s) (e.g. visual, hearing, cognitive and/or verbal) and problem(s) (e.g. co-ordination of movement)
- quantity of wheelchair(s) each user has
- length of time of using wheelchairs
- type of wheelchair(s) the users own (e.g. manual self-propelled wheelchair, manual attendant propelled wheelchair, powered indoor/outdoor wheelchair)
- source of supply of user's wheelchair(s) (e.g. public or private market).

This information may also be part of a company database useful for defining a company's strategy in the launching of future products and an on-hand source for selecting and recruiting users to take part in user trials. It is important to have in mind that for some particularly data
gathering tasks from users, e.g. focus groups and discussion group, a sample of "typical users" is more appropriate to be used than a "representative sample" of the wider population of wheelchair users.

Profiles of other stakeholders
Apart from the wheelchair users themselves, there are other stakeholders involved directly or indirectly with wheelchair use such as carers and the service/product provider.

Establishing the profile of carers is almost, if not equally, as relevant to a user-centred design as specifying the characteristics of the wheelchair users themselves. This is particularly important where carers are also elderly or disabled themselves. Important data to be included in carer profiles should be:

- age
- gender
- ethnic origin
- education level
- time the carer spends assisting the wheelchair user
- physical limitations.

It is also important to keep records of contact with therapists and rehabilitation engineers for future participation in focus groups and product evaluation.

In terms of product development, apart from the external stakeholders mentioned above, there are also others stakeholders involved. These include those who reside within the company, such as the sales force, the service organisation, and the production departments. Producing a list of internal stakeholders serves as a reminder to consider the needs of everyone who will influence the product and be influenced by it.

6.2.2.3 Contacting wheelchair users and carers

In addition to contacting some wheelchair users included in the company's database, users of wheelchairs manufactured by competitors must be recruited to guarantee the participation of users with different experience, viewpoints and knowledge in dealing with the product.
Deciding how many participants to include

The participation of direct and indirect users in the User-centred method for wheelchair design intends to: a) produce inputs for the "Preliminary strategic planning"; b) identify wheelchair users' and carers' needs and c) involve a number of wheelchair users and carers in the design process.

It is important to keep in mind that consulting the users to identify user needs is not a research study. The purpose of involving the users in the product development is to uncover the most serious problems that users are likely to have in using the product and obtain suggestions in order to incorporate their needs and wants into the design of the product.

Defining how many users should be approached in the identification of user needs is a matter that strongly involves monetary costs. The answer to this question has been addressed by a number of authors including Caplan (1990), Dumas and Redish (1993), Griffin and Hauser (1993) and Virzi (1992). Depending on the method used to approach the users, the authors generally agree, as a practical guideline, that conducting fewer than 10 interviews is probably inadequate and 50 interviews may be too many. In terms of focus groups and discussion groups, with a number of less than six people ideas and interactions may be sparse and the group may be monopolised by one or more talkative people. With more than ten, the group may be more difficult to control and to guarantee adequate participation by each group member. The number of participants is influenced by the availability of money to cover the costs, the time available to run this phase of the project and the scope and depth of information to be obtained.

The use of focus groups has been revealed as being an appropriate tool in obtaining information about users' opinions, attitudes, preferences, and self-reports about their performance when using the product (Caplan, 1990; Feeney, 1996a). In view of the previous story of success, focus groups is the method recommended to be used in this early phase of the design process.

A number of three to five focus group sessions is suggested. Each session should include between six and ten people in total with a ratio of about four wheelchair users to one carer. This represents in total a number of about 15 to 40 wheelchair users and 3 to 10 carers to be recruited.

Recruiting participants

The company's own database is the primary source to find participants to take part in focus groups. As was previously mentioned, it is also essential to have users of competitor
companies as members for the sessions. Although the participation of eventual wheelchair
users employed by the company in the focus group session can apparently reduce the costs of
the sessions, this is not recommended because: a) they may feel intimidated and not criticise
the wheelchairs manufactured by their own company; b) there may be difficulty in obtaining
their release for the participation due to company's hierarchy and internal issues; and c) the
company, in fact, may lose more money by releasing them to take part in focus groups
sessions than having them do their ordinary jobs.

As most of participants have difficulties of locomotion, the company must recruit wheelchair
users and carers who live near the place where the focus group sessions will be held. So, the
main means of finding participants will be:

- advertising in local newspapers, supermarket, schools, university and/or Community
  Centres
- contacting local and nearby wheelchair user groups
- contacting local and nearby N.H.S. wheelchair services
- contacting local and nearby charity organisations.

Ideally, depending on the company's interest and availability of funds, the focus groups may be
carried out in different regions of the country to improve the chances of obtaining a variety of
responses and point-of-views from people of different lifestyle, living environments, and
different climatic conditions.

Apart from arranging transport to and from the meeting(s), the company has to budget for
payment or other incentives for the participants. Additionally, the accessibility of the location
must be considered in detail including not only the room where the meetings will occur, but
also the immediate environment such as toilets, ramps, lifts, the lunch room and the table that
the participants sit around.

6.2.2.4 Selecting wheelchair users and carers

There are no specific requirements for the participants, apart from having experience as
wheelchair users and carers and the ability to communicate verbally. The participation of
"typical users", covering the extremes of the population such as fat man, thin woman, young
user, elderly user, experienced user, novice user, is recommended. Also, participants with
different disabilities will almost certainly provide different types of requirements.
6.2.2.5 Carrying out focus groups with wheelchair users and carers

It is recommended that the extent of each focus group session in the User-centred design method should be 2-3 hours. The major components of focus groups are the facilities, the moderator, the participants, the procedures and results. They are described as follows.

The facilities

The facilities can be understood in this context as the link between the company, the moderator and the participants in the groups. Good facilities perform an essential role to the success of the focus group which includes the following actions:

- confirming participants' attendance and providing adequate transport
- providing a reception area for greeting participants
- guaranteeing a large and comfortable focus group room with easy external access for the participants and enough internal space to permit participants movements with their wheelchairs
- conducting the participants to the focus group room and accommodating them comfortably around a large table in a way that their wheelchairs are placed under the table
- establishing a designated location for each participant to sit around the table with visible name cards on the table to promote interaction among participants and help moderator communication
- guaranteeing, if appropriate, an extra space in the focus group room for the analysis of competitors' wheelchairs, models or prototypes
- guaranteeing an observation room where the company's director(s) and members of the design and marketing team can see the proceedings easily. This is usually done using a one-way mirror. Alternatively a TV close-circuit may be used. It is important to be sure that the observers are comfortable and the sound system must allow each of the participants to be heard, even if they speak in a very low voice
- providing, if required, a display panel for figures, photographs or other visual stimuli in the focus group room
- providing a white board or a flipchart and markers in the focus group room so the moderator can make notes if necessary
- providing appropriate support materials, e.g. photocopies, pencils and notepads
- providing audio and/or videotape support
- providing food and drinks for the participants and observers
- assuring that the materials used during the sessions are returned to the company in a way to keep confidentiality
- providing remuneration to the participants.
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The moderator
A considerable part of the success of a focus group lies in the hands of the moderator. The session moderator should be familiar with the objectives to be achieved by the focus group sessions and should understand the product or problem being discussed. Skilled moderators can ensure that:

- a good atmosphere is created
- rules for the discussion are established
- the discussion is directed along relevant lines
- disruptive behaviour on the part of specific participants is avoided or curtailed
- individuals, ideas and ideologies are protected
- all participants get an opportunity to contribute and the proceedings are not dominated by any one person or group
- bias is eliminated so far as possible from the findings
- the degree of probing and the depth of insight are sufficient to accomplish the research objectives.

Unskilled moderators find themselves conducting individual interviews with each of the participants rather than stimulating interaction within the group. If no member of the design or marketing team has experience in running focus groups, it is strongly advised to hire the service of experts in the field.

The role of the moderator, the manager of the research process, in the focus group with wheelchair users and their carers should be specified in terms of preparation, implementation and postgroup procedures as following:

Preparation (to be carried out with company director(s) and the design and marketing teams)
- developing research objectives
- defining the criteria for participant inclusion in the groups
- determining the number of groups needed to achieve the research objectives and the facilities for running the sessions such as access to the room, food requirements, instruction to the members to fill up questionnaires
- deciding on the use of pictures, prototypes or wheelchair samples to be analysed; establishing concept statements and demonstrating ideas
- producing a guide for the moderator including the set of questions to be addressed, the timing of various topics and the use of external stimuli.
Implementation

- ensuring that the right people participate in the sessions
- briefing the company's personnel, who will observing the groups, on the objectives of the session and the content of the guide for the moderator
- conducting the group so as to cover all the elements in the guide provided to the moderator
- finishing on time.

Postgroup procedures

- obtaining audio- and/or videotapes that were made with the groups
- analysing the results
- producing a report explaining the findings and their consequences

It is important to ensure that if the moderator is a person outside the company, he or she should be aware of any information that will enhance the effectiveness of the focus group, including strengths and weaknesses of company and competitor's wheelchairs and new ideas and concepts that may be explored. It is advisable to consider the use of an "assistant moderator" to help the moderator with some tasks such as taking comprehensive notes, operating the tape and/or video recorder, handling the environmental conditions and logistics (refreshments, lighting, seating, etc) and responding to unexpected interruptions.

The participants

Additional attention should be given to the wheelchair participants in the sessions. It is important to guarantee their comfort and easy movement around the room with their wheelchairs. Details of the participants' involvement were previously described when the role of the moderator was explained. Other recommendations concerning the involvement of the participants in the focus groups sessions include that they:

- should speak as clearly as possible, one at the time, and facing the audience
- ask the moderator to clarify or repeat the question if necessary
- if appropriate, feel free to make any comments and express eventual dissatisfaction in regard to any of the products which are being discussed
- respect others' opinions even if they strongly disagree and follow the normal rules of polite conversation.
The procedures

The first moments in focus group discussion are critical and may be responsible for its success. Excessive formality and rigidity may inhibit and/or restrain interaction among participants. On the other hand, too much informality and humour can lead participants not taking the discussion seriously. The responsibility for creating a good atmosphere will depend basically on the moderator. The sessions procedures should include:

- **Introduction**, the moderator introduces him or herself to the participants, briefly explaining the purpose of the session, alerting the participants that the session is being audio and/or video-recorded, the existence (if it is the case) of a one-way mirror, the ground rules of the session and, finally, asking participants to introduce themselves.
- **The core**, the participants are asked to discuss the issues related to the topic, are guided to identify important information about the wheelchairs including their feelings and needs, the strength and weaknesses of the wheelchair and to make suggestions about how to improve the design of the wheelchair. Special emphasis must be given to the establishment of user needs.
- **Summary**, the participants have the opportunity to share any information about the topic that they may have forgotten or otherwise omitted.
- **Debrief**, the moderator should finalise the session thanking the participants and hand out the honoraria.

The results

Analysing the findings of focus groups is a very time-consuming activity comprising the transcription of hours of tapes and observation of video-records. It involves a systematic analysis to gather and handle the data in a form useful for the design activity. The analysis must be verifiable in a way to permit another researcher to arrive at similar conclusions using the same documentation and raw data. The researcher must have the skill to select and interpret the data focused on the study from the large amount produced in several sessions. The analysis process involves consideration of a) the words used by participants and their meanings, b) the context of the discussion including the tone and intensity of the oral comment, c) internal consistency as a result of changing positions, d) extensiveness, frequency and intensity of some comments, e) specificity of responses based on experiences and e) finding the big ideas emerging from an accumulation of evidence - words used, body language, intensity of comments - rather than from isolated comments alone.

The focus group findings should be stated in the form of a report and should include:

- a description of the purpose of the study
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- a description of the focus group sessions
- the number of focus groups
- the methods of selecting and recruiting participants
- the number of people in each focus group
- the results, their interpretation and consequential actions
- the appendix including for instance the questioning route for the focus group, the screening questionnaire, additional quotations and a list of the wheelchair user needs classified by categories of wheelchair components (seat, back, handles, cushions, etc).

It is important to draw attention to the need for data reduction for both the analysis and the quotations to be included in the report. The report should be a reasonable length and not over long.

As shown in the flowchart illustrated in Figure 6.1 (page 272), approaching the users is an activity that interacts in a loop with Preliminary Strategic Planning. This means that the Preliminary Strategic Planning defines a series of queries to be discussed by the focus groups and is expected to receive a number of feedback including the identification of strengths and weaknesses in some wheelchair models, the establishment of user needs and so forth.

6.2.2.6 Selecting members of the User Panel

As previously commented, the use of focus groups is an excellent technique for evaluating concepts, identifying issues and determining users' attitudes about products. However, the focus groups approach is established on a consultative basis. For instance, the design and/or marketing team and the moderator choose the topics for discussion and the criteria against which products are evaluated. Although this is very useful and a recommended approach in the pre-design phase, the User-centred method for wheelchair design requires the participation of users in the further steps of the design process not just "consulting" them, but also "involving" them in the entire process.

Some crucial aspects such as task analysis, user trials, model and prototype evaluations require the constant involvement of users. Focus groups, as a technique of a consultative nature, do not show how users actually behave with products. In view of this, it is recommended to select a group of about eight wheelchair users and two carers from the focus group sessions to assist in the following phases of the design process. This group of participants will be called the User Panel henceforth.
Observing the participants in the focus group sessions should be a good way to select those candidates who make good contribution to take part in the User Panel. Some factors such as the participants' capacity for criticism, observation, enthusiasm and giving useful suggestions; the guarantee of availability of the participants in the several User Panel meetings, in terms of time commitment; and a suitable financial remuneration should be taken into account.

Although it can be argued that users are in general non-technical, have lack of knowledge of how the product works and the adequacy of different materials and components, and know very little about the limitations imposed by the manufacturing process; their participation in the design process can be justified by the fact that their unique experience using the product can be transformed into a rich, creative and innovative source of information which will improve the quality and usability of the product.

According to Feeney (1996b), many of the practical problems in involving users in the design and manufacturing process arise as a result of traditional attitudes on the part of the manufacturers and designers rather than problems to be overcome.

To improve the communication between the User Panel and the design team, User Panel participants should be informed about how products are designed, manufactured and sold including the constraints imposed by the production process. This procedure will start the involvement of the User Panel, stimulating them to question the way things have been done and preparing them to propose new and creative ideas and solutions.

A number of sessions should be established at significant points of the design process to enable the participation of the User Panel, with the design team, having discussion and making decisions related to issues to be incorporated in the future steps of the design process. At each design review the panel should be informed about the design development, asked to discuss the results and point out suggestions to the further phases. The involvement of the manufacturing, marketing and commercial personnel in the design review sessions will contribute to give extra inputs to the discussion and may contribute to improve the quality of the results.

A chairperson, maybe one of the directors of the company, should be chosen to run the User Panel meetings. It is important to take into account that some review decisions may not have the full agreement of the User Panel. Wherever possible this must be avoided through discussion or modifications to the design to ensure that the needs and wishes of all members of the panel are met. If this were not possible, a decision may be taken by the Chairperson.
In addition to taking part in the *User Panels* and contributing to resolving design conflicts, the participation of the wheelchair users and their carers in the phase of *Testing and Verification* is essential. Practical participation of the members of the panel includes task analysis, user trials, evaluation of mock-ups, models and prototypes and instruction manual. Eventually, the *User Panel* can be supplemented by other subjects recruited for special tests, e.g. anthropometric tests which require subjects of specific body size.

An indication of each phase of the design methods with the major stakeholders involved in the design process, including the participation of the *User Panel*, is given in Table 6.1. The participation of member(s) of the design and/or marketing team in running the focus group sessions may be substituted by a qualified external consultant. The phases of *Development, Manufacture and Assembly, Market Product and User Support* are not described in detail because they are not part of the Design Process.

### 6.2.3 Investigating the problem

The definition of the steps included in the design process depends strongly on a correct identification of the problems to be solved. Broadly speaking, products in general, including wheelchairs, can be understood as material systems comprised of a set of properties. These properties are made to fulfil functions that, in their turn, will permit users to perform specific actions which will or will not meet their needs (Figure 6.2). If the product does not fulfil entirely user needs, a potential situation for redesigning the product or designing a new one can be established to overcome the identified problems.

![Material and human system interaction](image)
Table 6.1
Design phases involving the several stakeholders in the design process

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<tr>
<th>Production Phases</th>
<th>Stakeholders</th>
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<td>User Panel</td>
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<td>Preliminary Strategic Planning</td>
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<td>• Define business plan and overall budget</td>
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<td>• Lay down outline timetables</td>
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<td>• Establish preliminary guidelines for innovation</td>
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<td>• Define applicable technologies</td>
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<td>• Define target market</td>
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<td>• Identify competitive products</td>
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<td>Approaching the Users</td>
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<td>• Design focus group</td>
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<td>• Carry out focus group sessions</td>
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<td>• Result of focus group including the establishment of user needs</td>
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<td>• Select users for the User Panel</td>
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<td>Investigating the Problem</td>
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<td>• Recognising the Problem</td>
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<td>• Delimitation of the Problem</td>
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<td>• Formulating the Problem</td>
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<td>• Carrying out Task analysis</td>
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<td>• Refining user needs</td>
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<td>• Reviewing the state of the art</td>
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<td>• Applying QFD to wheelchair development</td>
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<td>• Elaborating the Wheelchair Design Specification document</td>
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<td>• Generating concepts</td>
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<td>• Detailing design</td>
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<td>• Designing the user manual</td>
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<td>• Designing promotional material</td>
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<td>Prototyping</td>
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<td>• Building the prototype</td>
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<td>Testing and Verification</td>
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<td>• Mock-ups and models evaluation</td>
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<td>• Prototype evaluation</td>
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<td>• Prototype modification</td>
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<td>• Re-testing prototype</td>
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<td>• Test and review user manual</td>
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<td>• Test and review promotional material</td>
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<td>Market Product</td>
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<td>Customer Support</td>
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* An external consultant can be hired to run the focus group instead of the design and/or marketing team.
Thus, investigating the problem will give the design team basis to decide what to do and how to do it. Investigating the problem can be split into three steps: a) recognising the problem, b) delimiting the problem and c) formulating the problem.

6.2.3.1 Recognising the problem

The approach to investigating a problematic situation can be carried out by describing what is lacking in the product or situation to be analysed, in terms of fulfilling user needs, and/or what exists but actually does not perform its actions as required to meet user needs.

*Recognising the problem* corresponds to investigating the most serious and flagrant problems that immediately appear in the analysis of the problematic situation. This preliminary phase provides the first inputs to the design team and establishes an initial set of problems that needs deep investigation. These inputs are presented in a form of *List of Problems* collected in a non-systematic way.

Undoubtedly focus groups are an excellent tool for recognising the problems in this initial phase. Certainly wheelchair users will be able to verbalise their wishes, wants and complaints in relation to the products they currently use and other products that may be introduced.

6.2.3.2 Delimiting the problem

The previous step generates a *List of Problems* obtained from the company and the focus groups sessions and non-systematically identified. The *List of Problems* should be now selected, classified and expanded emphasising the most relevant design problems. This should be done by the design team and further submitted for appreciation and comment by the *User Panel*.

The selection and classification of the various aspects of the problem situation is described through the *Analysis of Dysfunction of the Wheelchair-User Interface*. These dysfunctions can be divided into: a) ergonomic, b) human and c) machine. Examples of the several distinct dysfunctions applicable to the wheelchair-user interface (either for manual or powered wheelchairs) are shown below (adapted from Moraes, 1992; Moraes and Mont'Alvão, 1998 and Soares, 1990).

*Ergonomics dysfunction*
- Interface problems
Poor posture as a result of inadequate location of controls which respond to actions by the
wheelchair users or carers.
Use of inadequate anthropometric values in defining wheelchair dimensions.
Location of displays out of the field of vision of extreme users.
Location of controls outside the users' dynamic area of comfort.
Limited space to accommodate trunk and legs.
Poor support to accommodate arms and feet.

- **Instrumental problems**
  Displays and/or controls provided with no consideration of prioritisation, ordering and
  standardisation.
  Movements of displays and/or controls with no consideration of stereotypes of movement
  and consistency.

- **Informational problems**
  Poor location of objects to be perceived and discriminated as a function of their shape and
  distance from the user.
  Poor visibility of warning and graphic signals.
  Poor legibility of characters.

- **Control problems**
  Pain in fingers, wrists, elbows, arms, shoulders, trunk, feet and legs causing by repetitive
  effort, resistance or vibration of the controls, and poor position of the hands in
  consequence of position and movements of the manual controls.
  Poor dimension and shape of the manual controls exerting pressure on specific points of
  the hands.
  Poor dimension and shape of foot support.
  Lack of safety in controls with possibilities of electrical shocks, burning, cutting, or
  injuries.
  Location of handles and foot supports out of the user's dynamic reach area and
  biomechanic angles of comfort.
  Difficulty to visualise and/or reach components which require maintenance and repair.

- **Cognitive problems**
  Deficiency in the operational logic resulting from the layout and movement of displays and
  controls, without considering the consistency of the system, users' stereotypes and
  operational images.
  Poor comprehensibility of the graphic symbols as a result of cultural incompatibility,
  newness or lack of knowledge of the codes used.

- **Movement problems**
  Excessive weight of the wheelchair causing difficulties in lifting for storage into car boots
  or pushing on difficult terrain.
Excessive weight of some wheelchair components that need to be replaced (e.g. battery). Wheel sizes incompatible with certain terrain.

- Natural problems
  Lack of accessories to protect the user against rain or cold weather.

- Instructional problems
  Poor quality of instructional manuals.

**Human dysfunction**

- Postural problems
  Back pain resulting from poor posture assumed when activating controls and other components, getting visual information from displays (wheelchair users) or using push handles at inappropriate height (carers)
  Damage to the spinal column due to lifting and transporting wheelchairs which are excessively heavy.
  Muscle fatigue resulting from repetitive efforts and poor posture when users and carers are pushing the wheelchair

- Social problems
  Difficulty in being socially active due to using an unfriendly wheelchair which is incompatible with use in tight public places such as shops and pubs
  Lack of self-esteem due to the use of a product with a design that reinforces the image of disability

**Machine dysfunction**

- Structural and movement problems
  Poor stability of the wheelchair structure
  Too little or too great resistance to effort
  Poor adjustability and interchangeability of components
  Sharp edges and protruding nuts and bolts in the wheelchair structure
  Frame difficult to unfold
  Lack of security for fixed wheelchair components
  Movement system excessively stiff or flexible
  Noise in the movement system
  Failure in the brake system
  Lack of flexibility in the use of accessories.

- Problems of poor performance of components and sub-systems
  Lack of confidence due to failures and non-functionment of components
  Components functioning below the standard required
  Poor durability of sub-systems and components
• Problems of robustness, reliability, standardisation and manufacture
  Lack of resistance of materials to bad weather
  Lack of resistance of materials to physical aggression
  Lack of standardisation, modularisation and interchangeability of components with consequences for the cost of the product, speed of production and the achievement of high levels of quality during manufacture.
  Costs of manufacturing incompatible with the scale of production.
  Excessive use of different materials with an increase in the number of manufacturing operations and costs.
  Inadequacy of the manufacturing process to the company capacity in terms of raw material and equipment available, know-how and qualified personnel.

• Social-cultural and semiology problems
  Design inadequacy in terms of representation of user's uniqueness, values and status.

• Aesthetic/form problems
  Lack of originality in the wheelchair design with no distinction between the company's and competitor's products.
  Design aesthetically unpleasant with poor configuration and inadequate use of materials, colours and textures.

This phase of Analysis of Dysfunction of the Wheelchair-User Interface will be more successful with the use of photographs to illustrate the problems. It can be done using members of the User Panel and will be a strong tool to persuade the company to invest in a new product.

6.2.3.3 Formulating the problem

In this last phase of investigating the problem, the situation is reduced to its most significant and soluble aspects considering the competence of personnel, the available knowledge and what was required by the users and the company. This can be shown by using a table named Formulation of Problems. The table should contain the main problems, the system requirements, the user constraints, the human costs, suggestions, and the system constraints for ergonomics, human and machine dysfunctions. For the purpose of illustration, Table 6.2 shows some possible examples of ergonomic dysfunction problems that may be contained in the table of Formulation of Problems for the design of wheelchairs. This table aims to guide the design for the next steps of the design methodology.
### Table 6.2

Some examples of ergonomic dysfunction problems for a table of *Formulation of Problems*

<table>
<thead>
<tr>
<th>Problems</th>
<th>Design Requirements</th>
<th>Human Problems</th>
<th>Human costs</th>
<th>Suggestions</th>
<th>System constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interface</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Backrest does not support the lower back</td>
<td>Backrest profile which considers the buttock protrusion and supports the lumbar region</td>
<td>Kyphosis dorsal and flattening of the lumbar curve</td>
<td>Pain in the back</td>
<td>Provide a new backrest profile</td>
<td>Available technology, Lack of interest of buyers and manufacturers</td>
</tr>
<tr>
<td>Inappropriate support to accommodate the feet</td>
<td>Considers the length of the feet of biggest users</td>
<td>Legs do not touch the foot support</td>
<td>Discomfort</td>
<td>Provide an adjustable foot support</td>
<td>Lack of interest of buyers and manufacturers</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inappropriate shape of the hand controls</td>
<td>Profile that does not cause pressure on the users hands</td>
<td>Pressure on specific areas of the hands</td>
<td>Pain in hands and wrist</td>
<td>Provide new profile for the hand controls</td>
<td>Available technology, Lack of interest of buyers and manufacturers</td>
</tr>
</tbody>
</table>

#### 6.2.4 Product planning

The problem is now adequately defined and the project boundary established. This step involves finding the information directly relevant to the designers' further activities of generating and selecting feasible solutions to the creation of new wheelchair models. This phase covers the following steps:

- Carrying out a task analysis
- Refining user needs
6.2.4.1 Carrying out a task analysis

Task analysis is an important method in the ergonomics repertoire. It is a method for producing a hierarchical flowchart of all the things the user will do with a product. Each activity in which the user engages using the product can be broken down into a set of tasks. Each of those tasks can then be broken down further into subtasks; subtasks can often be broken down further, and so on. Tasks and subtasks can be organised in terms of subsystems and sub-subsystems of the product.

Task analysis provides the ergonomist and designer with details on:

- the sequence in which the user uses the product
- the place in the hierarchy of each activity
- user-product interface requirements
- product evaluation and decisions that must be made in design
- task times and
- environmental conditions.

In using the User-centred method for wheelchair design, designers and ergonomists should use task analysis as a tool to examine the wheelchair-user interface in detail. Although this technique is usually carried out by ergonomists, the participation of the designers is essential because task analysis provides a rich source of inspiration on new product concepts and a rational basis for design decisions. Task analysis will also provide useful information about anthropometric aspects of the wheelchair users and their wheelchairs.

The use of task analysis in the User-centred method for wheelchair design should complement the data obtained from the Analysis of Dysfunction of the Wheelchair-User Interface described in the Delimitation of the Problem (page 287). As product users, the members of the User Panel should be invited to take part in the task analysis for investigation of both the tasks performed by the carers and those performed by the wheelchair users themselves.

This technique is very familiar to all ergonomists. Details of various task analysis approaches and illustrations of operational sequence diagrams, useful for product design, can be found in a number of books and book chapters including those by: Baxter (1996); Chapanis (1996);
Cushman and Rosenberg (1991); Dumas and Redish (1993); Kirwan and Ainsworth (1993); Meister (1985); Stammers, Carey and Astley (1995) and Woodson (1981).

6.2.4.2 Refining user needs

The previous phases of the design process will have identified a considerable number of wheelchair user needs as a result of the expression of users' wants, wishes and complaints. The needs verbalised by the users are expressed in their own language and, although they are a clear expression of their interests and desires, they are not specifically described at guiding to designing and engineering the product. This leaves designers and engineers with the task of interpreting the users' needs with a minimum of subjective interpretation.

The most appropriate way to translate the user needs into the design process is to establish the Product Requirements. Product Requirements comprise a set of specifications which will address what the product has to do, in a precise and measurable way, to meet user needs. This means that, for example, a user needs to "reduce the weight of wheelchair", will correspond to the specification that "the weight of the wheelchair should be 10 kg". Ideally each user need should correspond to only one value specification, although this is frequently not possible. Issues related to how the product will perform to satisfy user needs are not yet addressed in this phase of the method.

The user needs, previously established in the form of a list, have now to be selected, categorised and ascribed a level of importance. The selection of the user needs must include those which are within the designer's competence to solve. Categorising them, refers to associating each identified and selected need with the respective subsystem of the wheelchair. For instance: "reduce weight of wheelchair", "produce wheelchair foldable", "reduce vibration in the handles", "allow ease of traversal of difficult terrain", are needs that can be associated with the subsystem "Structure". "Seat and backrest should be made to stop stretching and sagging", "provide further cushion on seat and backrest", "washable and easily removable upholstery" are examples of needs related to the subsystem "Seat-backrest". The designer should consult the User Panel to attribute levels of importance to each need varying from 1 (the less important need) to 5 (the most important need). This will be essential to decide which user needs have to be taken in resolving subsequent design dilemmas.

The List of refined user needs should now be associated with a correspondent metric. Attention must be called to the fact that there will be some needs that can not easily be transformed into quantifiable metrics. In this case the user need should be kept and the metric
is evaluated as "subjective". Table 6.3 shows an example of user needs for the subsystem "Structure", their relative importance, the associated metrics and the units of measurement.

Table 6.3
List of refined user needs and their associated metrics

<table>
<thead>
<tr>
<th>No.</th>
<th>Subsystem</th>
<th>Need</th>
<th>Imp.</th>
<th>Metrics</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Structure</td>
<td>Reduce weight of wheelchair</td>
<td>5</td>
<td>Total mass</td>
<td>kg</td>
</tr>
<tr>
<td>2</td>
<td>Structure</td>
<td>Produce foldable wheelchair</td>
<td>4</td>
<td>Fold width</td>
<td>mm</td>
</tr>
<tr>
<td>3</td>
<td>Structure</td>
<td>Reduce vibration in the handles</td>
<td>3</td>
<td>Attenuation from push bar to main structure at 10 Hz</td>
<td>dB</td>
</tr>
<tr>
<td>4</td>
<td>Structure</td>
<td>Allow easy traversal of difficult terrain</td>
<td>4</td>
<td>Spring preload</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>Structure</td>
<td>Easy to remove wheels</td>
<td>1</td>
<td>Time to disassemble/assemble</td>
<td>min</td>
</tr>
<tr>
<td>6</td>
<td>Structure</td>
<td>A wide variety of wheels and tyres fit the wheelchair</td>
<td>2</td>
<td>Headset size</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td>Structure</td>
<td></td>
<td></td>
<td>Steer tube diameter</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td>Structure</td>
<td></td>
<td></td>
<td>Wheel sizes</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td>Structure</td>
<td></td>
<td></td>
<td>Castor sizes</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td>Structure</td>
<td></td>
<td></td>
<td>Maximum tyre width</td>
<td>mm</td>
</tr>
<tr>
<td>7</td>
<td>Structure</td>
<td>Easy of access to maintenance the components</td>
<td>2</td>
<td>Time to disassemble/assemble</td>
<td>min</td>
</tr>
<tr>
<td>8</td>
<td>Structure</td>
<td>Sharp edges are smoothed off</td>
<td>3</td>
<td>Sharp edges are smoothed off</td>
<td>subj</td>
</tr>
<tr>
<td>9</td>
<td>Structure</td>
<td>Easy to fit accessories</td>
<td>3</td>
<td>Time to assemble the accessories</td>
<td>min</td>
</tr>
<tr>
<td>10</td>
<td>Structure</td>
<td>Easy to manoeuvre</td>
<td>4</td>
<td>Minimum corridor width of 1000 mm</td>
<td>mm</td>
</tr>
<tr>
<td>11</td>
<td>Structure</td>
<td>Last a long time</td>
<td>4</td>
<td>Test of steer tube duration</td>
<td>hours</td>
</tr>
<tr>
<td>12</td>
<td>Structure</td>
<td>Provide good stability</td>
<td>5</td>
<td>Test of stability ISO 7176-1</td>
<td>degree</td>
</tr>
<tr>
<td>13</td>
<td>Structure</td>
<td>Easy of kerb climbing</td>
<td>3</td>
<td>Test of obstacle climbing ability ISO 7176-10</td>
<td>mm</td>
</tr>
<tr>
<td>14</td>
<td>Structure</td>
<td>Is safe</td>
<td>5</td>
<td>Fatigue test</td>
<td>N and kerb drops</td>
</tr>
<tr>
<td>15</td>
<td>Structure</td>
<td>Is not expensive</td>
<td>5</td>
<td>Unit manufacturing costs</td>
<td>£</td>
</tr>
</tbody>
</table>
To provide a metric value corresponding to each need is necessary to guarantee that meeting the specification will lead to satisfaction of the associated user needs. Tables such as 6.3 will be a key element in the House of Quality. This is one of the components that will comprise part of the QFD matrix which is described later.

6.2.4.3 Reviewing the existing state of the art

Reviewing the existing state of the art is paramount in determining the commercial success of the product to be launched in the marketplace. Apart from collecting information on the ergonomics, wheelchair technical specification, and safety and regulatory standards, information on competing products must be gathered in order to specify the position of existing products, both the company's and competitor's.

Review of literature and standards
A literature search will enable the design team to find technical reports, books, magazines, journals and conference proceedings with relevant articles related to wheelchair issues. Steps recommended to the designer in finding information about wheelchair issues include:

- examining lists of references that follow articles on wheelchairs and related topics in journals, conference proceedings, and books
- reading newsletters of professional societies and technical groups
- obtaining listings and abstracts of recent reports prepared under government contracts
- searching computer databases and the internet
- searching patents and standards.

The Medical Devices Directorate and the Disabled Living Foundation usually publish reports with data useful for the design of wheelchairs. Also, journals such as the British Journal of Occupational Therapy, the British Journal of Therapy and Rehabilitation, the Journal of Rehabilitation, the Clinical Rehabilitation are extremely useful sources of data.

Information from the ergonomics literature related to disabled issues in general, and wheelchairs in particular, is very rare. Anthropometric data available in the literature to define the body sizes and shapes of disabled people is not extensive. It is recommended, as a way to overcome this lack of anthropometric data, that designers carry out their own tests using members of the User Panel who represent the extremes of the population: e.g., the short, the tall, the thin, the fat. Carrying out task analysis and user trials with members of the User Panel will also help in the establishment of users' anthropometric dimensions.
Although designers are destined, at least at present, to fail in their search for extensive information on the dimensions of people in their wheelchairs, the ergonomics literature has a number of other data sources extremely useful for the design of products. These sources include data concerning user behaviour, user physical and mental capabilities, techniques for the application of task analysis, issues related to testing and user trials, data about displays, information design, controls and control arrangements, and product safety. Some books within the ergonomic literature which are useful for the design of wheelchairs include Cushman and Rosenberg (1991), Jordan (1998), Jordan et al. (1996), Stanton (1998), Wilson and Corlett (1990), Roebuck (1995), Sanders and McCormick (1992).

There is also some lack of comprehensive data concerning wheelchair dimensions. This, however, was recently remedied in a report published by the Transport Research Laboratory in which a wide range of wheelchairs was photographed and their dimensions computed for the height and length of the occupant plus wheelchair, and for the width of the wheelchair itself (Stait and Savill, 1995).


Standards, either mandatory or voluntary, contribute to improve the quality and, above all, the safety of products. Standards for disability equipment are listed and indexed in the British Standards Institute Catalogues (BSI, 1991). Actually manufacturers in the United Kingdom have to meet mandatory standards to produce wheelchairs. They also have to comply with international standards such as ISO to have their products exported to other countries. Designers must ascertain if there are standards or regulations applied to the markets where the wheelchairs will be distributed in order to guarantee compliance with requirements from the beginning of the design phases.

*Analysis and evaluation of competitive products*

Analysing and evaluating competitive products is an absolutely essential activity to determine the strengths and weaknesses of competing products in relation to the company's own product. Information gathering from competitive products will clarify problems associated with existing products which must be overcome to increase the chances of success for the company's own new product.

A database is the most effective way to store and retrieve information on the characteristics of competitive products. In this way, data can be easily updated and used and can provide on-
hand information about opportunities for product improvement. Examples of information to be included in the database are:

- the results of ergonomics tests
- findings from the direct observation of product use
- the results of surveys and interviews with wheelchair users and carers
- the outcomes of evaluations by experts (marketing, engineering, ergonomics, industrial design)
- product reviews in consumer publications, trade publications, and design publications
- product description in sales literature and advertising.

The most useful way to handle the competitive products to be used in the concept design phase is to prepare a "Chart of Competitive Wheelchairs". In fact, this chart should be split in two: the first based on metrics and the second based on user satisfaction. Both charts will be part of QFD matrix later.

**Chart of Competitive Wheelchairs based on metrics**

Gathering data from competitor products is very time-consuming and may involve purchasing, testing, disassembling, and estimating their production costs. Independent evaluations, such as the reports from the Medical Devices Agency, may be a good source of obtaining data. It is important to draw attention to the fact that sometimes the data included in competitors' catalogues and supporting literature are not accurate. An example of a Chart of Competitive Wheelchairs based on metrics is shown in Table 6.4. The data in the table are fictional with companies identified by letters. The only purpose of Table 6.4 is to illustrate the technique.

**Chart of Competitive Wheelchairs based on user satisfaction**

Table 6.5 shows a comparison amongst competing wheelchairs based on users' perceived satisfaction of the degree to which the different wheelchairs satisfy their needs. Wheelchairs which scored more "dots" correspond to greater perceived satisfaction of the user needs. This is a subjective evaluation and should be carried out with the assistance of the User Panel.

6.2.4.4 Applying Quality Function Deployment to wheelchair development

The appropriateness of Quality function deployment as a formalised method of matching the expressed needs of the users to the features and functions of the product make it an ideal choice to be used as part of a User-centred method for wheelchair design. Quality function deployment was reviewed in Chapter 2, section 6.2.
### Table 6.4
Chart of competing wheelchairs based on metrics

<table>
<thead>
<tr>
<th>Metric No.</th>
<th>Need Nos.</th>
<th>Total mass</th>
<th>Fold width</th>
<th>Attenuation from push bar to main structure at 10 Hz</th>
<th>Preload on the suspension spring</th>
<th>Time to disassemble/assemble wheels</th>
<th>Headset sizes</th>
<th>Wheel sizes</th>
<th>Castor sizes</th>
<th>Maximum tyre width</th>
<th>Time to disassemble/assemble components</th>
<th>Sharp edges smoothed off</th>
<th>Time to assemble the accessories</th>
<th>Minimum corridor width of 1000 mm</th>
<th>Test of steer tube duration</th>
<th>Test of stability ISO 7176-1 (using a 100kg test dummy)</th>
<th>Test of obstacle climbing ability ISO 7176-10</th>
<th>Fatigue test</th>
<th>Unit manufacturing costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>1</td>
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</tbody>
</table>
Table 6.5
Chart of competing wheelchairs based on user satisfaction

<table>
<thead>
<tr>
<th>Needs No.</th>
<th>Needs</th>
<th>Imp.</th>
<th>Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reduce weight of wheelchair</td>
<td>5</td>
<td>A B C D E</td>
</tr>
<tr>
<td>2</td>
<td>Produce foldable wheelchair</td>
<td>4</td>
<td>* ** * *</td>
</tr>
<tr>
<td>3</td>
<td>Reduce vibration in the handles</td>
<td>3</td>
<td>** * * *</td>
</tr>
<tr>
<td>4</td>
<td>Allow easy traversal of difficult terrain</td>
<td>4</td>
<td>* * *** *</td>
</tr>
<tr>
<td>5</td>
<td>Easy to remove wheels</td>
<td>1</td>
<td>*** * * *</td>
</tr>
<tr>
<td>6</td>
<td>A wide variety of wheels and tyres fit the wheelchair</td>
<td>2</td>
<td>* ** *** *</td>
</tr>
<tr>
<td>7</td>
<td>Easy access for maintenance of the components</td>
<td>2</td>
<td>*** * * *</td>
</tr>
<tr>
<td>8</td>
<td>Sharp edges smoothed off</td>
<td>3</td>
<td>** * **** *</td>
</tr>
<tr>
<td>9</td>
<td>Easy to fit accessories</td>
<td>3</td>
<td>*** * *** *</td>
</tr>
<tr>
<td>10</td>
<td>Easy to manoeuvre</td>
<td>4</td>
<td>**** * *** *</td>
</tr>
<tr>
<td>11</td>
<td>Lasts a long time</td>
<td>4</td>
<td>** *** *** **** ****</td>
</tr>
<tr>
<td>12</td>
<td>Provides good stability</td>
<td>5</td>
<td>* *** *** **** ****</td>
</tr>
<tr>
<td>13</td>
<td>Ease of kerb climbing</td>
<td>3</td>
<td>** * *** *** ****</td>
</tr>
<tr>
<td>14</td>
<td>Is safe</td>
<td>5</td>
<td>*** * *** **** ****</td>
</tr>
<tr>
<td>15</td>
<td>Is not expensive</td>
<td>5</td>
<td>*** * * * * *</td>
</tr>
</tbody>
</table>

As previously discussed in Chapter 2, the *House of Quality* (HOQ) is a multidimensional figure that shows the relationship of the user requirements to the engineering characteristics of the product. Figure 6.3 shows a partially completed QFD figure for the design of a wheelchair. The data are fictional and were used only as an example of the application of this technique to the development of wheelchairs.

The HOQ consists of twelve regions. These are shown in brief form in the right hand corner of the Figure 6.3. Each of these regions is described below and appropriate sources of information to elaborate each region are also given.
Figure 6.3

Sample of a partially completed QFD table for the design of a wheelchair

1. User Requirements
2. User Importance
3. Engineering Characteristics
4. Correlation Matrix
5. Relationship Matrix
6. User Competitive Assessment
7. Absolute Importance
8. Relative Importance
9. Units of Measurement
10. Technical Competitive Assessment
11. Target Value
12. Technical Difficulty (Risk)

<table>
<thead>
<tr>
<th>Engineering Characteristics</th>
<th>User Competitive Assessment</th>
<th>Relative Importance (%)</th>
<th>Target Value</th>
<th>Technical Difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mass (kg)</td>
<td>Company A</td>
<td>242</td>
<td>150</td>
<td>5</td>
</tr>
<tr>
<td>Front width (cm)</td>
<td>Company B</td>
<td>196</td>
<td>165</td>
<td>1</td>
</tr>
<tr>
<td>Wheelchair frame strength at 90° (N)</td>
<td>Company C</td>
<td>72</td>
<td>180</td>
<td>1</td>
</tr>
<tr>
<td>Spring preload (N)</td>
<td>Company D</td>
<td>15</td>
<td>150</td>
<td>1</td>
</tr>
<tr>
<td>Headrest size (cm)</td>
<td>Company E</td>
<td>150</td>
<td>150</td>
<td>1</td>
</tr>
<tr>
<td>Wheel size (mm)</td>
<td></td>
<td></td>
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<tr>
<td>Ceator size (mm)</td>
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<tr>
<td>Maximum tyre width (mm)</td>
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<tr>
<td>Sharp edges smoothed off</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Easy to remove wheels</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>A wide variety of wheels and tyres fits the w/c</td>
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<tr>
<td>Easy of access for maintenance of the components</td>
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<td>Sharp edges smoothed off</td>
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<td>Lasts a long time</td>
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<tr>
<td>Provide good stability</td>
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<tr>
<td>Ease of kerb climbing</td>
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<td>Is safe</td>
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<tr>
<td>Is not expensive</td>
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</tbody>
</table>

Technical Competitive Assessment

| Company A | 15.5 | 330 | 12 | 480 | 1000 | 1325 | 14° | 20 | 1000 | 6208 | 1615 |
| Company B | 20.0 | 580 | 15 | 760 | 1000 | 1325 | 14° | 20 | 1000 | 6208 | 1615 |
| Company C | 17.3 | 910 | 14 | 500 | 1000 | 1325 | 14° | 20 | 1000 | 6208 | 1615 |
| Company D | 16.8 | 730 | 12 | 520 | 1000 | 1325 | 14° | 20 | 1000 | 6208 | 1615 |
| Company E | 18.0 | 815 | 15 | 680 | 1000 | 1325 | 14° | 20 | 1000 | 6208 | 1615 |

Target Value

| 13.0 | 330 | 10 | 450 | 146 | 1000 | 1293 | 14° | 20 | 1000 | 6208 | 1615 |

Technical Difficulty

| 5   | 5   | 4   | 2   | 3   | 1   | 1   | 1   | 1   | 1   | 2   | 1   | 2   | 3   | 2   | 3   | 2   | 5   |
1. User requirements grouped by arranging them according to each subsystem. An illustration of user requirements for the structure subsystem is given in column 3 (Need) in Table 6.3.

2. User importance ratings or weighted values as indicated by the users. This is illustrated in column 4 (Imp) in Table 6.3.

3. Metrics or engineering characteristics established in terms of measurable quantities. This is illustrated in column 5 (Metrics) in Table 6.3.

4. Correlation matrix shows the relationship between the different wheelchair's engineering characteristics. This is illustrated in the triangular roof of the HOQ shown in Figure 6.3.

5. A relationship matrix identifying the levels of influence and effect between each engineering characteristic and the users' requirements. A scale of 9 (strong), 3 (moderate) and 1 (weak) is used to weight those engineering characteristics that affect user requirements. The relationship matrix is shown in the body of the HOQ in Figure 6.3, where the relevant values are 1, 3 or 9. These scale values aid in the definition of issues of the highest absolute importance as described in 8 below.

6. The User competitive assessment is a summary of a five point scale (higher value is better) of the extent to which a company's wheelchair (A, B, C, D or E) meets user' requirements. The summary is given as a graphical profile on the right hand side of Figure 6.3. These data are a direct transcription of values on user satisfaction given in Table 6.5.

7. Absolute importance of an issue is the sum of the product of the numerical value of each element in a column of the relationship matrix with its corresponding user importance rating. For instance, in the first cell of the column "Total mass", the value 9 is multiplied by the user importance value 5, giving a total of 45). This is repeated down the column and in this instance an absolute value of 242 is obtained. This will give the inputs to obtaining the final results that are displayed in region 8. The absolute importance row is shown in the HOQ (Figure 6.3).

8. Relative importance is the determination of the percentage of the total numerical score each engineering characteristic has. The total numerical score is the sum of all the values of absolute importance appearing in row 8 (the total numerical score in Figure 6.3 = 1677). The relative importance percentage for each engineering characteristic value is obtained by multiplying the total numerical value (e.g. 242 in the first column) by 100 and dividing it by the total numerical score. For instance, for the column "Total mass": 242 X 100 = 24200 ÷ 1677 = 14.4). Those engineering characteristics with the highest ranking are the characteristics relating to a requirement considered the most important to the user and should be prioritised by the design team.

9. Units of measurement for the values corresponding to each engineering characteristic (e.g. hour, minute, kilograms, millimetres, etc). These units are given toward the foot of the HOQ (Figure 6.3) and are derived from column 5 in Table 6.4.
10. Technical competitive assessment compares the competitor's specifications for each of the product's engineering characteristics and the proposed specification to either meet or exceed each characteristic (the data are those shown in Table 6.3 and are transcribed into Figure 6.3).

11. Target values for each of the wheelchair's engineering characteristics. These values are frequently determined, in part, from benchmarking data and from independent assessment of how strongly the values impact the product's performance, attributes and features.

12. Technical difficulty, is a judgement, on a scale from 1 to 5, based on the experience of the design team and indicates the ease with which each of the product's specifications can be achieved. The lower the number the easier it is and, consequently, the risk of not meeting that characteristic is lower.

6.2.4.5 Elaborating the Wheelchair Design Specification Document

The Wheelchair Design Specification Document contains all the facts related to the product. It provides qualitative information about the functional goals of the product and quantitative information defining product performance. The Wheelchair Design Specification Document is a statement of what the product has to do and is the fundamental control mechanism and basic reference source for the entire product development activity. This document forms the basis of specifications of the wheelchair as designed and manufactured. It should be submitted to the User Panel for suggestions and criticisms.

The Wheelchair Design Specification Document should contain:

- The product title.
- A general description including the product concept and strategic goals specifying why there is a need for the new wheelchair.
- A user profile and summary of wheelchair user needs.
- Design objectives for the wheelchair.
- An ergonomic analysis including a description of product function and dysfunction and of a task analysis.
- The specification of the wheelchair user requirements and the correspondent engineering characteristics in a form of a QFD matrix.
- Design constraints related to cost, technology, regulations and standards, user capabilities, and the environment.
- Marketing requirements, including an analysis of what types of wheelchair it will be competing with, who makes them and what market it will serve.
The anticipated demand and target price.

Most of the components of the Wheelchair Design Specification Document stated above were described in the previous sub-sections with exception of some aspects such as product strategic goals, costs, technology which are not central to the remit of this thesis.

6.2.5 Concept design

As wheelchair users' requirements become defined there is a need to study the alternatives of satisfying these requirements in terms of the three-dimensional shape of the product. This phase of the User-centred method for wheelchair design involves generating solutions to meet the statements included in the Wheelchair Design Specification Document. The solution will represent the sum of all of the subsystems and their components which go to make up the whole system working as required to satisfy user needs. So, the Concept design process will start with a set of user needs and product specifications and will result in a set of wheelchair concepts from which the design team and the User Panel will make a final selection.

The Concept design phase is very complex in as much as it has several goals, many constraints and an even greater number of possible solutions. The major challenge to the design team will be to design a new wheelchair in order to meet the needs of a wide range of users, exploiting to the full the abilities of sales, marketing and distribution channels, fitting in with existing manufacturing facilities and suppliers and ending up making a profit for the company.

The Concept generation should be carried out systematically. It will be divided into the following phases: Generating concepts, Evaluating concepts, Selecting concepts, Refining concepts and Detailing design.

6.2.5.1 Generating concepts

It is essential to begin with the generation of concepts having the design problem sufficiently clarified. Clarifying the problem consists of developing a general understanding and then breaking the problem down into subproblems. This was previously done in the phase named Investigating the Problem. The Analysis of Dysfunction of the Wheelchair-User Interface revealed a number of problems that should be improved by the designers in the design of the new wheelchair.
The generation of new ideas is at the heart of the *Generating concepts* phase. There are a wide range of techniques for the generation of creative ideas such as: brainstorming, brainwriting, synectics, removing mental blocks, morphological charts, parametric analysis, problem abstraction. The choice of which technique or techniques to use is a personal choice of the designers and will depend on which one they are more familiar with. Each technique has its advantages and disadvantages. They are exhaustively described by Baxter (1995), Jones (1992) and Rozenburg and Eekels (1995). A summary of some techniques for the generation of creative ideas is shown in Table 6.6.

The objective of this phase is to accumulate as many ideas as possible, so attempts to filter them at this stage should be suppressed. As idea generation comes from imagination and creativity, rational associations, commonly used in everyday life, should be avoided. Also, ideas which initially may appear not feasible can often be improved by other members of the design team. Designers should invite the User Panel to take part in some creative sessions to help in finding solutions to specific problems. The use of renderings and mock-ups to express the designers' ideas will be more appropriate than text and spoken language. Computer-aided industrial design (CAID) tools may also be used to generate three-dimensional designs on a computer screen, with the possibility of producing a great number of detailed concepts which can be rapidly modified. Figure 6.4 illustrates the phase of *Generating concepts* with the sketch of some solutions for the design of wheelchairs (Design bei Rollstühlen, 1993).

It is important to draw attention to the fact that, as opposed to the engineers' team who focus their attention upon finding solutions to the technical subfunctions of the product, the design team will concentrate upon creating the product's form and user interface. Naturally the concepts resulting from the design team intervention should meet user needs and product specifications previously defined.

### 6.2.5.2 Evaluating and selecting concepts

According to Roozenburg and Eekels (1995), design is a process of divergence and convergence. As an evolutionary process, the design of a product grows from a product idea via solution principles, concepts and preliminary designs to a detailed definitive design. A number of concepts are generated in each phase and need to be evaluated and selected in order to find the best solution to the design problem.
Table 6.6
Summary of some techniques for idea generation (from Baxter, 1995 and Jones, 1992)

<table>
<thead>
<tr>
<th>Technique</th>
<th>Procedures</th>
</tr>
</thead>
</table>
| Brainstorming   | • Select a group of people to produce ideas.  
• Enforce the rule that no idea is to be criticised and make it clear that wild ideas are welcome, quantity is wanted and that participants should try to combine, or to improve upon, the ideas suggested by others.  
• Record the ideas put forward and evaluate them afterwards.                                                   |
| Brainwriting    | • Select a group of people to write a limited number of ideas on a single sheet of paper, either in columns or rows.  
• Each sheet is then handed to someone else in the group and they have to try to improve or develop all of the ideas a step further by adding a new row or column until ideas have been exhausted or until each sheet has been round every group member.  
• Carry out a conventional session of brainstorming to bring out any completely new ideas not on any of the sheets but stimulated during the brainwriting process. |
| Synectics       | • Form a group of highly selected people to operate as an independent development department  
• Give the group a lot of practice in the use of direct, personal, symbolic and fantasy analogies to relate the spontaneous activity of brain and nervous system to the problem.  
• Submit to the group difficult problems that the parent organisation cannot solve and allow plenty of time for solving  
• Submit the group's output to the present organisation for evaluation and implementation.                          |
| Removing Mental Blocks | • Transformation rules that can be applied to an existing unsatisfactory solution or to parts of it (e.g. put to other users?, adapt?, modify?, substitute?, reverse?)  
• Searching for new relationships between parts of an existing unsatisfactory solution.  
• Re-assessment of the design situation.                                                                          |
| Morphological chart | • Define the function that any acceptable design must be able to perform.  
• List, on a chart, a wide range of sub-solutions, i.e. alternative means of performing each function.  
• Select an acceptable set of sub-solutions, one for each function.                                                   |
| Parametric Analysis | • Pick up an existing product which comes closest to solving the problem with particular attention being paid to the parameters in which the product fails to provide a complete solution.  
• Analyse the product features in terms of quantitative parameters (size, power, speed, strength, price, efficiency, durability), qualitative parameters (ranked or scaled to other products) and categorical parameters (categories the product belongs to).  
• Indicate how these parameters would have to be different to fully solve the problem.                             |
| Problem Abstraction | • Make a statement of the problem.  
• Ask "why" the design team want so solve the problem.  
• The answer is then challenged with further "why" questions until the company's ultimate objective is reached.  
• Each level of abstraction should reveal a new set of potential solutions.                                           |
Thus, the objective of this phase of the User-centred method for wheelchair design will be to establish criteria in which a large number of functional and conceptual ideas will be filtered and selected in a form to choose the best options to meet user requirements and product specifications.

The use of matrices as a means of structuring or representing evaluation and selection procedures is advocated by a number of authors including Baxter (1996), Fox (1993), Magrab (1997), Pugh (1991) and Ulrich and Eppinger (1995). In the User-centred method for wheelchair design, it is recommended to use some or all of the user requirements, identified in the previous phases, as criteria to evaluate the design concepts.

The Matrix for evaluating and selection concepts (Table 6.7, based on Magrab, 1997; Pugh, 1991 and Ulrich and Eppinger, 1995) works as a means to narrow and improve a number of product concepts. The phase of evaluating and selecting concepts permits that: a) the several concepts may be compared; b) some alternatives be eliminated; c) iterations may be performed in such a way that new alternatives may arise from the combination of the features of some concepts; and d) further reduction may be carried out to choose a few concepts entitled to a refined selection.
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The *Matrix for evaluating and selection concepts* should be used to analyse different aspects of the product such as its subsystems, sub-subsystems, components, or combinations of them. Also, it would be extremely useful to analyse aesthetic aspects of the product and its components. The participation of the *User Panel* to help the design team to analyse certain aspects of the matrix, for example aspects concerning aesthetics and usability, is indispensable.

Table 6.7 - The matrix for evaluating and selecting concepts

<table>
<thead>
<tr>
<th>SUBSYSTEM: PUSHANDLE</th>
<th>Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection criteria</td>
<td></td>
</tr>
<tr>
<td>Ease of handling</td>
<td>A</td>
</tr>
<tr>
<td>Ease of use</td>
<td>B</td>
</tr>
<tr>
<td>Ease of removal</td>
<td>C</td>
</tr>
<tr>
<td>Manoeuvrability</td>
<td>D</td>
</tr>
<tr>
<td>Sharp edges are smoothed off</td>
<td>E</td>
</tr>
<tr>
<td>Reduction of vibration in the hands</td>
<td>F</td>
</tr>
<tr>
<td>Good stability</td>
<td>G</td>
</tr>
<tr>
<td>Adjustability</td>
<td>H</td>
</tr>
<tr>
<td>Help in kerb climbing</td>
<td>I</td>
</tr>
<tr>
<td>Easy to fit accessories</td>
<td>J</td>
</tr>
<tr>
<td>Wheelchair foldable</td>
<td>K</td>
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<tr>
<td>Safety</td>
<td>L</td>
</tr>
<tr>
<td>Low manufacturing costs</td>
<td>M</td>
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<td>Sum +'s</td>
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<td>Net Score</td>
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<td>Continue?</td>
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<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of handling</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ease of use</td>
<td>R</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>0</td>
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<td>Ease of removal</td>
<td>E</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Manoeuvrability</td>
<td>F</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Sharp edges are smoothed off</td>
<td>R</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Reduction of vibration in the hands</td>
<td>E</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Good stability</td>
<td>N</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Adjustability</td>
<td>C</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Help in kerb climbing</td>
<td>E</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Easy to fit accessories</td>
<td>C</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Wheelchair foldable</td>
<td>O</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Safety</td>
<td>N</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Low manufacturing costs</td>
<td>C</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Sum +'s</td>
<td>E</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>6</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Sum 0's</td>
<td>P</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Sum -'s</td>
<td>T</td>
<td>3</td>
<td>-3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>-1</td>
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<tr>
<td>Net Score</td>
<td>R</td>
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<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
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<tr>
<td>Rank</td>
<td>S</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Combine</td>
<td>Combine</td>
<td>No</td>
</tr>
</tbody>
</table>
The steps involved in preparing the matrix, as in Table 6.7, include the following phases:

**Preparation**
- define the team which will take part in the evaluation and selection sessions including the User Panel. Be sure that all members are supplied with enough information about the concepts to be evaluated and selected and a list of criteria to be used
- provide a display panel for figures, white board and or a flipchart, if required
- provide appropriate support materials, e.g. pencils and notepads
- be sure that each concept is presented in the form of sketches, rendering, mock-ups and/or models and they are all illustrated/presented with the same level of detail
- establish the selection criteria against which the concepts are to be evaluated and list them down the first column on the left-hand side of the matrix. The criteria should be based on user needs and the needs of the company such as low manufacturing costs or minimal risk of product liability. Be sure that the criteria chosen are absolutely important, relevant, unambiguous, understood and accepted by all participants in the evaluation and selection sessions
- choose a concept to become a reference against which all other concepts are rated. The reference may be: a) an industry standard; b) an obvious solution to the problem; c) a design/concept commercially available for the product, subsystem or sub-subsystem; and d) in the case where competitive designs/concepts do not yet exist, any one of the concepts under consideration that the group agree intuitively as the best choice. The reference concept is placed in the second column of the matrix

**Rating the concepts**
- make comparison between each concept and the chosen reference
- according to a team consensus, for each concept attribute relative scores, such as "better than" (+), "same as" (0), or "worse than" (-) the chosen reference and in relation to each one of the selection criteria
- write down the relative score in each cell of the matrix which makes the intersection between the concept and the selection criteria on which is currently being analysed, for instance, when the concept "B" was rated against the selection criterion "Ease of handling", it got the score "+".

**Ranking the concepts**
- add the +'s scores ("better than") and enter the result in the appropriate cells in the lower row of the matrix
- do the same with the 0's ("same as") and -'s ("worse than") and enter the result in the appropriate cells
• calculate the Net Score subtracting the number of scores which have received "worse than" ratings from those which have received the "better than" ratings. Ignore those which have been rated "same as"
• rank ordinally the concepts which have received more pluses and fewer minuses.

Combining and improving the concepts
• observe if there are any good concepts which are affected by any bad features
• if affirmative, consider if these concepts may be combined to preserve the "better than" and cancel the "worse than" qualities, e.g. In the sample on Table 6.7, concepts E and F can be combined to form a new concept (Concept EF) and will be considered in the next phase of Refining concepts

Select the concepts and reflect on the results
• decide with other the participants (including the User Panel), which concepts are to be selected for further refinement
• reflect on the result of the process

As previously mentioned, the design team will use mock-ups and models to represent their design concepts. The terms mock-up, model and prototype may sometimes be ambiguous. In this thesis the word "prototype" refers to a functional and physical representation of the entire product as it will eventually be manufactured. "Prototypes" are different from "mock-ups" which represents the size and shape of a product subsystem or component, but with no relation to function and appearance; and "models" which represents the size, shape and appearance of a product, subsystem or component, but with no relation to function. If on the one hand prototypes are working representations of the product in full size scale, mock-ups and models are generally built on a small scale and according to the level of detail required to represent the types of static evaluations and simulations that are planned. Mock-ups and models are used to evaluate the feasibility of specific design concepts with the objective to validate the concept and to identify any obvious or foreseeable problems before incurring the cost of building a working prototype. So, mock-ups and models, differently from prototypes, can be made of paper, foam, wood or any other material without connection with the material which will be used in the final version of the product. Figure 6.5 shows examples of some wheelchair models made to represent different design concepts (Design bei Rollstühlen, 1993).
6.2.5.3 Refining concepts

Refining concepts is used to help in the final decision to select one or more concepts able to be developed. A matrix of refining concepts (Table 6.8), similar to the previous Matrix for evaluating and selecting concepts, is built using the following steps:

Preparation
- similar to the previous matrix each concept is presented in the form of sketches, rendering, mock-ups and/or models and may include more details to express its forms and functions
- establish the selection criteria against which the concepts are to be evaluated as was previously done. Most of the criteria should be the same as those used in the previous Matrix for evaluating and selecting concepts and, if appropriate, can be deployed to help the assessment.
Table 6.8
The matrix of refining concepts

<table>
<thead>
<tr>
<th>SUBSYSTEM:</th>
<th>Weight</th>
<th>Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUSHHANDLE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selection criteria</td>
<td></td>
<td>Rating</td>
</tr>
<tr>
<td>Ease of handling</td>
<td>5</td>
<td>R 3</td>
</tr>
<tr>
<td>Ease of use</td>
<td>5</td>
<td>C 4</td>
</tr>
<tr>
<td>Ease of removal</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Manoeuvrability</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Sharp edges are smoothed off</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Reduction of vibration in the hands</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Good stability</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Adjustability</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Help in kerb climbing</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Easy to fit accessories</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Wheelchair foldable</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Low manufacturing costs</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Total Score</td>
<td></td>
<td>P 270</td>
</tr>
<tr>
<td>Rank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continue?</td>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>
Chapter 6: Wheelchair Design Method

Rating the concepts

- make a comparison between each concept and the chosen reference concept for each selection criterion
- according to a team consensus, for each comparison produce a rating of:
  1 = much worse than reference concept
  2 = worse than reference concept
  3 = same as reference concept
  4 = better than reference concept
  5 = much better than reference concept

For example, when the concept "B" was rated against the reference concept for the selection criterion "Ease of handling" it got the rating of 3.

- for each selection criteria and for each concept, multiply the "weight" by the "rating" and write down the value in the Score column. For example, completing the case described under the previous bullet point, the rating of 3 is multiplied by a weight of 5 to give a score of 15.

Rank the concepts

- add the scores for each concept, e.g. the total score for concept "B" is 270, for "D" is 250, and for "EF" is 420.
- order the concepts, with that obtaining the highest total score in the first place and the lowest total score in the last place

Combining and improving the concepts

- as in the previous matrix, observe if there are ways to combine and improve good concepts

Select the concept and reflect on the results

- decide, in consensus with the participants, which concept is to be selected for further development
- reflect on the result of the process and be sure that the concept is in accordance with what was previously established in the QFD matrix.

6.2.5.4 Detailing design

The objective of this phase of the User-centred method for wheelchair design is to show, in the form of drawings (using either paper or an electronic Computer Aided Industrial Design
system), that the chosen concept has its properties detailed sufficiently well to be modelled and/or prototyped, and manufactured.

Products comprise certain properties. Only some of the product properties can directly be determined by industrial designers. Examples of some properties which can be determined by industrial designers include: the structure of the entire product (the arrangement of the parts), the shape, the dimensions, the material, the colours, the surface quality and texture. Properties which are not usually part of an industrial designer's body of knowledge include the analysis of tolerance, corrosion resistance, strength and durability of materials, the choice of manufacturing method, the analysis of product value. Most of the product properties, in terms of specifications, have been defined since the first phases of the design process and have already been incorporated in the concept choice.

This phase of the design process includes progressive levels of complexity between the production of sketches, mock-ups and/or models made in the conceptual phase and the more detailed specification of materials, principles and manufacturing process required in the design of a prototype or the "job one" (the master copy of the product which will later be mass produced). Part of the Detailing design phase can be considered as included in the production development and production planning of the product which are mentioned briefly in the next step of this design method. These steps involve the participation of other technical professionals such as manufacturing and mechanical engineers.

Based on sketches and models built in the previous design phase, the industrial designer will draw and detail the product's geometrical shape, dimensions, material, colour, arrangement of subsystems and components. Details related to some aspects of the product such as aesthetic appeal, safety, user interface, product maintenance, should be carefully specified. Intermediate stages in the detailing design may require that designers produce models to check the accuracy of data. The Detailing design phase also involves decision about which components will be bought in (i.e. as standard catalogue items) and which will be manufactured, either in-house or by sub-contractors.

It is important to mention that in this phase of the design process, all the subsystems and components, which represent customer needs, functionality and style, should be brought together and integrated into the whole product ready to be manufactured.

Two other design activities are also included in this phase of the User-centred method for wheelchair design: the design of the user manual and the design of promotional material.
The design of the user manual

One of the major objectives of the user manual is to give instructions on product operation. The prevalence of inadequate user manuals contributes to the fact that users may ignore important information or simply avoid consulting the manual. A clear understanding of user needs and the way they perform using the product is the first step to enabling the design team to develop an adequate user manual.

The designing and writing of usable user manuals have been covered by a number of authors including Cushman and Rosenberg (1991), Coskuntuna and Mauro (1980), Instruction for consumer products (1988), Laughery and Young (1994), Weiss (1985) and Wright (1981).

Cushman and Rosenberg (op. cit.) recommend the following steps for the design of good user manuals:

- Organise material in a logical manner consistent with reader expectations.
- Provide adequate structure (e.g. different type styles and sizes for main headings and subheadings, use of spacing for demarcation, descriptions in margins, highlighting, etc.).
- Present only information that the reader will need.
- Use words that the reader will understand.
- Use simple sentences and the active voice.
- Present sequential instructions and procedures in lists, outlines with "bullets", or flow diagrams rather than in paragraph form.
- Use figures to help to clarify the message.
- Place figures and accompanying verbal explanations on the same page or facing pages.
- Test, revise, and retest the user manual until novice users can perform all tasks without difficulty.

As a product which may have among its users, a significant number of people with poor cognitive ability, designers should pay special attention to the design of user manuals for wheelchair users including the use of large and sans-serif fonts, the provision of illustration wherever feasible and the provision of text description for all illustrations. The design team should submit a draft of the user manual of the new wheelchair for the appreciation and criticism of the User Panel.
The design of promotional material

The design of promotional material is part of the company's marketing strategy. This phase does not directly involve industrial designers and ergonomists and is not part of the scope of this thesis.

6.2.6 Prototyping

Although a number of design and engineering problems can be solved using computer simulation, drawings, mock-ups and models, building a physical prototype, as a functional representation of the final product, permits the design team to test and evaluate the design concept. The prototype will help to evaluate the wheelchair performance in terms of meeting the required specifications and user needs and will reveal problems that arise from the engineering of the product.

It is expected that tests with the prototype will identify any remaining problems, in terms of product specification, that were not be identified in the previous phases of design. Otherwise a large amount of money and time may be spent later in the production process to remedy any failures. An example of a prototype of a wheelchair built to test product performance is shown in Figure 6.6 (Design bei Rollstühlen, 1993).

The building of a prototype for the new wheelchair concept will be useful for:

- learning if the concept represented by the prototype will work and meet the customer needs and the product specifications
- communicating the product concept and its features to the top management personnel, partners, vendors, users and other members involved in the product development process. It is easier to obtain feedback on the product using a visual, tactile and three-dimensional representation than by verbal description or even sketches and drawings of the product
- integrating the subsystems and components of the product in a such way as to ensure that they work together as expected
- testing and verification of the new wheelchair in terms of the user-product interface and assembly and interconnection of all parts
- checking if safety and legal issues are satisfied
- assuring that raw materials and purchased components will meet performance and delivery requirements
- checking if costs and production scheduling will be within specified limits.
6.2.7 Testing and verification

Product testing and verification is usually carried out throughout the phase of Concept design, with an evaluation of the first mock-ups and of the design and engineering models, and it concludes with verification tests of prototypes at field sites. In fact, one of the major aims in building a three-dimensional representation of the product is to compare objective user-performance data obtained from the test with the product specification. In such a way, testing and verification is a critical phase to improve product usability and quality, to reduce the likelihood of legal action against the product's manufacturer and contribute to the success of the product in the marketplace.

In this method, the word testing is used to refer to those procedures which take place in a laboratory or other controlled environment. Verification refers to those tests that are carried out in a field environment rather than in a laboratory. A review of product evaluation is given in section 2.3.4, page 24, of this thesis.
Although physical tests are essential to verify the wheelchair's technical quality such as fatigue tests, they are not part of the objective of this thesis. The User-centred method will focus on usability tests involving representative product users (the User Panel) and working prototypes. Figure 6.7 illustrates an example of testing the technical, functional and handling properties of a wheelchair prototype.

According to Hekstra (1993), the main issues regarding wheelchair testing programmes are:

- the user-wheelchair interface with respect to dimensions and operations
- the performance of the wheelchair with respect to matters such as rolling resistance and manoeuvrability
- the performance of the wheelchair with respect to safety including its stability and the efficiency of its brakes
- the technical quality of the wheelchair under different conditions of use involving strength and durability requirements.

It is suggested that in the User-centred method for wheelchair design the coming guidelines be followed by the design team in the usability testing and verification of wheelchair prototypes (based on Cushman and Rosenberg, 1991; and Dumas and Redish (1993).

Planning the usability test

- provide the facilities in which the tests will be carried out. The facilities here are similar to those used in the focus group sessions and the same recommendations are applied (see page 279)
- define the resources (people, equipment, time, money, etc.) that should be devoted to the testing and verification phase. Members of the User Panel should be invited to take part in the tests.
- carry out a literature review on standards and previous tests of this or other similar products
- establish the aims of the testing and verification including what will be measured (objective measures, e.g. time to complete a task and error rates; and subjective measurements, e.g. user's perceptions, opinions, and judgements).
- select the tasks that users will perform including assembly, storage, maintenance, and following instructions in the user manual, bearing in mind that the tests will probe areas of potential usability problems. Information obtained from task analysis, interviews and focus groups can help the design team to set what to measure.
Figure 6.7
Example of testing of technical, functional and handling properties of a wheelchair prototype
• establish qualitative (subjective measurements) and quantitative criteria (objective measurements) for measuring performance which focus on users and not on the wheelchair
• define the duration of sessions and tests, taking into considering the product complexity, the objectivity of the tests, the number of participants involved and the length of time each task will be performed by the user
• decide on the test scenario, which means the description of tasks to be carried out in a way that takes some of the artificiality out of the tests. The scenario will tell the participants what they will do during the test.
• decide where the tests will be performed either a) in a laboratory or other controlled environment, and/or b) in a field setting (e.g. users' home or public premises).
• define the techniques used for observing and recording the tests including video recording, automated data collection, questionnaires, focus group sessions
• organise files, with name and data of each participant, to register their performance doing the tasks
• be sure that the Concept of Minimal Risk is strictly observed. Minimal Risk means that "the probability and magnitude of harm or discomfort anticipated in the test are not greater, in and of themselves, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests" (Dumas and Redish, 1993, p. 205)
• obtain a written informed consent from the participants stating that they are aware about the procedures the tests will follow, the purpose of the test, any risks involved, the opportunity to ask questions and the opportunity to withdraw at any time.

The use of the findings from the Analysis of Dysfunction of the Wheelchair-User-Interface in the phase of Delimiting the problem (page 287) should be extremely useful.

Conducting the usability test
• greet the participants and create a relaxing atmosphere calming any fears or anxieties the users may have in testing the new wheelchair
• explain the test scenario to participants being sure that they understand clearly all the tasks to be performed
• take special care if the tests will be performed in the user's home or public premises considering that other persons may be present at the location and the participant may be shamed
• ask participants to think out loud so the design team can hear and record their reactions to the wheelchair. Give users instruction on how to think out loud as if they are alone in a room and one or two warm-up exercises before they start to perform the required task.
• use checklists with the task scenario
• register, on an appropriate form, the results of the tasks as they are being performed
• register, on an appropriate form, any unforeseen problems that may appear
• record the whole session using a video camera

Analysing the results
• tabulate the data and use, if appropriate, statistics to describe the findings of the data
• summarise the findings organising the problems a) by subsystems, b) prioritising those which have the widest scope and c) organising them by level of severity
• analyse and interpret the results making clear if the prototype is meeting or not user needs
• propose recommendations

Reporting the usability test
• organise a meeting with the managers and product development team to show the results of the usability tests
• to support the presentation, the design team may use figures, graphics and a highlighted videotape including the most important findings
• in addition to the verbal presentation, write a report to the company’s managers and other members of the product development team with the findings of the usability tests in a similar way to that made to report the focus group findings (see page 279). This written report will constitute the documentation of this phase of the User-centred method for wheelchair design

6.2.8 The phases of Product Production and Marketing

A product design is ready for production if all design properties have been specified definitively and with all required details. Although the manufacturing process should have been considered in the later phases of concept and detail design, and prototyping, the wheelchair must be almost entirely specified for the manufacturing process.

According to Magrab (1997), there are basically three very important, and inextricably linked, elements in the product development cycle: assembly methods, manufacturing process and material selection. These greatly affect the final product's cost, marketing time, plant production, degree of manufacturing automation, productibility, and reliability. The Quality Function Deployment technique should continue to be used throughout the product development and manufacturing processes to guarantee that the users' voices will continue to be heard (see Chapter 2, page 67).
The final phases of the User-centred method for wheelchair design - product production (including manufacture and assembly), market product and customer support - are not directly involved with design and, in view of this, are not discussed in this thesis.

6.3 Investigating the suitability of the proposed methodology

A sample of four designers who had previously participated in the field study at the start of the work was approached. This relatively small number was due to the time available which made it impossible to have more respondents involved. The aim was to collect their views on the extent to which the proposed method was acceptable to them. The main criterion for choosing the selected designers was to represent those companies which provided the best practice in terms of Design Methods (sub-chapter 3.2.3, page 77). One of these companies may be considered as one of the biggest wheelchair manufacturers in the United Kingdom. Another company was a manufacturer of scooters, whose design and production process has a number of similarities with that of electrical wheelchairs.

**Procedures**

Each designer was willing to be interviewed in their workplace for about one hour. The designers were shown a summary of the method (Appendix 6.1, page 465) in a form to be read and commented on during the time available for the interview. It was decided not to structure the interview with specific questions to avoid guiding the interviewee and drawing attention to certain points. Instead, they were asked to read the summary and to produce comments while they were reading the text. In this way the researcher tried to explore their comments, questioning respondents when appropriate. The interviews were tape-recorded and transcribed. The comments provided by the designers are described in the next section.

6.3.1 Designers comments

Highlights of the comments and recommendations made by the designers are shown according to each phase of the method. There was no comment related to the phases of Product Production and Market Product. Their general comments about the method is shown at the end of this section. For reasons of comprehensibility and brevity the comments were slightly edited. Where possible, the original words were kept.
Preliminary Strategic Planning

Companies A and B
- No comments on this phase.

Company C
- You are going from Preliminary Strategic Planning straight to approaching the users. It is not possible, as we know, to actually design a wheelchair that will suit all disabled people. The way that wheelchairs are now being supplied and developed is to target specific people. I would suggest that one of the steps that is missing here is identifying what the user group in fact is. If you actually choose to get a lot of users in, you will get a very diverse range of requirements and will not be able to design anything to meet that lot of requirements. The way to actually produce wheelchairs these days is to specifically aim to supply a particular need and then from that need to identify specific problems related to that type of group or that type of people or that type of environment. Unfortunately, as you get narrower and narrower with you identification of the user you are building more and more specific features, the things become more targeted and the volume of manufacturing to develop it will determine the costs of the finished product.

Company D
- It is necessary to stress the importance of the "Identification of the target market" as one of the first points to be considered in this phase because it represents the business opportunity that the company may have missed.

Approaching the Users/User Panel

Company A
- Dealer Panels are very important and should be used in addition to the User Panels. This is because dealers promote the product to a user and they need to be happy about the product costs and ease of use. It is also important to involve therapists. Users have strong opinions dependent on their particular disability leading to difficulties in reaching a consensus. Dealers, carers and therapists all together can help balance out the view to get a good practical design.

Another important point to pay attention to is related to secrecy. It is necessary to choose users of products produced by their own company and who will usually agree to stay silent
Chapter 6: Wheelchair Design Method

...on certain things. Although therapists have a lot of knowledge and give useful insights, they can make comments which can be detected by competitors which can be a problem.

Company B
- Just saying wheelchair users is probably insufficient. It is necessary to be very clear about the type of disability to be targeted with the design of the new wheelchair. Be aware that lots of research on wheelchairs fails because it uses wheelchair users who have just been around the laboratory or paraplegic athletes that do not represent the whole population of users. So, if the wheelchair is aimed at a broad range of disabilities there will be a need to have a broad range of wheelchair users. You need to make sure that the focus groups are representative in the first place.

Company C
- No comments on this phase.

Company D
- It is important that the User Panel is representative. It should include elderly users whose physical abilities are deteriorating very fast. These have as a consequence a range of specific requirements.

Investigating the Problem

Company A
- This is a very difficult step in view of the diversity and complexity of problems and the number of requirements which they involve. It is essential to split the problems and then decide what to work on because it is not possible to produce a single solution to all the problems involved.

Company B
- You have to be critical at this stage because investigating the problems you can produce very different problems with different people using wheelchairs.

Company C
- One aspect that it is not mentioned here is identification of standards. Certainly within this context my view would be that there should be an analysis of relevant legislative requirements as well. So, in addition to the user input, there is also an input of legislation and requirements and constraints that are also demanded.
Company D

- You must pay attention to standards. The Medical Device Directory came into force on 16th June 1998 requiring that manufacturers have to declare in writing that their products are safe according to the items stated by the standard.

Product Planning

Company A

- To have a written specification is absolutely essential. The Design Specification Document is a document that the design team always needs to refer back to see if the specifications are met correctly. It is also important to compare competitors' strengths and weaknesses. The QFD matrix is nicely laid out and will help in making a decision and keeping in the right direction. It is mainly important for the less experienced designers.

Company B

- In terms of attributing level of importance to the List of Refined User Needs and their associated Metrics (Table 6.2, page 291), the hard bit is not really how to quantify, the hard bit is actually interpreting what the User Panel specifies in the first place to find out what their needs actually are, that is very difficult and expensive.

Company C

- No comments on this phase.

Company D

- "I like the QFD matrix. My goodness, that's a good way to handle it. That's brilliant, I like that. That's a very logical and progressive way of going about this".

Concept Design

Company A

- It is important to consider the different markets abroad and to provide a different flavour of the chair to each country. E.g. in Scandinavia the users often want an offset push handles that fit away from the back of the chair whereas in the UK and France users do not want offset push handles. In this company we use brainstorming to develop new concepts.
Chapter 6: Wheelchair Design Method

The tables to evaluate the concepts (pages 307 and 311) are very useful to help the designers to evaluate the concepts in a systematic way. My company does not use a systematic approach to select concepts. The principle shown in the method is very sound because it will help people to sort out the problem and add weight to their argument.

Company B
- No comments on this phase.

Company C
- I think that the pre-conceptual statement "to meet the needs of a wide range of users" I wouldn't quite say that. I would say to meet the needs of users more adequately. In terms of modularisation, I think that our view in this company is that it is more engineering assessment then designing fitness for purpose. But if you can actually do that, fine.

Company D
- The modularity should be a solution to producing a wheelchair to suit a larger number of the wheelchair user population.

Prototyping

Company A
- Prototypes are essential not just for physical tests but also to show people who usually have difficulties in visualising drawings, even 3D drawings and computer simulations. Prototype importance is evident as dealers can be invited to be present at some test sessions.

Companies B, C and D
- No comments on this phase.

Testing and Verification

Company A
- Testing is very important and will always be done to an ISO, TUV from Germany, or British Standard. If results of the test show any product failure, the prototype should
return to the concept phase. So, I suggest that there should be a feedback loop in the phases of Concept Design, Prototyping, and Testing and Verification.

Companies B and C
- No comments on this phase.

Company D
- It could be difficult to obtain agreement and consensus when the User Panel judges aspects of the Concept Design.

Manufacture and Assembly

Companies A, B and D
- No comments on this phase.

Company C
- You make a prototype and test, you then do an evaluation and complete your design work and go to production. In production you may well make a small run which is closely monitored by the design quality engineering. You then make 500 of them and they don't reflect what was required. So, certainly the viability of the process needs to be assessed here. There is a need for continuing monitoring.

Customer Support

Company A
- It is important to pay attention to the importance of the Customer Support phase because it will give customer feedback to check if the product is meeting the needs of the user.

Companies B, C and D
- No comments on this phase.

General comments about the method

Company A
- I like what I see, that is good. If you just strengthen up this loop between design and redesign and include European Community requirements. This is good - a well laid out design. I have used something like that in a more sophisticated market, not for
wheelchairs. I don't know what our competitors do, but I haven't seen it used in this type of market. Good.

Company B
- I think that this is actually very good. However, I don't know how likely it is to be used for smaller, low value market products. The most likely place it would be used is where the N.H.S. has the contract. It is time to replace the old design. I think that you really need to produce for a very large quantity. I could use this kind of method for small quantities but you have to maybe tailor the concept to your particular market, your particular wheelchair category. You made the assumption that the users will tell you what their needs are but in fact the needs of the users were perceived and may not actually be real needs or may perhaps be a false perception resulting from the way they communicate their needs. But the method is very comprehensive and very good.

Company C
- It is a very comprehensive analysis of the process of design you've done there. My main comment is the identification of users will be more useful in the early stages because if you have done it you will give the designers a chance to actually find a problem that you can solve. I do not think that producing a wheelchair for a large market is possible. In this company we will never use that type of formal analysis. I think that may be because we are traditional. We prefer a more hands-on, good feel approach, than an analytical approach like this. Talking to people about your product and getting involved with users does not necessarily mean creating a hard analytical thing. As I said, we will actually find more success from speaking to people about their problem. We have several formal ways of doing that. But there is no one route and we don't think that there is a particular department, we have several departments with user contacts. I have got user contact...

Company D
- The method is much more rigorous than what is done in this company. This is because my company is a direct selling organisation which is a very close to the market and able to monitor what the market wants. The method could be used for large companies aiming to produce a wheelchair in large quantities but I'm worried about the amount of time spent to carry out the User Panels.

6.3.2 Lessons learned from the designers comments

Generally speaking the designers who investigated the suitability of the proposed method for wheelchair design provided positive comments. There was not a pre-presentation of the
method and it was found to be difficult to introduce a method with such a level of complexity in only one hour of interview. Although a file with a graphical summary of the method was used (Appendix 6.1), the respondents sometimes made comments on aspects of design that were already taken in consideration, but which were not described in detail in the summary form presented to the designers. For example, the designers said that more people should be used than the number prescribed for the User Panel. However, this would occur in the focus group sessions in the phase concerned with Approaching the Users.

Some of their comments which need to be taken into consideration are described below.

- Only one designer (Company C), whose company is an N.H.S. supplier and does not sell directly to the end user, disagreed with the concept of a mass produced wheelchair. According to him, "the way to supply wheelchairs these days is to specifically aim at supply to a particular need". A recent publication from the Disability Information Trust (Barret et al., 1998) shows a number of wheelchairs currently available in the market place: there are 21 different models of standard self-propelled wheelchairs (pages 72 and 73) and 13 different models of attendant-propelled manual wheelchairs (pages 48 and 49). By definition, these categories of wheelchairs should satisfy a large range of users: those with or without upper limb strength to propel and manoeuvre the wheelchair by themselves, or those who rely on a carer. The views of the designer from Company C were much more related to the manufacturing of wheelchairs on an individual basis than an industrial scale. Certainly the 34 different models currently available in the market place were designed to be manufactured on an industrial scale and to meet a larger range of disabilities than those manufactured "to supply a particular need".

- The involvement of other stakeholders (e.g. therapists and rehabilitation engineer) in the design process, suggested by the designer of Company A, and the needs for the User Panel to be representative of the different ranges of disabilities had already been taken into consideration. The suggestion to involve the dealers in part of the design process is an important point to be considered.

- The importance of considering standards in the design method, mentioned by two designers, was mentioned in "Reviewing the state of the art", in the phase of Product Planning but was apparently overlooked.

- Correctly interpreting the needs of the users, as stated by one of the designers, is without doubt one of the points responsible for the success of a product. It will basically depend on the skill of the design team. The help of other stakeholders, such as carers and therapists, may be useful to help to clarify points which the users have difficulty in articulating themselves.
• A loop in the phases of Concept Design, Prototype and Testing and Verification should be considered in such a way that the concept that is not successful in the phase of Testing and Verification may be returned to be modified in the Concept Design and Prototyping phases again.

• The need to assess the phase of Manufacture and Assembly as a function of what was defined in the Preliminary Strategic Planning should be taken into consideration.

• The possibility of using the Customer Support phase to monitor the product performance in the marketplace and obtain feedback to be used for other products to be developed by the company in the future should also be considered.

• The designers were unanimous about the quality of the method. They drew attention (with the exception of the designer of Company C) to the fact that, in their opinion, this method is only justified if it is applied to manufacturing on a large scale.

A revised version of the flowchart of the User-centred method for wheelchair design including the recommendations made by the designers is shown in Figure 6.8. Observe that, compared with the previous version (Figure 6.1, page 272): a) a Dealer Panel was included to provide views on some phases of the design process including the Preliminary Strategic Planning and Test and Verification; b) there is a link between the phases of Testing and Verification and Concept Design which permits a loop between these two phases and the phase of Prototyping; c) there is a link between the phases of Manufacture and Assembly and Preliminary Strategic Planning (this will allow checks to be made on whether or not the manufacturing process is in accord with what was previously established); d) the phase of Manufacture and Assembly feed back to the Product Production phase (two-way arrow) to permit the checking of the first manufactured units against what was established in Production Planning; and e) the feedback of the Customer Support phase will generate inputs to the development of future products.

The final proof of the pudding¹ is whether the method is accepted, works well in an organisation and produces better quality products at less cost. Unfortunately, the effective implementation of the method involves time and resources beyond those available for the completion of this Ph.D. work.

¹ "The proof of the pudding is in the eating", an old English proverb.
Figure 6.8
A revised version of the User-centred method for wheelchair design

Preliminary Strategic Planning
- Define overall budget
- Lay down outline timetables
- Establish preliminary guidelines for innovation
- Define applicable technologies
- Define market segments
- Identify competitive products

Approaching the Users
- Establishing user's needs
- Select users for the User Panel

Investigating the Problem
- Recognising the Problem
- Delimiting the Problem
- Formulating the Problem

Product Planning
- Carrying out Task Analysis
- Refining User Needs
- Reviewing the State of the Art
- Applying QFD to Wheelchair Development
- Elaborating the Wheelchair Design Specification Document

Product Production
- Production development
  - Select manufacture methods and process parameters
  - Select materials
  - Select suppliers
  - State expected costs
  - Select assembly needs and procedures
  - Execute production design documentation
  - Design technical trials
  - Conduct technical tests
  - Appraise the results of trials and modify design if necessary
- Production planning
  - Prepare marketing plans
  - Prepare production plans
  - Design jigs and tools

Manufacture and Assembly
- Meeting product design specification
- Meeting production schedule

User Panel

Dealer Panel

Concept design
- Generating concepts
- Evaluating concepts
- Selecting concepts
- Refining concepts
- Detailing design
- Designing the user manual
- Designing promotional material

Prototyping
- Building the prototype

Testing and Verification
- Prototype evaluation including user manual
- Prototype modification and retesting
- User manual revised
- Promotional material

Customer Support
- Giving training to users
- Providing product maintenance
- Providing repair service
- Monitoring product's performance
- Carrying out user surveys
- Carrying out product review

Market Product
- Producing product advertising
- Giving training to the sales personnel
- Distributing the product

Feedback to develop futures
"Preliminary Strategic Plannings"
Part 4: OUTCOMES

- Findings, conclusions and recommendations for further studies
Chapter 7: Findings, conclusions and recommendations for further studies

An assessment of the major findings of this thesis is made in this final chapter. Initially the major points from the literature search and the field studies are briefly reviewed. A number of lessons were learned from the field studies on the stakeholders involved in the process of wheelchair design, prescription and use (the designers, the therapists, the rehabilitation engineers, the user and the carers). Such lessons are briefly reviewed. Finally the conclusions of the study are presented and some recommendations are made for further work.

7.1 Review of the major findings of the research

The starting point of this thesis was that mismatches occur between the design and use of a number of products for both the able-bodied and disabled population. Considering wheelchairs as the product which this thesis focused on, it was not clear what roles usability, ergonomics and the modern techniques of design performed in guaranteeing better wheelchairs with a consequent improvement of consumer satisfaction. The literature review and the field studies provided answers which gave inputs to the production of a user-centred method. The importance of such answers to the major objective of this thesis, that is to investigate how user needs can be translated into the design of wheelchairs, will be briefly discussed and the major findings described.

7.1.1 The literature review

The literature review analysed issues related to the major objective of this thesis such as usability, product quality, ergonomics, product design, consumer needs and design methods. The main questions in section 1.2 (page 7) were adequately addressed and some important findings were revealed. The more important one are discussed in succeeding paragraphs.
Chapter 7: Findings, Conclusions and Recommendations

The literature review has shown that competitiveness in modern consumer markets has stimulated companies to look for quality. Attaining quality, independent of whether the product is produced for the able-bodied or disabled population, is based on the reduction of losses during product manufacturing, reducing warranty claims, reducing the product development cycle time and improving user satisfaction.

Consumer satisfaction, one of the aims of product quality, is based on products having features which meet the needs of customers. The concept of consumer satisfaction, apart from the needs of the disabled related to their specific disabilities, was found to be the same for both the able-bodied and the disabled user. So, designing products for those with disabilities, keeping the able-bodied in mind, and vice versa, should be an economic and social strategy to enlarging a market, increasing the volume of production, reducing the price and the associated stigma which the user might have in using a product whose design increases his or her sense of being disabled. It was found to be a cruel reality that the provision of products for disabled people with styling associated with medical and assistive needs, may lead to the product being rejected and abandoned even though such products may be of clinical benefit.

The fact that designers do not apparently consider the elderly and the disabled in the design of consumer products may require re-examination of the ethical foundations upon which their claim to professional status rests. Certainly the idea of achieving a design which meets the needs of the whole population is utopian because there will always be those whose physical, mental, emotional and other characteristics are at the extremes of the population. However, designers must remember the limits of the population as well as those more centrally placed.

The literature review showed that ergonomics, as a discipline that has the human being as its principal focus and usability aspects as its main objective, is a strong tool to provide essential attributes to a product (e.g. ease of use, ease of learning, comfort, safety and adaptability). Ergonomics is also a means of contributing to quality aspects being incorporated in the product. In such a way, ergonomics should be used by wheelchair designers as a means to provide safety, efficiency, comfort and aesthetic satisfaction, under normal conditions of use, and under foreseeable conditions of misuse. The field study carried out with wheelchair designers showed that, in most of the cases, this is not true.

Methods in the development of products were also investigated. The literature search revealed that the level of complexity in the product development process varies according to the nature of the product. So, although the general methods and knowledge involved in designing products have a number of similarities, designing products for the elderly and disabled
populations requires that the abilities and limitations of these segments of the population are considered as an integral part of the design, product requirements and purchasing process.

Another two major lessons were learned. First, the product design process for consumer products, in general, does not incorporate ergonomics as perhaps it would be expected to. Second, it was established that some methods in product development based on an assessment of customer needs have been successfully used in a number of products. These findings resulted in the need to check to what extent ergonomics and design methods based on consumer needs are effectively incorporated in the practice of wheelchairs designers. The results from the survey of wheelchair designers showed that ergonomics is not effectively used in their design methods and that they are unaware of modern techniques which incorporate the establishment and satisfaction of user needs in the design process.

The findings from the literature review were strong indicators of the need to produce a user-centred method for wheelchair design. They also pointed out the need to carry out field studies aimed at examining what was regarded as being good practice, in terms of the design process, design outcome and meeting wheelchair users' requirements.

7.1.2 The field studies

A number of lessons were learned from the survey of designers, therapists, rehabilitation engineers, users and carers. Those lessons have provided answers concerned with the involvement of the stakeholders in the design process and their views about the wheelchairs actually available in the market place.

One important point that should be drawn to the readers attention is related to the true meaning of what people said in the field studies. Difficulties in articulating descriptions of some complex activities, such as the design method, may have generated some communication problems. There was not an opportunity to carry out an investigation of designers and prescribers in their workplaces and observe them in their daily activities. This approach would validate (or invalidate) what was said. However, although the findings can not be considered conclusive, this probably give a strong clue about what people actually do. In some cases, of course, where a feeling is expressed, it is virtually impossible to get behavioural confirmation of what is said.

The principal findings of the field studies are discussed as follows.
Chapter 7: Findings, Conclusions and Recommendations

Approaching wheelchair designers

One of the main question addressed in this thesis was posed to the wheelchair designers, as follows:

"Do you try to take account of the range of needs of disabled people when designing wheelchairs?"

It was found that smaller companies that produce custom-built wheelchairs made to meet individual requirements usually have direct contact with users in some phases of the product development process. These companies are not really the principal target of this thesis. In terms of the other companies which produce their wheelchairs on a large scale, only very few designers said they made contacts with users. Such contacts were made with disabled people employed by the company, with users of the company's products with whom the company had a good relationship or from feedback from the Marketing Department and/or other in-house professionals such as occupational therapists.

In addition to deficiencies in the process of collecting the views of users, the design process is also carried out, in the majority of cases, in an unsystematic way. According to the results of the survey, it could be said that the wheelchair designers carry out design based mainly on their assumptions about users' expectations. Designers assumed that they could rely on their own experience to design wheelchairs rather than systematically assessing the real experiences and requirements of end users. As a result, the predications of product use and performance, as confirmed by the majority of answers given in the survey of users and carers, do not match users' expectations. It was also found that not using a systematic approach resulted in some companies failing to carry out part or whole phases of design process. Aspects of design not considered by designers included identifying users' needs, evaluating competitive products, establishing user profiles, defining product performance requirements and determining design constraints. If these factors are not taken into account it would not be surprising to find customer dissatisfaction and rejection of the product by the user.

Costs were stressed by all designers as one of the prime element to be considered in the design process. This made clear that the use of a high volume production, modern techniques of manufacturing and distribution may be solutions to reducing the price of wheelchairs in the public and private market place. The survey of designers produced findings which justified the need for a method capable of incorporating the user systematically in the design process.
Although the sample of designers in the survey comprised only eleven people, they represented the principal manufacturers of wheelchairs in the United Kingdom. In view of this, the results of the survey may be considered to give a strong indication of the design practice of wheelchair designers in this country.

It is important to make clear that the design process is only one part of the product development cycle. Design needs to take into account marketing, engineering, manufacturing and finances. Sometimes these are in conflict and compromises need to be made between them. If designers have the support of customers in their arguments, the chances of their views being maintained over those of other members involved in product development will increase.

Approaching therapists

The survey of therapists provided a number of answers which help to understand the process of wheelchair assessment and prescription.

A number of weaknesses in the process by which clients are assessed and wheelchairs prescribed were pointed out by almost all therapists in the sample. These weaknesses are ascribed to, for instance, budget constraints, a limited range of wheelchairs available for prescription, and not enough time allowed for assessment. The respondents agreed unanimously that such weaknesses have implications for design and indicated the need to improve design quality. "Take carers into account" and "consult disabled people during the design process" were recommendations made by therapists and revealed the need to introduce a user-centred design method into the wheelchair design process.

A large majority of therapists in the sample answered that they had been in contact with manufacturers about problems connected with wheelchairs. However, almost two-thirds of the respondents said that they had received no feedback from the manufacturers or did not know if the manufacturers had taken any notice of what they said and whether they had carried out in consequence any modification to the wheelchairs. They said almost unanimously that had never been involved in wheelchair design with a company that produced wheelchairs for a large market.

The apparent lack of communication between therapists and manufacturers is a strong indication that manufacturers are not yet aware of the contribution which therapists can provide on wheelchair design. The majority of respondents in the survey stressed that,
although they had never been involved previously, they would like to be involved in wheelchair design in the future with companies that mass produce wheelchairs for a large market.

A considerable number of respondents said that the wheelchairs which best meet users' needs are the most expensive.

One important lesson from the survey of therapists is that there seems to be a vicious circle of miscommunication occurring in the chain of conception, prescription and distribution of wheelchairs. First, in terms of conception, the design process is based on the designers' assumptions about users' expectations without hearing the views of users and prescribers. Second, in the majority of cases in the prescription process, the wheelchair tends to be prescribed by professionals rather than being chosen by the users with the aid of professional advice, which means that again users are not being fully heard. Third, the N.H.S. and government agencies, as the main consumers of wheelchairs, have as their prime concern the fulfilment of the wheelchair users' physical and medical needs, without taking into account what users and their carers have to say about their satisfaction with the product; Government agencies also seem to fail to take into account what prescribers have to say in terms of their experience in dealing with wheelchairs and their users; and what designers have to say in terms of product requirements, including aesthetics and usability.

Overcoming of the chain of miscommunication should be the first step in the production, prescription and provision of better wheelchairs. A good computer database linking the various N.H.S. Wheelchair Services throughout the country, which would provide up-to-date data to the manufacturers and designers and the N.H.S. and governmental agencies, should be the first step to overcome the communication problems. Furthermore, standards using national guidelines, with a margin for some local adjustment, for the assessment of users and provision of wheelchairs with the active participation of the user will provide consistency, uniformity and a central guidance to the wheelchair services. They will also provide a tool for audits and a framework for having the views of clients taken into account.

Approaching rehabilitation engineers

The lessons learned from the survey of rehabilitation engineers also provided an insight into the process of wheelchair assessment, prescription and design. The majority of findings in this particular survey were similar to those from the survey of therapists.
It was found that the majority of respondents in the survey identified weaknesses in the process by which clients are assessed and wheelchairs prescribed. These weaknesses included budget constraints, insufficient time to evaluate users, limitations of available equipment, staff without experience or with no formal training to prescribe wheelchairs, and a long lapse of time between client assessment and the delivery of the wheelchairs. These views reflected those of therapists. Rehabilitation engineers also echoed therapists regarding the implications of such weaknesses in the design of wheelchairs. The need to produce wheelchairs with more adaptability, interchangeability and adjustability of parts were the recommendations most mentioned by respondents in both surveys.

Although almost all rehabilitation engineers in the sample said that they had been in contact with manufacturers about problems connected with wheelchairs, more than one-third of those respondents either said that the manufacturers did not take any notice of them or were unsure if the manufacturers took any notice of what they said and carried out modifications to the wheelchairs.

As with the therapists, the vast majority of rehabilitation engineers had never been involved in wheelchair design with a company that produced wheelchairs for a large market. A large majority of respondents answered that they would like to be involved, or continue to be involved, in wheelchair design with companies that mass produce wheelchairs.

The same suggestions, offered to overcome the chain of miscommunication, made in relation to the survey of therapists above, may be applied to the survey of rehabilitation engineers.

**Approaching wheelchair users**

The survey of users casts much light on wheelchair prescription and design. The survey revealed that the majority of wheelchair users in the sample were over 45 years old and more than one-third of them were over 55 years old. They suffered from neurological conditions. The users mainly lived in an urban area: town or city.

The majority of wheelchair users in the sample had more than one wheelchair and had been using a wheelchair for more than ten years. They owned a manual self-propelled wheelchair as the most used and the next most used wheelchair. The wheelchairs were generally obtained through the N.H.S., for both the most used and the next most used wheelchair, and had been owned for less than five years.
The majority of respondents felt that their needs and abilities were taken into consideration during the process of assessment and prescription. However, almost two-thirds of wheelchair users in the sample were able to identify some weaknesses in the process by which they were assessed, their wheelchairs prescribed and followed-up. Among the problems identified was the long delay between assessment by prescribers and subsequent delivery. This may cause problems in the design process because some user requirements could have changed over this period of time. Other problems identified were the lack of communication between prescribers and users and the wheelchair not suiting the users needs. The latter may have been caused by the criteria for choosing the wheelchair having been focused mainly, if not solely, on whether it fulfilled the user's physical and medical needs and not considering the user's lifestyle and expectations in terms of the product's characteristics including, for example, aesthetics.

Safety, comfort, reliability, suitability and portability due to weight were considered the five most important design characteristics of wheelchairs by the majority of the sample. They also judged the design of their own wheelchairs as being "very good" or "good" in terms of safety, ease of use, stability, manoeuvrability, suitability and reliability although this level of satisfaction was not achieved as consistently as might be hoped for.

The majority of respondents judged the design of their own wheelchairs to be "average", "poor" or "very poor" in terms of cost to buy, cost to repair, provision of accessories, cost to maintain, adjustability, ease of repair, aesthetic appearance and portability due to weight. They had the view that privately acquired wheelchairs were designed taking into consideration the needs of disabled people and that those issued by the N.H.S. were not.

Although a large number of respondents stressed the need to involve users in the design of wheelchairs, only seven in the sample had ever been involved in wheelchair design with companies that mass produced wheelchairs. Almost half of the sample answered that they would like to be involved, or continue to be involved, in wheelchair design.

The contributions of the users are indispensable for the design of wheelchairs which are intended to fulfil user requirements and needs for an independent life. Such contributions may help in the evaluation of wheelchair characteristics including safety, comfort, adjustability and reliability. Taking part in user trials, focus groups and other situations to gather user opinions would also help to achieve a balance between the various requirements of the product such as suitability, ergonomics, aesthetics, structure, costs and manufacturing.

It is important to be aware that this balance is a matter of compromise. This will involve paying-off the user's demands on the one hand and product requirements on the other.
Unfortunately there does not seem to be a set of rules which specify how the compromises should be carried out.

**Approaching carers**

The majority of respondents were over 35 years old (almost one quarter of them were over 65 years old) and had the relationship of spouse with the wheelchair user whom they assisted. The majority of carers assisted users every day.

The majority of the carers in the sample rated their own health at the time they answered the questionnaire as "average", "poor" or "very poor". They suffered from pain in the regions of lower back, buttocks, mid back and right shoulder as a consequence of assisting the user with the wheelchair.

Half of the carers pointed out that going up or down steps, stairs, kerbs and hills were the most difficult outdoor tasks they performed. Getting the wheelchair into and out of the car was the second most difficult activity and manoeuvring through doorways the third. In terms of indoor activities, getting people or lifting people into and out of the wheelchair was considered the most difficult activity. Manoeuvring the wheelchair with the user through doorways was considered the second most difficult indoor task and manoeuvring in tight spaces, the third. Taking these considerations into account during the design of wheelchairs will certainly contribute to the success of the wheelchair in the market place.

Safety and portability due to weight were considered by the majority of the sample as the most important design characteristics of wheelchairs. They also judged the design of the wheelchairs belonging to the wheelchair user who they assisted as being "very good" or "good" in terms of safety, ease of use, stability, reliability, robustness and suitability although this level of satisfaction was not achieved as consistently as might be hoped for.

When asked to judged the design of the wheelchairs belonging to the wheelchair user whom they assisted, the majority of them rated the wheelchair as being "average", "poor" or "very poor" in terms of cost to buy, cost to repair, provision of accessories, cost to maintain and aesthetic appearance. They thought that the wheelchairs issued by the N.H.S. were not designed to take into consideration the needs of disabled people and their carers.

Broadly speaking, contrary to the results from the survey of wheelchair users, it can not be concluded that the carers expressed a high level of satisfaction with the wheelchairs issued by
the private market. However, the high level of dissatisfaction with the N.H.S.-supplied wheelchairs was found to be similar to that expressed by the wheelchair users in their survey.

The carers in the sample had never been involved in wheelchair design with a company that mass produced wheelchairs. Almost half of the sample said that they would like to be thus involved. They said they could contribute with personal experiences and suggestions from the point-of-view of carers.

The findings of the survey of wheelchair users and their carers has provided a clear indication of the several demands that a wheelchair needs to meet in terms of fulfilling the requirements of both groups.

7.1.2 The user-centred method for wheelchair design

The need to produce a method for wheelchair design which considers users in the different phases of the process was indicated by all stakeholders involved in the process of design, assessment, prescription, and use.

Even not considering aspects such as costs and manufacturing in depth, the *User-centred method* has the virtue of allowing user needs to guide the steps of design so that a product is made which fully provide consumer satisfaction.

Industrial designers and ergonomists are directly involved in the five phases of the method including *Approaching the Users, Investigating the Problem, Product Planning, Concept Design, Prototyping, and Testing and Verification*.

The method was introduced to four designers to see to what extent it was acceptable to them. Although the designers had had just about one hour to evaluate the method, they unanimously responded in a positive way to the method. The criticism and suggestions that they made did not affect the essence of the method and were incorporated in a revised version shown in Figure 6.1, page 330. One useful suggestion was to incorporated a *Dealer Panel* in addition to the existing *User Panel*. The major criticism, made by just one respondent, was the impossibility of producing a mass produced wheelchair. This criticism can be considered unfounded and was discussed on page 328.
7.2 Conclusions

Products are designed to be used and to provide pleasure and satisfaction to their users. Disabled people need products that meet not only their medical and therapeutic needs but also improve their independence, quality of life, and give pleasure and satisfaction. Designing products for disabled people having in view just sales and profits is at best short-sighted and at worst immoral. Designing products solely for the able-bodied population without considering those with physical and cognitive disabilities is a form of design discrimination.

For how long will products continue to harm and kill people? For how long will people continue to be unaware of the risk of exposing themselves and their families to the danger of potentially dangerous consumer products? For how long will millions of able-bodied users continue to have problems in using consumer products in general and disabled people wheelchairs in particular? For how long will designers continue to be insensitive to the voices of users (either able-bodied or disabled) and to translating their needs into product design? Unfortunately this thesis was not able to answer these questions.

On the other hand, this thesis showed that it is indeed possible to hear the voice of able-bodied and disabled users in the design of products. It was shown that, although incorporating the needs of wheelchair users in product design is not current practice amongst the more influential wheelchair designers in the United Kingdom, designers may now have a method that used in its totality (or maybe tailored for a specific situation), helps them to improve their design practices and the level of consumer satisfaction. Nowadays there is tremendous competition in the market for products for the disabled. Consumer satisfaction is the key point to guarantee product quality and to improve the performance of products that face competitors in the marketplace.

At first sight, it may sound utopian and not financially feasible to incorporate enough features in a wheelchair to achieve a design which satisfies a large range of users, or to produce a design for the disabled with enough modularity to incorporate the needs of many individuals. Certainly there will continue to be limitations in such an approach for those with many severe and extreme disabilities. However, countless users who will be helped by this approach will surely overcome the initial financial investment in design and manufacturing. Indeed, the creativity and imagination of designers will help in finding adequate solutions and new concepts able to balance the distinct requirements of user needs and manufacturing, marketing, and financial requirements. But one essential and first point for designers and manufacturers is to discard the preconceptions and false distinctions about who is young and old, and who is able-bodied and disabled.
The design method provided in this thesis, following from the lessons learned from the literature review and from the surveys of the stakeholders involved in the processes of design, prescription and use of wheelchairs was an answer to the question "how to translate user needs into product design for wheelchair users".

It is important be keep clear that there is no methodology of which the author knows to resolve the compromises between the several demands involved in product development. Methodologies are procedures which will give the designers and other people involved in the product development ways to guide the project according to specific approaches. Such approaches could prioritise consumer needs, technological and manufacturing specifications or costs. This thesis echoes the modern techniques of design and manufacturing by using a consumer-oriented approach. In such a way this method is intended to solve the design problems based on user needs.

The User-centred method for wheelchair design has incorporated consolidated design practices found in the literature (and not currently practised by the wheelchair designers) with the innovative incorporation of users (including carers, prescribers and dealers) throughout the several phases of the design process. As was said before, a design method itself is not a sufficient guarantee the good quality of the design of any particular product or the success of the product in the marketplace. But the risks as well the costs can be minimised by following good practice and incorporating the users' needs to achieve consumer satisfaction. The only way to guarantee that a design method represents good practice is if designers accept the method, implement it and consequently produce better products. By having incorporated key components of successful design methods, the User-centred method for wheelchair design has all the ingredients to turn it into good design practice.

Ultimately the validity and acceptability of the User-centred method for wheelchair design can be only evaluated after its full and effective implementation. This will involve the companies which use it changing their production line to support properly the design process in a mass-production context. Only then can the product and the method on which it is based be evaluated against the competition. Users, carers and prescribers will evaluate the new product to check if it is in fact meeting user needs. This is beyond the time and resources available for completion of this Ph.D. thesis. A preliminary shot at the evaluation problem was to consult some wheelchair designers and to seek their views on the method.

The current User-centred design method was originally created to be used in the design and manufacture of wheelchairs. It is the author's belief that it would be suitable for use for other kinds of products for the disabled or the able-bodied in general. However, due to its level of
detail it may produce better results when used principally for products which have a certain level of complexity. The method is intended to be used in a mass-production setting.

Although a good design method is fundamental to achieving a high level of quality in the design of wheelchairs, it would be of little value if there is a failure in the processes of assessment and prescription. A number of weaknesses in these processes were pointed out by prescribers, users and their carers. Although the surveys were perhaps not conclusive, they were certainly indicative. Incorporating the users' and carers' needs (and not only the clinical and therapeutic needs) into the process of assessment and prescription is essential to guarantee user satisfaction. The lapse of time between prescription and delivery should be not so long as to allow alterations in the client's physical condition, thus requiring consequent changes in the wheelchair design because the original design is no longer appropriate.

A number of therapists and rehabilitation engineers said that they have been in contact with manufacturers about problems connected with wheelchairs and said that they had received no feedback. Therapists, rehabilitation engineers, users and carers, generally speaking, said that they had never been involved in wheelchair design. This was confirmed by the designers themselves when they confessed that they did not systematically approach users and prescribers in the process of wheelchair design. The N.H.S. and governmental agencies, the main primary customers for wheelchairs in this country, have a limited budget and apparently do not consider a) what wheelchair users and their carers have to say in terms of product satisfaction; b) what prescribers have to say in terms of their experiences in dealing with wheelchairs and their users; and c) what designers have to say in terms of product requirements, aesthetics and usability.

A vicious circle of miscommunication occurs in the chain of conception, prescription, distribution and use of wheelchairs. Overcoming this problem should be the first step in the prescription, production and provision of better wheelchairs. A good computer database linking the N.H.S. Wheelchair Services, manufacturers and governmental agencies should be a first step in overcoming this communication problem.

The results obtained from the surveys of designers, therapists and rehabilitation engineers is a lamentable state of affairs. The need of all stakeholders to hear each other involves a change of mentality. Prescribers and rehabilitation engineers need to hear users and carers; designers and manufacturers need to hear prescribers, rehabilitation engineers, users and carers. The N.H.S. and Government agencies should hear all the stakeholders involved in the processes of assessment, prescription, design and use.
Time pressure and limited budget may be a constant issue in the activities of designers and prescribers. It results in a number of consequences including a) the wheelchair is designed in a short time, b) the large number of clients does not permit an assessment in the required detail, c) the budget available does not permit the provision of the number of models adequate to the range of user requirements. Stakeholders and users should exert pressure on the Governmental bodies to improve the quality of services. This certainly may be a political problem which may take years to be solved, but a start must be made sometimes.

The author is conscious of some disappointment in working on this thesis.

- In terms of the literature review, although it can be considered extensive enough and successful in covering issues regarding design, ergonomics, consumer needs and methods of design and manufacture of products, it has not entirely succeeded in covering issues specifically related to the disabled as was originally desired. This was, sadly, because of a lack of comprehensive data on the characteristics of the disabled population.
- As previously mentioned, the true meaning of what people said in the field studies may or may not represent what they really do in their daily activities. This could not be investigated due to the lack of time and resources to carry out behavioural observations. This issue applies to the survey of designers, therapists and rehabilitation engineers.
- A problem in the use of questionnaires in field studies is concerned with those who did not respond. It is not known if non-respondents would have produced similar answers to those presented in this thesis. This problem, common to this kind of investigation, is inherent in this study to the surveys of therapists, rehabilitation engineers, users and carers.
- The design method was created to be used in the large scale production of complex products. With few exceptions, the current wheelchairs in this country are manufactured in low-volume workshops, using a very traditional design approach. Modern methods of manufacture are not considered and manufacturers target their wheelchairs at a niche market, relying on the N.H.S. as their main customer.
- In an ideal world, evaluating the suitability of the user-centred method would involve persuading designers to accept and implement it and to check the quality of the outcome products in terms of consumer satisfaction, product safety, standards compliance and so on. As this is beyond Ph.D. work and would almost certainly involve years to its completion, it was decided to consult a number of wheelchair designers and collect their views on the method.
- The phase of Investigating the suitability of the proposed methodology had a series of limitations. Due to the lack of time and resources available the number of four designers involved in this phase of the thesis was far from what was ideally required. The time the designers were allowed to be interviewed (about one hour) was very short. In view of this,
they were able to see just a summary of the method and provided their comments without going into depth.

- There is, of course, the slightly alarming possibility that the four designers responded positively to the method because they knew it had been devised by the person who was asking them to evaluate it. It would, doubtless, have been preferable to get the method checked by independent interviewers and, in turn, to have had independent behavioural studies carried out on the designers to see if what they said they felt and would do were borne out in practice.

The millions of wheelchair users in this country and overseas merit the production of wheelchairs of high quality on a large scale. The scheme of providing vouchers for wheelchair users to complement the purchase of the wheelchairs more suitable to their needs may signal the change of wheelchair provision. In the near future, the N.H.S. may cease to be the main customer for wheelchairs in this country and N.H.S. clients will have the opportunity to make their purchases directly from dealers and manufacturers using N.H.S. vouchers or other similar schemes.

So, the User-centred method for wheelchair design used with creativity, modern techniques of manufacturing and marketing, and the use of alternative materials (e.g. plastic mouldings and thermo-forming components) are essential elements to exploit this potential business opportunity. Marketing research will determine the different markets segments for wheelchairs. Due to the current level of dissatisfaction, the use of such techniques, which will certainly reduce substantially the wheelchair unit cost, and an appropriate design, seems to be an effective option to win at least part of the European market. Even a small part of this market would be sufficient enough to recover the investments made. But, essentially, the use of the User-centred method for wheelchair design is an effective option to guarantee that wheelchair users and their carers have their voice heard and their needs incorporated in a product which will have a good chance of providing fully consumer satisfaction.

7.3 Indications for further studies

The findings and conclusion of the present study suggest the following as profitable directions for further work:

1. The User-centred design method translates user needs into product requirements. User needs are expressed in the consumers' own words about their perceived feelings and
needs. Efforts should be made to establish formal techniques to help the interpretation of the perceived user needs into engineering characteristics.

2. In this work, the analysis of the suitability of the method was limited due to the few number of designers who were consulted. An investigation of the views of a more extensive sample of designers on the User-centred design method is required. To achieve this an international study is required (see item 5 below).

3. The User-centred design method has focused solely on aspects related to product design and ergonomics. For its effective implementation it is necessary to investigate the activities which comprise the later phases of product development such as the manufacturing aspects (including an analysis of the manufacturing, components and assembly costs), an economic analysis (including the building of a financial model to estimate the timing and magnitude of future cash flows) and the managing of the project planning (including project schedule, budget and risk areas).

4. Assuming that the User-centred design method is effectively used, it is suggested that a comparison should be run between wheelchairs produced with the method against others wheelchairs available in the market place. This comparison should incorporate the views of wheelchair prescribers, users and carers.

5. The time and availability of resources in this thesis has limited the survey of wheelchair designers to those whose practice is limited to the United Kingdom. It is recommended that an investigation be carried out of the methods that designers use to design wheelchairs in North America and other countries of Europe, particularly from Scandinavia which seems to have developed a more mature user-centred design practice.

6. The ergonomics literature on the disabled is not very strong. Data on human characteristics such as seeing, hearing, making decisions, reacting, skill levels associated with disabilities are not extensive, if existent at all. Surprisingly, there is not as much data as might be expected on static and dynamic characteristics of disabled people. More fundamental research related to all these characteristics is needed.

7. There needs to be produced an extensive literature in product design for the disabled user describing in depth aspects including physical and cognitive abilities, technology to help in the performance of tasks, design of written instruction and so forth. This literature should provide recommendations for the design of products categorised by type of impairment (vision, hearing, motor, and cognitive impairments) suffered.

8. An epidemiological study on safety and number of accidents involving products for independent living should be carried out and continued on a regular basis.
9. This thesis assumed that finding good design solutions to include a large range of users is a matter of creativity of designers. In the real world it should involve cost. Investigating the financial feasibility of using "universal" (also known as "design for all") method for a range of products which are currently deficient is a vital requirement.

10. Carry out a study to audit a range of wheelchairs available in the market place to establish to what extent they provide consumer satisfaction, safety and compliance with recent standards.


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Smith, C. and McCreadie, M. (1994). A heavy load: a survey of the carers of wheelchair users found that under half felt that their needs were being met. Health Service Journal, 28 April.


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(the numbers associated with each type of wheelchair refer to those give in Figure 2.4)

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<th>No.</th>
<th>Types</th>
<th>Characteristics</th>
<th>Price range (£)</th>
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<td></td>
<td>Class 1 Vehicles</td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>Self-propelled wheelchairs with rigid frame</td>
<td>These are manual wheelchairs to be used indoors and outdoors.</td>
<td>115-7175</td>
</tr>
<tr>
<td>2</td>
<td>Self-propelled wheelchairs with folding frame</td>
<td>Self propelled wheelchairs are propelled by the user and are primarily for daily living, although they are sometimes used for sport. Standards models usually have fixed rear wheels, fixed axle position and limited choice of frame size. The weight of these wheelchairs ranges from 12kg to 23 kg.</td>
<td>564-599</td>
</tr>
<tr>
<td>3</td>
<td>Standard attendant-propelled manual wheelchairs</td>
<td>These models have to be pushed by an attendant and are primarily intend to be used on short outings or shopping trips.</td>
<td>155-865</td>
</tr>
<tr>
<td>4</td>
<td>Castor wheelchairs</td>
<td>Compact, manoeuvrable chairs, with four castor wheels, for use indoors only, on smooth surfaces. They may be propelled by an attendant, or by the person pushing on the floor with their feet.</td>
<td>148-1700</td>
</tr>
<tr>
<td>5</td>
<td>Porter or Hospital wheelchairs</td>
<td>Designed for transporting patients in and around hospitals. They are usually large, with a rigid frame, fixed footboard, and, to avoid losses, no removable parts.</td>
<td>115-620</td>
</tr>
<tr>
<td>6</td>
<td>Pushchair or Children's self-propelled wheelchairs</td>
<td>Typified by lightweight folding frames and a canvas sling seat. They are often available with additional supports and can be usually fitted with special seating systems.</td>
<td>411-463</td>
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Different types of wheelchairs and other vehicles for the disabled mobility and their characteristics (cont.)

<table>
<thead>
<tr>
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<th>Types</th>
<th>Characteristics</th>
<th>Price range (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Comfort wheelchairs</td>
<td>These are attendant or self-propelled wheelchairs with comfortable seating that provides good postural support and a wide range of adjustments. They are intended for people who sit in a wheelchair all day, require a high degree of comfort and postural support and who need to change position throughout the day.</td>
<td>1595-1895</td>
</tr>
<tr>
<td>8</td>
<td>High-performance lightweight wheelchairs with rigid frame</td>
<td>Designed for everyday use by active users, both indoors and outdoors, often lighter than standard self-propelled wheelchairs. They are easier to propel, more manoeuvrable, and weigh from 10kg. to 16 kg. They are available in a range of sizes and some are custom-built. Lightweight high-performance wheelchairs are easy to propel and lift. They can be used, with some adaptations, for sports.</td>
<td>400-2395</td>
</tr>
<tr>
<td>9</td>
<td>High-performance lightweight wheelchairs with folding frame</td>
<td>Same as above but foldable. Lightweight high-performance wheelchairs are easy to store and to transport in a car.</td>
<td>565-1650</td>
</tr>
<tr>
<td>10</td>
<td>Basketball, rugby and court wheelchairs</td>
<td>These are purpose-designed wheelchairs for use in court sports with emphasis on its manoeuvrability. Many are custom made to suit the user, and most can be adjusted. The seat position may be different to those wheelchairs used in everyday activities to give the maximum advantage to the user. There are rules in competitive wheelchair sport for the allowable features and set-up of the wheelchair. Sports wheelchair frames are rigid, non-folding, and may be made of titanium, stainless steel, carbon fibre, chrome-moly racing bicycle standard steel or aluminium. The material used determines the weight, strength and structural rigidity of the wheelchair.</td>
<td>1175-1500</td>
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### Different types of wheelchairs and other vehicles for the disabled mobility and their characteristics (cont.)

<table>
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<th>Types</th>
<th>Characteristics</th>
<th>Price range</th>
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<tbody>
<tr>
<td>11</td>
<td>Tennis wheelchairs</td>
<td>Most characteristics are the same as above, but with specification for tennis.</td>
<td>1197-1500</td>
</tr>
<tr>
<td>12</td>
<td>Racing wheelchairs</td>
<td>Most characteristics are the same as above but purpose-designed to emphasise speed rather than manoeuvrability.</td>
<td>1630-1755</td>
</tr>
<tr>
<td>13</td>
<td>Hand cycles and handlebar systems</td>
<td>These are usually intended for on- and off-road recreation use by active users. On the road they can achieve speeds similar to a bicycle. They may use standard bicycle parts and are easy to maintain.</td>
<td>495-1895</td>
</tr>
<tr>
<td>14</td>
<td>Tilt-in-space wheelchairs</td>
<td>Designed to permit the complete seat unit to tilt back, keeping the angle between the seat and backrest fixed for altering posture and redistributing the user's weight.</td>
<td>560-1650</td>
</tr>
<tr>
<td>15</td>
<td>Elevating-seat wheelchairs</td>
<td>These models allow the user to raise the seat to gain access to different heights for a wider range of activities at home, work or school, and also allow the user to have eye contact with people standing up. They are generally heavier than standard wheelchairs. The elevating mechanism is battery powered.</td>
<td>625-1995</td>
</tr>
<tr>
<td>16</td>
<td>Stand-up wheelchairs</td>
<td>Stand-up wheelchairs allow the user to bring the seat and backrest to an almost vertical standing position to gain access to different heights for a wider range of activities at home, school, or work. They also allow the user to have eye contact with people standing up. Stand-up wheelchairs are available in manual or powered versions and are generally heavier than standard wheelchairs.</td>
<td>2800-3995</td>
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Different types of wheelchairs and other vehicles for the disabled mobility and their characteristics (cont.)

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<th>Types</th>
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<th>Price range</th>
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<td>17</td>
<td>Manual car wheelchairs</td>
<td>These models are designed to fit certain adapted standard production cars, allowing the wheelchair use to drive the car from the wheelchair, or to sit in it as a passenger. The system allows the user to remain in the wheelchair and be transferred in and out of the driver or front passenger seat of an adapted car by an integral hoist.</td>
<td>3960-7175</td>
</tr>
<tr>
<td></td>
<td>Self-propelled wheelchairs for hemiplegic people (no picture in Figure 2.4)</td>
<td>Wheelchairs for people with function in only one arm. They are propelled by using a double pushing rim on one side, by operation of a single lever, or by pushing with the feet on the ground.</td>
<td>370-950</td>
</tr>
<tr>
<td></td>
<td>Class 2 Vehicles</td>
<td>Class 2 comprises powered wheelchairs, scooters and buggies with a maximum speed of 6.4kph (4mph), a maximum unladen weight of 114kg, and brakes which hold the vehicle on gradients of 20% (1 in 5). Lights are not required, but reflectors must be fitted for use at night and a rear light is required for use on the road if there is no pavement. Class 2 vehicles are allowed to be used on the pavement but not on the road (except for crossing the road or where there is no pavement).</td>
<td>666-7200</td>
</tr>
<tr>
<td>18</td>
<td>Electrical indoor wheelchairs</td>
<td>Designed to be self-propelled, these wheelchairs are generally quite small, manoeuvrable and designed for indoor use. They are not intended for use on rough ground, kerbs or steep slopes. Most have smooth tyres and can be dismantled for transporting. They have no kerb climbing device, but some will climb very small kerbs of 2.5-4cm (1-1.5in).</td>
<td>666-1899</td>
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</table>
Different types of wheelchairs and other vehicles for the disabled mobility and their characteristics (cont.)

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<td>Electrical indoor/outdoor wheelchairs</td>
<td>These wheelchairs can be used indoors and outdoors, and will cope with slopes and uneven ground. Some have a kerb climbing device, which may be detachable, and are able to climb kerbs forwards up to 10 cm (4in) high. Most can be dismantled for transporting.</td>
<td>1530-2595</td>
</tr>
<tr>
<td>20</td>
<td>Electrical outdoor wheelchairs</td>
<td>These are large, more robust wheelchairs, which can cope with rough ground and slopes, but which may have too large a turning circle for indoor use. They may be able to climb and descend kerbs forward of 10 cm (4in) high or more. They are used to cover medium to long distances. Most cannot be dismantled.</td>
<td>2350-3495</td>
</tr>
<tr>
<td>21</td>
<td>Electrical wheelchairs for children</td>
<td>These are mainly for use indoors and are more compact electrical wheelchairs with adjustments to permit component change as the child grows.</td>
<td>666-7200</td>
</tr>
<tr>
<td>22</td>
<td>Position and reclining electrical wheelchairs</td>
<td>Same characteristics as the &quot;Stand-up manual wheelchairs&quot; described above but for use indoor/outdoor and with the performance of an electrical Class 2 vehicle.</td>
<td>2819-12000</td>
</tr>
<tr>
<td>23</td>
<td>Outdoor front-wheel drive wheelchairs</td>
<td>Front-wheel drive wheelchairs have large front propelling wheels. They may be more manoeuvrable than rear-wheel drive wheelchairs, but they may swing out at the back when turning and have a large turning circle. These wheelchairs are generally designed for rugged outdoor use. The large front wheels may make sideways transfer more difficult, but enable the chair to climb and descend kerbs forwards with ease and to provide a comfortable ride.</td>
<td>2745-5275</td>
</tr>
</tbody>
</table>
Different types of wheelchairs and other vehicles for the disabled mobility and their characteristics (cont.)

<table>
<thead>
<tr>
<th>No.</th>
<th>Types</th>
<th>Characteristics</th>
<th>Price range</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>Stair climber wheelchairs</td>
<td>This electrical wheelchair is designed to provide independent mobility indoors, up stairs, outdoors on level ground or slopes and up and down kerbs.</td>
<td>5500</td>
</tr>
<tr>
<td>25</td>
<td>Indoor/outdoor scooters</td>
<td>These are three wheeled vehicles, for indoor use and limited outdoor use on even surfaces, have tiller steering, with the capability for short/medium distances. Some have a limited kerb climbing facility of 9cm (3.5in), and can be dismantled for transporting.</td>
<td>1000-2800</td>
</tr>
<tr>
<td>26</td>
<td>Outdoor scooters</td>
<td>These are three or four wheeled vehicles not appropriate for domestic indoor use. They can be used for medium/long distance journeys, can be used on uneven ground, can climb kerbs of 10cm and can be dismantled for transporting. They have tiller steering.</td>
<td>3-wheels: 1100-2500 4-wheels: 2000-2800</td>
</tr>
<tr>
<td></td>
<td>Class 3 Vehicles</td>
<td>These are electrical wheelchairs and other outdoor electrical vehicles that are allowed to be driven on the pavement at a maximum speed of 6.4kph (4mph) and on the road at a maximum speed of 12.8kph (8mph). The maximum permitted unladen weight is 150kg and maximum width 850mm. The brakes must hold the vehicle on a 20% (1 in 5) slope. Front and rear lights and reflector, indicators, horn and rear-view mirror are required. Vehicle tax and driver's licence are not needed.</td>
<td>995-8200</td>
</tr>
<tr>
<td>27</td>
<td>Electrical wheelchairs</td>
<td>Same characteristics as the Class 2 outdoor wheelchair with features of a Class 3 vehicle.</td>
<td>3300-8200</td>
</tr>
<tr>
<td>28</td>
<td>Scooters</td>
<td>Same characteristics as the Class 2 outdoor scooter with features of a Class 3 vehicle. They cannot be dismantled for transporting.</td>
<td>3-wheels: 995-3750 4-wheels: 1425-6950</td>
</tr>
</tbody>
</table>
Components of manual and/or powered wheelchairs and their characteristics
(a bullet point indicates if the feature is applied either to manual or powered wheelchairs or both).

<table>
<thead>
<tr>
<th>Components</th>
<th>Man. chair</th>
<th>Pow. chair</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>• *</td>
<td></td>
<td>It is responsible for the wheelchair structure, robustness and stability. Can be made of steel tubing, carbon fibre, aluminium or titanium alloys. The weight of the frame is important for ease of use and handling. It may also be rigid or folding and semi-rigid.</td>
</tr>
<tr>
<td>Tipping lever</td>
<td>•</td>
<td></td>
<td>Tipping lever is used by carer to tilt chair backward.</td>
</tr>
<tr>
<td>Skirt guard</td>
<td>*</td>
<td></td>
<td>Protects clothing from contact with wheel.</td>
</tr>
<tr>
<td>Push handle</td>
<td></td>
<td></td>
<td>When the wheelchair user is unable to propel him/herself when going longer distances, a carer can push the wheelchair using a push handle. Many push handle are an integral part of the backrest frame, others are an optional extra. Pushing handles which are adjustable in height are essential to reduce backache during prolonged pushing.</td>
</tr>
<tr>
<td>Drive wheels</td>
<td></td>
<td></td>
<td>Drive wheels range in size from 51-66cm. Wide tyres roll more easily on soft ground and reduce the problem of falling into cracks in uneven ground. Narrow tyres reduce friction and are more efficient on smooth surfaces. May have quick-release mechanism to permit dismantling and facilitate transport.</td>
</tr>
<tr>
<td>Pushing rims</td>
<td>*</td>
<td></td>
<td>Pushing rims or hand rims are available in different materials, diameters and thickness. They may be made of aluminium, chrome-plated steel or stainless steel. Smaller diameter pushing rims give a faster ride, but require more effort. A large diameter rim may suit someone with weak grip.</td>
</tr>
<tr>
<td>Castors</td>
<td></td>
<td></td>
<td>The size of front castor affects the ride and ease of propulsion. Small castors make the wheelchair more manoeuvrable but give a more jolting ride over pavements or rough ground and get caught in holes. Large diameter castors give a more comfortable ride and when moving forwards make the wheelchair more stable.</td>
</tr>
<tr>
<td>Kerb climbers</td>
<td>*</td>
<td></td>
<td>Kerb climbers may be a pair of swinging arms near the front wheels, a central wheel, or a central swinging arm. Wheelchairs with large front wheels may be able to climb kerbs without extra kerb climbers.</td>
</tr>
</tbody>
</table>
Components of manual and/or powered wheelchairs and their characteristics (cont.).

<table>
<thead>
<tr>
<th>Components</th>
<th>Man. Chair</th>
<th>Pow. Chair</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brakes</td>
<td>●</td>
<td>●</td>
<td>On manual wheelchairs brakes are not intended for stopping in motion, but to prevent the wheels from rolling when the wheelchair is parked. They must be applied for safety when transferring. The wheelchair is slowed down for stopping or on slopes by users braking the rims or tyres with their hands, or by a carer using the pushing handles. Manual wheelchairs have brakes that apply to the tyres. The brake levers may be mounted high, low, or midway on the frame, with a push or pull action, or scissors-type levers under the seat. Powered wheelchairs have automatic brakes built into the motors which slow the wheelchair down smoothly as the joystick is released. They also have electromagnetic brakes which are released (often with a distinctive click) when the joystick is moved initially and reactivated when the wheelchair comes to a standstill. These continue to work when the power is disconnected. They also have manual brakes.</td>
</tr>
<tr>
<td>Footrest</td>
<td>●</td>
<td>●</td>
<td>Footrest consists of hanger bracket (attaches footplate to chair), heel loop (prevent foot from slipping backward) and foot plate. It is usually adjustable. For comfort and good posture the footrest must be adjusted to the correct length for the user’s legs. The footrest needs to be at least 50mm from the ground to clear obstacles. Swing-aside and removable footrests help transfer and close access to furniture.</td>
</tr>
<tr>
<td>Tray</td>
<td>●</td>
<td>●</td>
<td>A detachable tray may be slotted in the armrests of many standard wheelchairs. This may be useful for activities such as eating, reading, or supporting a keyboard. It may also give extra support and safety to some people. Propelling a manual wheelchair is more difficult with a tray in place. Instead of a tray many prefer to use desk-style armrests which allow the wheelchair to be brought close to a table.</td>
</tr>
</tbody>
</table>
## Components of manual and/or powered wheelchairs and their characteristics (cont.).

<table>
<thead>
<tr>
<th>Components</th>
<th>Man. chair</th>
<th>Pow. chair</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>Permit the user to control the speed and direction of chair with a single small movement of a joystick. There are alternative controls for users with poor control such as a swash plate and switches that can be operated by the chin, tongue, head, elbow, or by sucking and blowing. The control box may have an speed knob or switch, which sets the maximum speed of the wheelchair. Some control boxes can be programmed by the supplier to set the maximum speed, acceleration, turning speed, etc. to suit the individual user when the chair is supplied.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seat</td>
<td>Seat determines posture and comfort, so it is vital that the user is accurately assessed for the correct seat size. Many wheelchairs have sling seats and backrests, generally made of a vinyl material or woven polyester or nylon canvas. These seats should be used with a cushion. Other wheelchairs have fully upholstered and padded seats with a solid base.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cushions</td>
<td>A cushion is essential for anyone sitting in a wheelchair for long periods, for comfort, support, and distribution of pressure over a great surface area. Wheelchair cushions are available in a variety of materials to suit individual needs. The most common is foam, which is available in a variety of types. Other materials include gel, water, air, and combinations of these.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upholstery</td>
<td>Upholstery should be chosen for comfort, appearance, hygiene, whether it can be cleaned and removed, and water-resistance if required for incontinence or use outside. Nylon upholstery is tough, stretch-resistant and easily cleaned. Vinyl is waterproof, but may be sticky in hot weather. Fabric may be washable and less slippery. Leather is heavier and more expensive, comfortable, long-lasting, and moulds itself to the user. Upholstery can sometimes be re-tensioned to overcome sagging.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Components of manual and/or powered wheelchairs and their characteristics (cont.).

<table>
<thead>
<tr>
<th>Components</th>
<th>Man. chair</th>
<th>Pow. chair</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armrests</td>
<td></td>
<td></td>
<td>Armrests give sideways support to the trunk, as well as arm support. They provide something to hold on to when leaning forward, and a surface to push on when transferring or shifting position. They also help to prevent clothes catching in the wheel. They may be fixed or removable, flip-up, or swing-side. Desk-style armrests are shorter or lower in front, to allow the wheelchair to be brought close to a table. Active users with a stable seating base may not want armrests as they can restrict arm movement for propulsion and increase the weight of the wheelchair.</td>
</tr>
<tr>
<td>Backrest</td>
<td></td>
<td></td>
<td>The backrest angle may vary. If it is too upright the person may fall forwards. If it reclines too much the person may slide down in the seat. Some backrests can be reclined for people who cannot sit upright or to redistribute load for people who have local areas of high pressure. Some high-performance wheelchairs for active users have very low backrests. For tall people a height backrest may be needed, and for people who need a head support a headrest extension can be added. Folding backrests can be useful for transport and transfer.</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td></td>
<td>The distance that the wheelchair can travel on a full battery charge. The range will depend on the conditions in which the wheelchair is used, the battery condition and the weight of the user.</td>
</tr>
<tr>
<td>Batteries</td>
<td></td>
<td></td>
<td>Powered wheelchairs usually run on two rechargeable 12V batteries. The capacity of a battery is measured in ampere hours (Ah), and varies with age, battery condition and temperature. The batteries need regular recharging, usually overnight. There are two different types of wheelchair battery: lead acid and &quot;sealed&quot; gel. The latter, in contrast to the former, does not need routine maintenance but requires extra care with the charging procedure. The user's fear that the battery will run out may cause the powered wheelchair be underused. A battery gauge helps to indicate the state of charge of the battery.</td>
</tr>
</tbody>
</table>
A - PERSONAL DATA

1. Name and Title
   
   2. Address
   
   3. Telephone Number (including Area Code)
   
   4. Fax Number (including Area Code)
   
   5. Name of company for whom you design wheelchairs?
   
   6. What is your educational background?
   
   Have you got any training in ergonomics?
   □ Yes (continue)  □ No (go to Question 7)
   
   If yes, could you describe it and give your qualifications please?
   (then, go to Question 8)
**B - EXPLORATORY QUESTIONS ABOUT ERGONOMICS**

7. Have you heard of the word 'ergonomics'?  
   - Yes (continue)  
   - No (go to Question 10)

8. What do you understand by the word 'ergonomics'?

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9. Do you think that ergonomics is important in the design of wheelchairs for disabled people?  
   - Yes, why?
   - No, why not?
C - EXPLORATORY QUESTION ABOUT DESIGN METHOD(S)

10. Do you use any systematic method(s) to design your wheelchairs?

☐ Yes (continue)  ☐ No (go to Question 11)

If yes, could you outline briefly the method(s) which you use?

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11. Do you try to take account of the range of needs of disabled people when designing wheelchairs?

☐ Yes (continue) ☐ No (go to Question 16)

If yes, how do you do that?

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12. Have you ever had any problems in the establishment of wheelchair user needs?

☐ Yes (continue) ☐ No (go to Question 13)

If yes, what is the major problem, in your view, of establishing their needs?

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13. Do you use marketing research in your design work?
   - Yes (continue)
   - No (go to Question 16)

14. How do you translate the information which you have gathered from the marketing research into design requirements?

15. Do you have any kind of problem using data from marketing research in your design work?
   - Yes (continue)
   - No (go to Question 16)

   If yes, what?
QUESTIONS 16-18 ARE JUST FOR THOSE WHO HAVE ANSWERED "YES" TO QUESTION 7. THOSE WHO ANSWERED "NO" SHOULD GO DIRECTLY TO QUESTION 19.

16. Do you use information from the ergonomics literature in your design work (e.g. from journals such as Applied Ergonomics, Ergonomics, Human Factors, Ergonomics in Design; or books such as Evaluation of Human Work - Wilson and Corlett, Human Factors in Engineering and Design - Sanders and McCormick, Human Factors in Product Design - Cushman and Rosenberg)?
   - Yes (continue)
   - No (go to Question 19)

17. How do you translate the information which you have gathered from the ergonomics literature into design requirements?

18. Do you have any kind of problem using data from the ergonomics literature in your design work?
   - Yes (continue)
   - No (go to Question 19)

19. Do you use information from scientific work on disability in your design work (e.g. that published in the MDD - Medical Devices Directorate Reports; publications from the Disabled Living Foundation and The Disability Information Trust and from journals such as the Journal of Rehabilitation, IEEE Transactions on Rehabilitation Engineering, etc.)?
   - Yes (continue)
   - No (go to Question 22)
20. How do you translate the information which you have gathered from these scientific sources on disability into design requirements?

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21. Do you have any kind of problem using data from these scientific sources in your design work?
   □ Yes (continue)  □ No (go to Question 22)
   If yes, what?

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22. Do you use more popular and everyday magazines or newsletters on disability in your design work (e.g. Disability Now, Carers World, Arthritis News, Spinal Injuries Association Newsletter)?
   □ Yes (continue)  □ No (go to Question 25)
   If yes, which?

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23. How do you translate the information which you have gathered from more popular and everyday magazines or newsletters on disability into design requirements?

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24. Do you have any kind of problem using data from more popular and everyday magazines or newsletters on disability in your design work?
   □ Yes (continue)  □ No (go to Question 25)
   If yes, what?

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25. Do you use information gathered about your competitors' products in your
design work (e.g. from catalogues, brochures, leaflets, technical specifications,
etc)?

☐ Yes (continue) ☐ No (go to Question 28)
If yes, which kind of information?

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26. How do you translate the information which you have gathered about your
competitors' products into design requirements?

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27. Do you have any kind of problem which you have gathered about your
competitors' products in your design work?

☐ Yes (continue) ☐ No (go to Question 28)
If yes, what?

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28. Do you use standards (e.g. from ISO, CEN and BSI) in your design work?
   ☐ Yes (continue)  ☐ No (go to Question 33)
   If yes, which?

29. What role do standards play in your design of wheelchairs?

30. How do you translate information on standards into design requirements?

31. Do you have any kind of problem using data from standards in your design work?
   ☐ Yes (continue)  ☐ No (go to Question 32)
   If yes, what?
32. Apart from the mandatory standards required by legislation, do you use any voluntary standards?

☐ Yes (continue)  ☐ No (go to Question 33)

If yes, could you please give me details of these voluntary standards?

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E - EXPLORATORY QUESTION ABOUT CONCEPTUALISATION

33. Do you use any systematic method(s) to generate, evaluate and select ideas when designing wheelchairs?
   ☐ Yes (continue) ☐ No (go to Question 34)
   If yes, could you outline briefly the method(s) which you use?

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F - EXPLORATORY QUESTIONS ABOUT PROTOTYPING

34. Do you produce representative models (computer graphics or non-working "mock-ups") and/or working models when designing wheelchairs?

☐ Yes (continue)  ☐ No (go to Question 36)

If yes, could you outline briefly how do you do that (kind of model, scale, method of evaluation, etc.)?

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35. Do users take part in your prototyping evaluation?

☐ Yes (continue)  ☐ No (go to Question 36)

If yes, could you explain the procedure??

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Appendix 3.1

G - EXPLORATORY QUESTIONS ABOUT PRODUCTION

36. Have you heard of Quality Function Deployment (QFD) which is a new method used in the design and manufacture of consumer products and which is based on customer demands as a means to define product requirements?
   ☐ Yes (continue) ☐ No (go to Question 37)
   If yes, do you use this method?
   ☐ Yes, how?
   ☐ No, why not?

37. Have you heard of Kansei Engineering which is also a new method used in the design and manufacture of consumer products and which is based on customer demands as a means to define product requirements?
   ☐ Yes (continue) ☐ No (go to Question 38)
   If yes, do you use this method?
   ☐ Yes, how?
   ☐ No, why not?
H - EXPLORATORY QUESTIONS ABOUT PRODUCT EVALUATION AND MARKETING

38. Do you or any other agency (e.g. university departments, consultancy organisations or test houses) carry out physical tests on your wheelchairs (e.g. tests of static stability, dynamics, manoeuvrability, brakes, speed and range, and fatigue)?

☐ Yes (continue) ☐ No (go to Question 39)

If yes, could you, please, explain to me what is done?

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39. Do you or any other agency (e.g. university departments, consultancy organisations or test houses) carry out any ergonomics tests on your wheelchairs (e.g. tests of usability, safety, comfort, dimensional compatibility, etc)?

☐ Yes ☐ No (go to Question 40)

If yes, could you, please, explain to me what is done?

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40. Do you compare your products against those of competitors?

☐ Yes (continue) ☐ No (go to Question 42)

If yes, what methods do you use to effect the comparison?

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41. How would you rate your products against those of competitors?

<table>
<thead>
<tr>
<th>Category</th>
<th>Superior</th>
<th>Equal</th>
<th>Inferior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physically</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ergonomically</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aesthetically</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

42. Do you use feedback from your customers after sale to obtain information about your products?

☐ Yes

☐ No

If yes, could you describe it please?

43. Which role do "costs" play in the design of your wheelchairs?

THANK YOU VERY MUCH!
LEICESTERSHIRE DISABLEMENT SERVICES CENTRE

WHEELCHAIR REFERRAL FORM

THIS FORM SHOULD BE COMPLETED AND SIGNED BY THE PERSONS GP, OCCUPATIONAL THERAPIST OR PHYSIOTHERAPIST

CRITERIA FOR SUPPLY

NON-POWERED WHEELCHAIR: PERSON HAS LIMITED WALKING ABILITY, LIKELY TO BE IN EXCESS OF SIX MONTHS, OR WHO IS TERMINALLY ILL.

POWERED INDOOR AND / OR OUTDOOR WHEELCHAIR: PERSON IS UNABLE TO SATISFACTORILY PROPEL A NON-POWERED WHEELCHAIR AND WOULD GAIN A MEASURE OF INDEPENDENCE (SUBJECT TO DSC ASSESSMENT FOR ELIGIBILITY).

PERSONAL DETAILS

| SURNAME: (Mr., Mrs., Miss, Child, Etc.) |  |
| FORENAME: |  |
| NHS NUMBER (If known): |  |
| HOME ADDRESS: | DELIVERY ADDRESS: |
| POST CODE: | POST CODE: |
| TEL NO: | CONTACT: |
| DATE OF BIRTH: | MAIN LANGUAGE: |
| GENDER: M / F | HEIGHT: |
| ETHNIC ORIGIN: | WEIGHT: |
| DISABILITY: |  |
| RELEVANT MEDICAL DETAILS: |  |
| CRITICAL CASE (Eg. Terminal Illness) | ESSENTIAL FOR HOSPITAL DISCHARGE? |
| YES ☐ NO ☐ | N/A ☐ YES ☐ NO ☐ |
| PLANNED DISCHARGE DATE: |  |
| IS THE PERSON ALREADY IN POSSESSION OF AN N.H.S. WHEELCHAIR? | YES ☐ NO ☐ |

LWR3 July 1996
### ASSESSMENT DETAILS: WHEELCHAIR

<table>
<thead>
<tr>
<th>WHAT IS THE PERSONS IMMObILE WALKING ABILITY WITHIN THE HOME?</th>
<th>Immobile □ Requires carers assistance □ Independent but limited distance □</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHAT IS THE PERSONS TRANSFER METHOD?</td>
<td>Hoist □ Requires assistance to stand □ Independent standing □ Requires assistance to slide □ Independent sliding □</td>
</tr>
<tr>
<td>HOW OFTEN WILL THE WHEELCHAIR BE USED?</td>
<td>All day indoors □ Part day indoors □ Daily outdoors □ Four times a week or more □ 1-3 times a week □ Occasionally □</td>
</tr>
<tr>
<td>WOULD THE WHEELCHAIR NEED TO FOLD TO TRANSPORT?</td>
<td>Yes □ No □</td>
</tr>
<tr>
<td>TYPE REQUIRED:</td>
<td>Non-Powered attendant push chair □ Non-Powered user propelled wheelchair □ Powered indoor wheelchair □ Powered outdoor occupant controlled wheelchair □ Powered outdoor attendant controlled wheelchair □ Special seating system (e.g. mould etc.) □</td>
</tr>
<tr>
<td>SUGGESTED WHEELCHAIR:</td>
<td></td>
</tr>
<tr>
<td>SUGGESTED SEAT SIZE:</td>
<td></td>
</tr>
<tr>
<td>ACCESSORIES REQUIRED:</td>
<td></td>
</tr>
</tbody>
</table>

### ASSESSMENT DETAILS: CUSHION

<table>
<thead>
<tr>
<th>IS STANDARD FOAM CUSHION ADEQUATE?</th>
<th>Yes □ No □</th>
</tr>
</thead>
<tbody>
<tr>
<td>If Yes</td>
<td>2” □ 3” □ 4” □</td>
</tr>
<tr>
<td>SUGGESTED CUSHION?</td>
<td></td>
</tr>
<tr>
<td>WHAT IS THE MAXIMUM DURATION THE PERSON WILL SIT IN WHEELCHAIR IN ONE SESSION?</td>
<td>1 Hour □ 1-4 Hours □ 5-8 Hours □ More than 8 Hours □</td>
</tr>
<tr>
<td>CAN THE PERSON MAINTAIN SITTING BALANCE IN THE WHEELCHAIR?</td>
<td>Yes □ No □</td>
</tr>
<tr>
<td>PERSONS TISSUE STATUS?</td>
<td>Previous sore/s Site Grade</td>
</tr>
<tr>
<td>Present sore/s Site Grade</td>
<td>Yes □ No □</td>
</tr>
<tr>
<td>CONTINENCE STATUS?</td>
<td>Continent □ Occasionally Incontinent □ Incontinent Catherised □</td>
</tr>
<tr>
<td>WHO WILL MAINTAIN AND MONITOR THE CUSHION?</td>
<td></td>
</tr>
<tr>
<td>WATERLOW OR NORTON SCORE? (IF KNOWN)</td>
<td>WATERLOW SCORE □ NORTON SCORE □</td>
</tr>
</tbody>
</table>
ASSESSMENT BY DISABLEMENT SERVICES CENTRE TEAM

IS FURTHER ASSESSMENT REQUIRED BY DSC? YES ☐ NO ☐

IF YES:
PERSON CAN ATTEND CLINIC APPOINTMENT AT DSC YES ☐ NO ☐
PERSON IS NOT WELL ENOUGH TO TRAVEL AND WILL REQUIRE HOME ASSESSMENT (INCREASES WAITING TIME) YES ☐ NO ☐

TRAVEL ARRANGEMENTS FOR CLINIC APPOINTMENTS

PERSON HAS OWN TRANSPORT ☐ PERSON NEEDS SITTING AMBULANCE ☐
PERSON ABLE TO TRAVEL BY AMBULANCE CAR ☐ PERSON NEEDS TWO MAN LIFT ☐
PERSON NEEDS TO TRAVEL IN WHEELCHAIR ☐
WOULD THE PERSON NEED TO TRAVEL WITH A CARER? YES ☐ NO ☐

DETAILS OF GP

NAME .......................................................................................................................... LOCATION ..........................................................................................................................
..........................................................................................................................
POST CODE .................................................. TELEPHONE NUMBER ........................................
IS THE PERSONS GP. AWARE OF THIS REFERRAL?

DETAILS OF PRESCRIBER

NAME .................................................. PROFESSION ..................................................
LOCATION ..........................................................................................................................
..........................................................................................................................
POST CODE .................................................. TELEPHONE NUMBER ........................................
SIGNATURE .................................................. DATE .....................................

THIS FORM MUST BE SIGNED BY A GP, OCCUPATIONAL THERAPIST OR PHYSIOTHERAPIST. INCOMPLETE FORMS WILL BE RETURNED FOR FURTHER DETAILS AND MAY RESULT IN A DELAY WITH THE ISSUE OF EQUIPMENT.
WHEELCHAIR REFERRAL FORM

THE WHEELCHAIR SERVICE PROVIDES APPROPRIATE EQUIPMENT FOR PEOPLE WITH A LONG TERM NEED (I.E. 6 MONTHS OR OVER).

IF A PERSON HAS A SHORT TERM NEED OF A WHEELCHAIR (I.E. UNDER 6 MONTHS) THEN CONTACT HOME LOANS, TELEPHONE 0332 385519.

THERE IS A WHEELCHAIR HIRE SERVICE AVAILABLE FOR OCCASIONAL USERS FOR SUCH THINGS AS HOLIDAYS, OUTINGS, VISITORS, ETC.

Name

D.O.B. / / SEX M/F

Address of Wheelchair User

Address

Postcode

Tel Nos.
Home
Work

Address for Wheelchair Delivery

Address

Postcode

Tel Nos.
Home
Work
<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>How urgent is this case?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If urgent give reason</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does user already have a wheelchair?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If chair has to be lifted, can carer/user do this?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is user at risk of pressure sores?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does user have impaired sitting balance?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does user have spinal deformity?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is the user strong enough to self-propel?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the user wish to self-propel?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the user have a cardio-respiratory problem which could affect the ability to self-propel?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How often will the wheelchair be used?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has an assessment of the environment in which the wheelchair is to be used been carried out?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are there any known problems with the environment which will affect use of wheelchair?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is a cushion required for wheelchair?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Appendix 4.1

Name & Address of G.P Consultant

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Height</th>
<th>Weight</th>
<th>Does user already have a wheelchair?</th>
<th>If chair has to be lifted, can carer/user do this?</th>
<th>Is user at risk of pressure sores?</th>
<th>Does user have impaired sitting balance?</th>
<th>Does user have spinal deformity?</th>
<th>Is the user strong enough to self-propel?</th>
<th>Does the user wish to self-propel?</th>
<th>Does the user have a cardio-respiratory problem which could affect the ability to self-propel?</th>
<th>How often will the wheelchair be used?</th>
<th>Has an assessment of the environment in which the wheelchair is to be used been carried out?</th>
<th>Are there any known problems with the environment which will affect use of wheelchair?</th>
<th>Is a cushion required for wheelchair?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Don't know</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TYPE OF WHEELCHAIR REQUIRED

SELF-PROPELLING

- Seat and back fold for transporting
- Removable armrests
- Suitable for adults up to 16 stone
- Seat size 17" x 17"
- Weight of chair 38lbs./18kg.

ATTENDANT PROPELLED

- Seat and back fold for transporting
- Removable armrests
- Suitable for adults up to 16 stone
- Seat size 17" x 17"
- Weight of chair 34lbs./15kg.

Tick box required

N.B. If specialist alternative wheelchair is required assessment will be carried out by wheelchair therapist or rehabilitation engineer.

Please tick box if required

Suggested alternative model

COMMENTS

DETAILS OF REFERRER

Name
Profession
Address
Post Code
Tel No.
Signature
Date

COMMUNITY HEALTH SERVICES
NHS TRUST
SOUTHERN DERBYSHIRE
WHEELCHAIR SERVICE, HOME LOANS STORE,
UTTOXETER ROAD, DERBY DE22 3NB.395
TELEPHONE: 0332 292080, FAX: 0332 299918
List of questions to informal meetings with wheelchair prescribers

1. Who is involved in the prescription of wheelchairs? Who prescribes wheelchairs?

2. In which context do prescriptions take place (hospital, community, medical centre, etc.)?

3. Could you please describe the wheelchair prescription process in each context?

4. Does follow up and evaluation go into prescription or is it outside? (Try to define the boundaries of each stage)

5. Do you think that this procedure is followed in the same way everywhere in the UK?

6. What happens if the patient has special needs?

7. Could you please trace a route by which people may come to have a wheelchair (based on community, GP or Physiotherapist/Occupational Therapist)?

8. What sources are there for wheelchair free of charge?

9. As far as private purchase is concerned, do patients use professional advice to buy wheelchairs or not? If yes, how does it work?

10. Have you ever been involved in wheelchair design?

11. What kind of contribution do you think prescribers can provide to wheelchair design?
14 May 1997

Dear Sir/Madam

In connection with our telephone conversation today, please find enclosed a copy of the pilot questionnaire. Please feel free to produce any comments about this pilot version. Your comments will be very much appreciated and valued.

The fundamental aim of my project is to examine the relationship between wheelchair user needs and product requirements from an ergonomics point-of-view. Part of this aim involves establishing whether or not various stakeholders (including wheelchair designers, therapists, rehabilitation engineers dealing with wheelchair issues, carers and wheelchair users themselves) participate in the design process. If they do participate, I want to establish their involvement in wheelchair design. If they do not, I want to establish if they would like to be involved and how.

Part of my field study was carried out last year to bring to light how a sample of designers approach the design of wheelchairs and what kind of data they need from users. For this purpose, a sample of design practitioners working in organisations in England, Scotland and Wales was interviewed. The designers who participated in this survey represent companies which provide the vast majority of wheelchairs produced in the United Kingdom.

I am now approaching therapists partly to gain a better understanding of the prescription process, but more importantly to determine what they contribute, actually or potentially, to design. I would like to clarify that, in this questionnaire, the interest is not in design for an
individual (bespoke design) or particular adaptations of wheelchairs for specific client needs. The interest is in the production of wheelchairs in large scale manufacturing (generic design) which is directed at a broad group of people.

Accordingly I would be extremely grateful if you would agree to spare about 15 minutes to answer the enclosed questionnaire. Your answers will be very much appreciated and valued and will help to make wheelchairs better suited to the needs of all their users. Any information which you provide will be strictly confidential.

Please find enclosed a freepost envelope to send the questionnaire back. I would be enormously grateful if you could help me.

Thanking you in advance and looking forward to hearing from you soon.

Yours sincerely

[Signature]

Marcelo M. Soares
A - PERSONAL DATA

1. What are you?
   - [ ] an Occupational Therapist
   - [ ] a Physiotherapist

2. Where do you work?
   - [ ] in a Disabled Living Centre
   - [ ] in an N.H.S. Wheelchair Service

3. What educational qualification do you have? (please tick all that apply)
   - [ ] Diploma
   - [ ] First degree
   - [ ] Master degree
   - [ ] Ph.D.

4. Have you had any training to enable you to assess patients and to prescribe wheelchairs for them?
   - [ ] Yes (continue)
   - [ ] No (go to Question 5)
   If yes, could you please describe the training and give the associated qualification (if any)? (then, go to Question 5)

B - EXPLORATORY QUESTIONS ABOUT ERGONOMICS

5. Have you heard of the word 'ergonomics'?
   - [ ] Yes (continue)
   - [ ] No (go to Question 9)

6. Have you had any training in ergonomics?
   - [ ] Yes (continue)
   - [ ] No (go to Question 7)
   If yes, could you please describe the training and give the associated qualification (if any)? (then, go to Question 7)
7. What do you understand by the word 'ergonomics'? 

........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

8. Do you think that ergonomics is important in the design of wheelchairs for disabled people?  
   • Yes, why? 
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................

   • No, why not? 
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................

C - EXPLORATORY QUESTIONS ABOUT WHEELCHAIR PRESCRIPTION

9. Can you identify from your experience any weaknesses in the process by which patients are assessed and wheelchairs prescribed?  
   • Yes (continue)  
   • No (go to Question 10)  
   If yes, what are they? 
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................

   Have these weaknesses any implications for design? 
   ........................................................................................................................................
   ........................................................................................................................................
10. When wheelchairs have been delivered to patients do you subsequently collect the views of the users about the wheelchairs which have been prescribed for them?

☐ Yes (continue)  ☐ No (go to Question 11)

How do you collect these views?

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..............................................................................................................................................................
..............................................................................................................................................................
..............................................................................................................................................................

To what use are these views put?

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..............................................................................................................................................................
..............................................................................................................................................................
..............................................................................................................................................................

Are these views fed back to designers and manufacturers of wheelchairs?

☐ Yes (continue)  ☐ No (go to Question 11)

Please describe any examples where you have used the views of patients to assist in the design of wheelchairs.

..............................................................................................................................................................
..............................................................................................................................................................
..............................................................................................................................................................
..............................................................................................................................................................

D - EXPLORATORY QUESTIONS ABOUT WHEELCHAIR DESIGN

11. Have you ever been in contact with manufacturers about problems connected with wheelchairs?

☐ Yes (continue)  ☐ No (go to Question 13)

If yes, did they take any notice of what you said and did they modify the wheelchair?

☐ Yes  ☐ No (go to Question 12)
12. Have you ever been involved in wheelchair design with a company that mass produces wheelchairs for a large market?

☐ Yes (continue)  ☐ No (go to Question 13)

If yes, what was your main contribution?

..............................................................................................................................
..............................................................................................................................
..............................................................................................................................
..............................................................................................................................

13. Would you like to be involved in wheelchair design with companies that mass produce wheelchairs for a large market?

☐ Yes (continue)  ☐ No (go to Question 14)

If yes, what kind of contribution do you think you can provide to wheelchair design?

..............................................................................................................................
..............................................................................................................................
..............................................................................................................................
..............................................................................................................................

14. Do you think that, in general, that wheelchairs actually in the market place are designed taking into account the range of needs of disabled people?

☐ Yes, why?
..............................................................................................................................
..............................................................................................................................
..............................................................................................................................
..............................................................................................................................

☐ No, why not?
..............................................................................................................................
..............................................................................................................................
..............................................................................................................................
..............................................................................................................................

☐ I do not know (go to Question 15)
15. How do you rate the wheelchairs provided by NHS against those provided by private companies?

**Manual Wheelchairs**
- Structurally: Superior, Equal, Inferior, I don't know
- Ergonomically: Superior, Equal, Inferior, I don't know
- Aesthetically: Superior, Equal, Inferior, I don't know

**Powered Wheelchairs**
- Structurally: Superior, Equal, Inferior, I don't know
- Ergonomically: Superior, Equal, Inferior, I don't know
- Aesthetically: Superior, Equal, Inferior, I don't know

16. Generally speaking, how do you rate the design of wheelchairs provided by NHS in terms of meeting the needs of disabled people?

**Manual Wheelchairs**
- Very Good, Good, Average, Poor, Very Poor

**Powered Wheelchairs**
- Very Good, Good, Average, Poor, Very Poor

17. Generally speaking, how do you rate the design of wheelchairs provided by private companies in terms of meeting the needs of disabled people?

**Manual Wheelchairs**
- Very Good, Good, Average, Poor, Very Poor

**Powered Wheelchairs**
- Very Good, Good, Average, Poor, Very Poor

THANK YOU VERY MUCH!
To the Attention of the Senior Therapist

28 May 1997

Dear Sir/Madam

My name is Marcelo M. Soares, a Brazilian Industrial Design lecturer carrying out a Ph.D. program at Loughborough University.

The fundamental aim of my project is to examine the relationship between wheelchair user needs and product requirements from an ergonomics point-of-view. Part of this aim involves establishing whether or not various stakeholders (including wheelchair designers, therapists, rehabilitation engineers dealing with wheelchair issues, carers and wheelchair users themselves) participate in the design process. If they do participate, I want to establish their involvement in wheelchair design. If they do not, I want to establish if they would like to be involved and how.

Part of my field study was carried out last year to bring to light how a sample of designers approach the design of wheelchairs and what kind of data they need from users. For this purpose, a sample of design practitioners working in organisations in England, Scotland and Wales was interviewed. The designers who participated in this survey represent companies which provide the vast majority of wheelchairs produced in the United Kingdom.

I am now approaching therapists partly to gain a better understanding of the prescription process, but more importantly to determine what they contribute, actually or potentially, to design. I would like to clarify that, in this questionnaire, the interest is not in design for an individual (bespoke design) or particular adaptations of wheelchairs for specific client needs.
The interest is in the production of wheelchairs in large scale manufacturing (generic design) which is directed at a broad group of people.

Accordingly I would be extremely grateful if you would agree to spare about 15 minutes to answer the enclosed questionnaire. Your answers will be very much appreciated and valued and will help to make wheelchairs better suited to the needs of all their users. Any information which you provide will be strictly confidential.

Please find enclosed a freepost envelope to send the questionnaire back. I would be enormously grateful if you could help me.

Thanking you in advance and looking forward to hearing from you soon.

Yours sincerely

Marcelo M. Soares

I certify, as Marcelo Soares' Ph.D. Supervisor, that he is a bona fide postgraduate research student in the Department of Human Sciences.

N. S. Kirk
Professor of Consumer Behaviour
A - PERSONAL DATA

1. What are you?
   - an Occupational Therapist
   - a Physiotherapist

2. Where do you work?
   - in a Disabled Living Centre
   - in an N.H.S. Wheelchair Service

3. What educational qualification do you have? (please tick all that apply)
   - Diploma
   - First degree
   - Master degree
   - Ph.D.

4. Have you had any training to enable you to assess clients and to prescribe wheelchairs for them?
   - Yes (continue)
   - No (go to Question 5)

   If yes, could you please describe the training and give the associated qualification (if any)? (then, go to Question 5)

B - EXPLORATORY QUESTIONS ABOUT ERGONOMICS

5. Have you heard of the word 'ergonomics'?
   - Yes (continue)
   - No (go to Question 9)

6. Have you had any training in ergonomics?
   - Yes (continue)
   - No (go to Question 7)

   If yes, could you please describe the training and give the associated qualification (if any)? (then, go to Question 7)
7. What do you understand by the word 'ergonomics'? 

........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

8. Do you think that ergonomics is important in the design of wheelchairs for disabled people? 
   □ Yes, why?
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................
   □ No, why not?
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................

C - EXPLORATORY QUESTIONS ABOUT WHEELCHAIR PRESCRIPTION

9. Can you identify from your experience any weaknesses in the process by which clients are assessed and wheelchairs prescribed? 
   □ Yes (continue)  □ No (go to Question 10)
   If yes, what are they?
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................
   Have these weaknesses any implications for design?
   ........................................................................................................................................
   ........................................................................................................................................
10. When wheelchairs have been delivered to clients do you subsequently collect formally the views of the users about the wheelchairs which have been prescribed for them?

- Yes (continue)
- No (go to Question 11)

How do you collect these views?

To what use are these views put?

Are these views fed back to designers and manufacturers of wheelchairs?

- Yes (continue)
- No (go to Question 11)

Please describe any examples where you have used the views of clients to assist in the design of wheelchairs.

D - EXPLORATORY QUESTIONS ABOUT WHEELCHAIR DESIGN

11. Have you ever been in contact with manufacturers about problems connected with wheelchairs?

- Yes (continue)
- No (go to Question 13)

If yes, did they take any notice of what you said and did they modify the wheelchair?

- Yes
- Unsure
- (No go to Question 12)
12. Have you ever been involved in wheelchair design with a company that mass produces wheelchairs for a large market?
   - Yes (continue)
   - No (go to Question 13)

If yes, what was your main contribution?

13. Would you like to be involved in wheelchair design with companies that mass produce wheelchairs for a large market?
   - Yes (continue)
   - No (go to Question 14)

If yes, what kind of contribution do you think you can provide to wheelchair design?

14. Do you think that, in general, that wheelchairs actually in the market place are designed taking into account the range of needs of disabled people?
   - Yes, why?
   - No, why not?
   - I do not know (go to Question 15)
15. How do you rate the wheelchairs provided by private companies against those provided by NHS?

Manual Wheelchairs

<table>
<thead>
<tr>
<th>Structural</th>
<th>Superior</th>
<th>Equal</th>
<th>Inferior</th>
<th>I don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ergonomically</td>
<td>Superior</td>
<td>Equal</td>
<td>Inferior</td>
<td>I don't know</td>
</tr>
<tr>
<td>Aesthetically</td>
<td>Superior</td>
<td>Equal</td>
<td>Inferior</td>
<td>I don't know</td>
</tr>
</tbody>
</table>

Powered Wheelchairs

<table>
<thead>
<tr>
<th>Structural</th>
<th>Superior</th>
<th>Equal</th>
<th>Inferior</th>
<th>I don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ergonomically</td>
<td>Superior</td>
<td>Equal</td>
<td>Inferior</td>
<td>I don't know</td>
</tr>
<tr>
<td>Aesthetically</td>
<td>Superior</td>
<td>Equal</td>
<td>Inferior</td>
<td>I don't know</td>
</tr>
</tbody>
</table>

16. Generally speaking, how do you rate the design of wheelchairs provided by NHS in terms of meeting the needs of disabled people?

Manual Wheelchairs

| Very Good | Good | Average | Poor | Very Poor |

Powered Wheelchairs

| Very Good | Good | Average | Poor | Very Poor |

17. Generally speaking, how do you rate the design of wheelchairs provided by private companies in terms of meeting the needs of disabled people?

Manual Wheelchairs

| Very Good | Good | Average | Poor | Very Poor |

Powered Wheelchairs

| Very Good | Good | Average | Poor | Very Poor |

THANK YOU VERY MUCH!
To the Attention of the Senior Therapist

20 June 1997

Dear Sir/Madam

A short time ago I sent you a questionnaire on wheelchair prescription. As you may recall, this survey, which is being conducted as part of my Ph.D. program at Loughborough University, aims to understand the wheelchair prescription process and the contribution of the therapists, actually or potentially, to wheelchair design.

The original questionnaires were sent to one Senior Therapist from each Disabled Living Centre and N.H.S. Wheelchair Service throughout the UK. As they were sent in an anonymous basis I do not have the names of the people who received and returned the questionnaire.

Thank you if you or another therapist in your Centre has already taken the time to complete the questionnaire and return it to me. It is very important to the success of my survey that I get as many completed questionnaire as possible so that the responses are truly representative. If you or one of your colleagues has not yet completed the questionnaire I would be very grateful if you could do so within a week of receipt of this letter.

Many thanks again for you help. It is much appreciated.

Yours sincerely,

Marcelo M. Soares
22 August 1997

Dear Sir/Madam

In connection with our telephone conversation today, please find enclosed a copy of the pilot questionnaire. Please feel free to produce any comments about this version. Your comments will be very much appreciated and valued.

I am a Brazilian Industrial Design lecturer carrying out a Ph.D. program at Loughborough University. The fundamental aim of my project is to examine the relationship between wheelchair user needs and product requirements from an ergonomics point-of-view. Part of this aim involves establishing whether or not various stakeholders (including wheelchair designers, health professionals who prescribe wheelchairs, rehabilitation engineers dealing with wheelchair issues, carers and wheelchair users themselves) participate in the design process. If they do participate, I want to establish their involvement in wheelchair design. If they do not, I want to establish if they would like to be involved and how.

Part of my field study was carried out last year to bring to light how a sample of designers approach the design of wheelchairs and what kind of data they need from users. For this purpose, a sample of design practitioners working in organisations in England, Scotland and Wales was interviewed. The designers who participated in this survey represent companies which provide the vast majority of wheelchairs produced in the United Kingdom.

Last month I finished a survey with therapists from Disabled Living Centres and N.H.S. Wheelchair Services throughout the country. I am now approaching
rehabilitation engineers partly to gain a better understanding of the prescription process, but more importantly to determine what they contribute, actually or potentially, to design. I would like to clarify that, in this questionnaire, the interest is not in design for an individual (bespoke design) or particular adaptations of wheelchairs for specific patient needs. The interest is in the production of wheelchairs on a large manufacturing scale (generic design) directed at a broad group of people. If your work does not involve, and has not involved, wheelchairs please ignore this letter and the enclosed questionnaire.

Accordingly I would be extremely grateful if you would agree to spare about 10 minutes to answer the enclosed questionnaire. Your answers will be very much appreciated and valued and will help to make wheelchairs better suited to the needs of all their users. Any information which you provide will be strictly confidential.

When you have completed the questionnaire, please fold it where indicated and staple or seal it. I would be extremely grateful if you could help me.

Thanking you in advance and looking forward to hearing from you soon.

Yours sincerely,

[Signature]

Marcelo M. Soares
A - PERSONAL DATA

1. What educational qualification do you have? (please tick all that apply)
   - Diploma
   - First degree
   - Master degree
   - Ph.D.

2. Have you had any training to enable you to assess clients and to prescribe wheelchairs for them?
   - Yes (continue)
   - No (go to Question 3)
   If yes, could you please describe the training and give the associated qualification (if any)? (then, go to Question 3)

B - EXPLORATORY QUESTIONS ABOUT ERGONOMICS

3. Have you had any training in ergonomics?
   - Yes (continue)
   - No (go to Question 4)
   If yes, could you please describe the training and give the associated qualification (if any)? (then, go to Question 4)

4. What do you understand by the word 'ergonomics'?
5. Do you think that ergonomics is important in the design of wheelchairs for disabled people?
   - Yes, why?
   - No, why not?

C - EXPLORATORY QUESTIONS ABOUT WHEELCHAIR PRESCRIPTION

6. Do you take part in the wheelchair prescription process?
   - Yes (continue)
   - No (go to Question 9)

7. Can you identify from your experience any weaknesses in the process by which wheelchairs are prescribed?
   - Yes (continue)
   - No (go to Question 8)

If yes, what are they?

Have these weaknesses any implications for design?
8. When wheelchairs have been delivered to clients do you subsequently collect formally the views of the users about the wheelchairs which have been prescribed for them?

☐ Yes (continue) ☐ No (go to Question 9)

How do you collect these views?

..................................................................................................................................................................................
..................................................................................................................................................................................
..................................................................................................................................................................................
..................................................................................................................................................................................

To what use are these views put?

..................................................................................................................................................................................
..................................................................................................................................................................................
..................................................................................................................................................................................
..................................................................................................................................................................................

Are these views fed back to designers and manufacturers of wheelchairs?

☐ Yes (continue) ☐ No (go to Question 9)

Please describe any examples where you have used the views of clients to assist in the design of wheelchairs.

..................................................................................................................................................................................
..................................................................................................................................................................................
..................................................................................................................................................................................
..................................................................................................................................................................................


D - EXPLORATORY QUESTIONS ABOUT WHEELCHAIR DESIGN

9. Have you ever been in contact with manufacturers about problems connected with wheelchairs?

☐ Yes (continue) ☐ No (go to Question 10)

If yes, did they take any notice of what you said and did they modify the wheelchair?

☐ Yes ☐ Unsure ☐ (No go to Question 10)
10. Have you ever been involved in wheelchair design with a company that mass produces wheelchairs for a large market?
   - Yes (continue)
   - No (go to Question 11)

   If yes, what was your main contribution?

11. Would you like to be involved, or continue to be involved, in wheelchair design with companies that mass produce wheelchairs for a large market?
   - Yes (continue)
   - No (go to Question 12)

   If yes, what kind of contribution do you think you can provide to wheelchair design?

12. Do you think that, in general, the wheelchairs actually in the market place are designed taking into account the range of needs of disabled people?
   - Yes, why?
   - No, why not?
   - I do not know (go to Question 13)
13. How do you rate the wheelchairs provided by private companies against those provided by NHS?

Manual Wheelchairs

<table>
<thead>
<tr>
<th></th>
<th>Superior</th>
<th>Equal</th>
<th>Inferior</th>
<th>I don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structurally</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Ergonomically</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Aesthetically</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Powered Wheelchairs

<table>
<thead>
<tr>
<th></th>
<th>Superior</th>
<th>Equal</th>
<th>Inferior</th>
<th>I don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structurally</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ergonomically</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Aesthetically</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

14. Generally speaking, how do you rate the design of wheelchairs provided by NHS in terms of meeting the needs of disabled people?

Manual Wheelchairs

<table>
<thead>
<tr>
<th></th>
<th>Very Good</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Very Poor</th>
</tr>
</thead>
</table>

Powered Wheelchairs

<table>
<thead>
<tr>
<th></th>
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<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Very Poor</th>
</tr>
</thead>
</table>

15. Generally speaking, how do you rate the design of wheelchairs provided by private companies in terms of meeting the needs of disabled people?

Manual Wheelchairs

<table>
<thead>
<tr>
<th></th>
<th>Very Good</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Very Poor</th>
</tr>
</thead>
</table>

Powered Wheelchairs

<table>
<thead>
<tr>
<th></th>
<th>Very Good</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Very Poor</th>
</tr>
</thead>
</table>

THANK YOU VERY MUCH!
6 October 1997

Dear Sir/Madam

I wonder if you could help me.

I have contacted NHS Wheelchair Services twice. The first time I sent a questionnaire to be filled in by the Senior Therapist. The second time I tried to identify Wheelchair User Groups through some but not all Wheelchair Centres. I have received an encouraging response on both occasions. I appreciate the kindness of your staff and the information which I received was extremely useful for my work. Thank you very much. I am sorry to bother you yet once again, but I need your help just once more to finalise my research.

I am a Brazilian Industrial Design lecturer carrying out a Ph.D. program at Loughborough University. The fundamental aim of my project is to examine the relationship between wheelchair user needs and product requirements from an ergonomics point-of-view. Part of this aim involves establishing whether or not various stakeholders (including wheelchair designers, health professionals who prescribe wheelchairs, rehabilitation engineers dealing with wheelchair issues, carers and wheelchair users themselves) participate in the design process. If they do participate, I want to establish their involvement in wheelchair design. If they do not, I want to establish if they would like to be involved and how.

Part of my field study was carried out last year to bring to light how a sample of designers approach the design of wheelchairs and what kind of data they need from users. For this purpose, a sample of design practitioners working in organisations in
England, Scotland and Wales was interviewed. The designers who participated in this survey represent companies which provide the vast majority of wheelchairs produced in the United Kingdom.

Last month I finished a survey with therapists from Disabled Living Centres and N.H.S. Wheelchair Services throughout the country. I am now approaching rehabilitation engineers partly to gain a better understanding of the prescription process, but more importantly to determine what they contribute, actually or potentially, to design.

Some weeks ago I sent out a copy of my questionnaire in the magazine REview - a newsletter of the Centre of Rehabilitation Engineering. Unfortunately the number of questionnaires received back was very low. To help to remedy the situation I would be extremely grateful, if you will be kind enough to send the attached questionnaire to the rehabilitation engineer who assists in your centre. If your centre is not assisted by a rehabilitation engineer or if he or she will be in the centre in more than two weeks time, please fill in the form below and send it back in the enclosed freepost envelope.

Thanking you in advance and looking forward to hearing from you soon.

Yours sincerely

Soares

---

Please detach and send this form back.

To:
Loughborough University
Att. Mr. M. M. Soares

☐ Sorry, my Centre is not assisted by a rehabilitation engineering
☐ Sorry, the rehabilitation engineering who assists in my Centre will not be in within the next two weeks.
Dear Sir/Madam

I wonder if you could help me.

Some weeks ago I sent out a copy of the attached questionnaire as an enclosure in the last issue of the magazine REview - a newsletter of the Centre of Rehabilitation Engineering. Unfortunately the number of questionnaires received back was very few. In an attempt to remedy the situation I am now contacting you.

I am a Brazilian Industrial Design lecturer carrying out a Ph.D. program at Loughborough University. The fundamental aim of my project is to examine the relationship between wheelchair user needs and product requirements from an ergonomics point-of-view. Part of this aim involves establishing whether or not various stakeholders (including wheelchair designers, health professionals who prescribe wheelchairs, rehabilitation engineers dealing with wheelchair issues, carers and wheelchair users themselves) participate in the design process. If they do participate, I want to establish their involvement in wheelchair design. If they do not, I want to establish if they would like to be involved and how.

Part of my field study was carried out last year to bring to light how a sample of designers approach the design of wheelchairs and what kind of data they need from users. For this purpose, a sample of design practitioners working in organisations in England, Scotland and Wales was interviewed. The designers who participated in this survey represent companies which provide the vast majority of wheelchairs produced in the United Kingdom.
Last month I finished a survey with therapists from Disabled Living Centres and N.H.S. Wheelchair Services throughout the country. I am now approaching rehabilitation engineers partly to gain a better understanding of the prescription process, but more importantly to determine what they contribute, actually or potentially, to design. I would like to clarify that, in this questionnaire, the interest is not in design for an individual (bespoke design) or particular adaptations of wheelchairs for specific patient needs. The interest is in the production of wheelchairs on a large manufacturing scale (generic design) directed at a broad group of people.

Accordingly I would be extremely grateful if you would agree to spare about 10 minutes to answer the enclosed questionnaire. Your answers will be very much appreciated and valued and will help to make wheelchairs better suited to the needs of all their users. Any information which you provide will be strictly confidential.

Please find enclosed a freepost envelope to send the questionnaire back. I would be enormously grateful if you could help me.

Thanking you in advance and looking forward to hearing from you soon.

Yours sincerely

Marcelo M. Soares
A - EXPLORATORY QUESTIONS ABOUT ERGONOMICS

1. Have you had any training in ergonomics?
   □ Yes (continue)  □ No (go to Question 2)

2. What do you understand by the word 'ergonomics'?
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................

B - EXPLORATORY QUESTIONS ABOUT WHEELCHAIR PRESCRIPTION

3. Do you take part in the wheelchair prescription process?
   □ Yes  □ No (go to Question 7)

4. Have you had any training to enable you to assess clients and to prescribe wheelchairs for them?
   □ Yes  □ No (go to Question 5)

5. Can you identify from your experience any weaknesses in the process by which wheelchairs are prescribed?
   □ Yes (continue)  □ No (go to Question 6)

   If yes, what are they?
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................

   Have these weaknesses any implications for design?
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................
6. When wheelchairs have been delivered to clients do you subsequently collect formally the views of the users about the wheelchairs which have been prescribed for them?

☐ Yes (continue) ☐ No (go to Question 7)

How do you collect these views?

To what use are these views put?

Are these views fed back to designers and manufacturers of wheelchairs?

☐ Yes (continue) ☐ No (go to Question 7)

Please describe any examples where you have used the views of clients to assist in the design of wheelchairs.

C - EXPLORATORY QUESTIONS ABOUT WHEELCHAIR DESIGN

7. Have you ever been in contact with manufacturers about problems connected with wheelchairs?

☐ Yes (continue) ☐ No (go to Question 8)

If yes, did they take any notice of what you said and did they modify the wheelchair?

☐ Yes ☐ Unsure ☐ (No go to Question 8)

8. Have you ever been involved in wheelchair design with a company that mass produces wheelchairs for a large market?

☐ Yes (continue) ☐ No (go to Question 9)

If yes, what was your main contribution?
9. Would you like to be involved, or continue to be involved, in wheelchair design with companies that mass produce wheelchairs for a large market?

☐ Yes (continue) ☐ No (go to Question 10)

If yes, what kind of contribution do you think you can provide to wheelchair design?

............................................................................................................................
............................................................................................................................
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10. Do you think that, in general, the wheelchairs actually in the market place are designed taking into account the range of needs of disabled people?

☐ Yes, why?
............................................................................................................................
............................................................................................................................
............................................................................................................................

☐ No, why not?
............................................................................................................................
............................................................................................................................
............................................................................................................................

☐ I do not know (go to Question 11)

11. How do you rate the wheelchairs provided by private companies against those provided by NHS?

Manual Wheelchairs

Structurally ☐ Superior ☐ Equal ☐ Inferior ☐ I don't know
Ergonomically ☐ Superior ☐ Equal ☐ Inferior ☐ I don't know
Aesthetically ☐ Superior ☐ Equal ☐ Inferior ☐ I don't know

Powered Wheelchairs

Structurally ☐ Superior ☐ Equal ☐ Inferior ☐ I don't know
Ergonomically ☐ Superior ☐ Equal ☐ Inferior ☐ I don't know
Aesthetically ☐ Superior ☐ Equal ☐ Inferior ☐ I don't know
12. Generally speaking, how do you rate the design of wheelchairs provided by NHS in terms of meeting the needs of disabled people?

Manual Wheelchairs
☐ Very Good ☐ Good ☐ Average ☐ Poor ☐ Very Poor

Powered Wheelchairs
☐ Very Good ☐ Good ☐ Average ☐ Poor ☐ Very Poor

13. Generally speaking, how do you rate the design of wheelchairs provided by private companies in terms of meeting the needs of disabled people?

Manual Wheelchairs
☐ Very Good ☐ Good ☐ Average ☐ Poor ☐ Very Poor

Powered Wheelchairs
☐ Very Good ☐ Good ☐ Average ☐ Poor ☐ Very Poor

Lastly, is there anything that you suggest that could be done to improve the design of wheelchairs in the market place?

________________________________________________________________________________________________________________________________________________________
________________________________________________________________________________________________________________________________________________________
________________________________________________________________________________________________________________________________________________________
________________________________________________________________________________________________________________________________________________________
________________________________________________________________________________________________________________________________________________________

Thank you very much for completing this questionnaire and for assisting us with our research. Would you please return the completed questionnaire to Loughborough University in the pre-paid reply envelope provided.

The address is: Questionnaire for Rehabilitation Engineers
Department of Human Sciences,
Loughborough University
FREEPOST
Loughborough, Leicestershire,
LE11 OBR
To the Attention of the Rehabilitation Engineer

November, 4th. 1997

Dear Sir/Madam

A short time ago I sent a questionnaire on wheelchair prescription and design to the senior therapist of your centre, who, I assume, will have passed it on to you. As you may recall, this survey, which is being conducted as part of my Ph.D. programme at Loughborough University, aims to understand the wheelchair prescription process and the contribution of the therapists, actually or potentially, to wheelchair design.

Thank you if you have already taken the time to complete this questionnaire and returned it to me. If this is the case please ignore this letter. It is very important to the success of my survey that I get as many completed questionnaires as possible so that the responses are truly representative. If you or one of your colleagues has not yet completed the questionnaire I would be very grateful if you could do so within a week of receipt of this letter. In case it got lost in the post or you have mislaid it, I am enclosing another copy along with a FREEPOST envelope for your reply.

Many thanks again for you help. It is much appreciated.

Yours sincerely,

Marcelo M. Soares
A few months ago I sent you a questionnaire on wheelchair prescription conducted as part of my Ph.D. programme at Loughborough University. As you may recall, the fundamental aim of my project is to examine the relationship between wheelchair user needs and product requirements from an ergonomics point-of-view. Part of this aim involves establishing whether or not various stakeholders (including wheelchair designers, health professionals who prescribe wheelchairs, rehabilitation engineers dealing with wheelchair issues, carers and wheelchair users themselves) participate in the design process. If they do participate, I want to establish their involvement in wheelchair design. If they do not, I want to establish if they would like to be involved and how.

Part of my field study was carried out last year to bring to light how a sample of designers approach the design of wheelchairs and what kind of data they need from users. Last month I finished a survey with therapists from Disabled Living Centres and N.H.S. Wheelchair Services throughout the country. I am now approaching rehabilitation engineers.

In a near future I will approach wheelchairs users. My intention is to consult people who take part in wheelchair's user groups. I have received a list of Wheelchair Service Centres that organise user groups from the College of Occupational Therapists, in which your Centre is
included. Accordingly I would be extremely grateful, if you will be kind enough to fill in the attached form including the address of the wheelchair user group. Please find enclosed a freepost envelope to send the form back. I would be enormously grateful if you could help me.

Thanking you in advance and looking forward to hearing from you soon.

Yours sincerely

Marcelo M. Soares

To:
Loughborough University
Att. Mr. M. M. Soares

Do you know any Wheelchair user group?
☑ Yes (please fill this form. You can also use the back side or an additional piece of paper if you know more than one user group).
☐ No (please send the form back anyway).

Address of Wheelchair User group and name of person to contact:
29 October 1997

Dear Sir/Madam

In connection to my phone call, I am including 15 questionnaires to be distribute amongst the wheelchair users. Please ask them to feel free to produce any comments about this pilot of the questionnaire. Your comments will be very much appreciated and valued.

As I mentioned before I am a Brazilian Industrial Design lecturer carrying out a Ph.D. program at Loughborough University.

The fundamental aim of my project is to examine the relationship between wheelchair user needs and product requirements from an ergonomics point-of-view. Part of this aim involves establishing whether or not various stakeholders (including wheelchair designers, therapists, rehabilitation engineers dealing with wheelchair issues, carers and wheelchair users themselves) participate in the design process. If they do participate, I want to establish their involvement in wheelchair design. If they do not, I want to establish if they would like to be involved and how.

Part of my field study was carried out last year to bring to light how a sample of designers approach the design of wheelchairs and what kind of data they need from users. For this purpose, a sample of design practitioners working in organisations in England, Scotland and Wales was interviewed. The designers who participated in this survey represent companies which provide the vast majority of wheelchairs produced in the United Kingdom.
I have also approached therapists and rehabilitation engineers partly to gain a better understanding of the prescription process, but more importantly to determine what they contribute, actually or potentially, to design.

I am now approaching wheelchair users and their personal assistants (carers). My intention is to analyse both the views of users and their carers about wheelchair design and the process of user assessment and wheelchair prescription.

I would be extremely grateful if you would agree to distribute the enclosed set of questionnaires to members of your wheelchair user group. The participation of users is essential for the success of my work. Their voice seems to be seldom heard. Any information provided by the wheelchair users and their carers will be strictly confidential.

Each set of questionnaires (one for the wheelchair user and another for the carer) has enclosed a freepost envelope to send the two questionnaires back. I would be enormously grateful if you could help me.

Thanking you in advance.

Yours sincerely

Marcelo M. Soares
This questionnaire is divided into sections dealing with different aspects of your use of wheelchairs and your characteristics. Please read each item carefully. Some questions provide a line for you to print your answer or they ask you to tick a box . Only tick one box unless you are asked to do otherwise. If you decide to change your response, please put a cross through it (e.g., ) and tick your new response. Even if you are not sure about the answer, do not leave the item blank, pick the answer that is closest to what you think. It is important that you complete all the sections and answer every question.

A - QUESTIONS ABOUT YOUR WHEELCHAIR(S)

1. How many wheelchairs do you have? (Please include those you regularly use, and any you keep if your main chair breaks down)

   One □ Three □
   Two □ Four or more □

2. For about how long have you used a wheelchair?

   Under a year □ 6-10 years □
   1-2 years □ Over 10 years □
   3-5 years □

If you have more than two wheelchairs please state your views on the two which you use most frequently. If you have only one wheelchair please state your views on it.

3. What makes and models of wheelchairs do you use (please name no more than 2)?
   Chair 1: ________________________________
   Chair 2: ________________________________
For questions 4 to 8 inclusive:
If you have only one wheelchair please put a tick in the appropriate cell in the first column (Chair 1).
If you have a second wheelchair put a tick in the appropriate cell in the second column (Chair 2).

4. Which type of wheelchair do you own?

<table>
<thead>
<tr>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual self-propelled wheelchair</td>
<td>☐</td>
</tr>
<tr>
<td>Manual attendant propelled wheelchair</td>
<td>☐</td>
</tr>
<tr>
<td>Powered indoor wheelchair</td>
<td>☐</td>
</tr>
<tr>
<td>Powered outdoor wheelchair</td>
<td>☐</td>
</tr>
<tr>
<td>Powered indoor/outdoor wheelchair</td>
<td>☐</td>
</tr>
<tr>
<td>Powered buggy</td>
<td>☐</td>
</tr>
<tr>
<td>Powered scooter</td>
<td>☐</td>
</tr>
<tr>
<td>Other (please give details)</td>
<td>☐</td>
</tr>
</tbody>
</table>

5. How did you obtain your wheelchair?

<table>
<thead>
<tr>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>From the NHS Wheelchair Service</td>
<td>☑</td>
</tr>
<tr>
<td>Bought privately</td>
<td>☐</td>
</tr>
<tr>
<td>Other (please give details)</td>
<td>☐</td>
</tr>
</tbody>
</table>

6. Which of the following accessories do your wheelchairs have? (Please tick as many as apply)

<table>
<thead>
<tr>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specially made seating</td>
<td>☐</td>
</tr>
<tr>
<td>Kerb climber</td>
<td>☐</td>
</tr>
<tr>
<td>Manual elevating foot rest</td>
<td>☐</td>
</tr>
<tr>
<td>Powered elevating foot rest</td>
<td>☐</td>
</tr>
<tr>
<td>Device to help you to a standing position</td>
<td>☐</td>
</tr>
<tr>
<td>Elevating seat</td>
<td>☐</td>
</tr>
<tr>
<td>Manual reclining seat</td>
<td>☐</td>
</tr>
<tr>
<td>Powered reclining seat</td>
<td>☐</td>
</tr>
<tr>
<td>Other(s)</td>
<td>☐</td>
</tr>
<tr>
<td>None</td>
<td>☐</td>
</tr>
</tbody>
</table>
Appendix 5.3

7. For about how many days per week do you use your wheelchairs?

<table>
<thead>
<tr>
<th></th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 5-6 days a week</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 3-4 days a week</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 1-2 days a week</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less often than this</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. For about how many hours per day do you use your wheelchairs?

<table>
<thead>
<tr>
<th></th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 1 hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 2-3 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 4-5 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over 5 hours</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B - QUESTIONS ABOUT THE WHEELCHAIR PRESCRIPTION

9. Do you feel that your needs and abilities were taken into consideration during the process of assessment and prescription?
   Yes ☐ No ☐ Unsure ☐

10. Have you received instructions explaining how to use your wheelchairs?
    Yes ☐ No ☐ (continue) (go to Question 11)

   If yes, do you consider that these instructions were satisfactory?
   Yes ☐ No ☐ Unsure ☐

11. Did you receive follow-up after your wheelchairs had been delivered to check on whether they were satisfactory for you?
    Yes ☐ No ☐
12. Can you identify any weaknesses in the process by which you were assessed, your wheelchairs prescribed and follow-up carried out?

Yes (continue) ☐  No (go to Question 13) ☐

If yes, what were they?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

C - QUESTIONS ABOUT THE WHEELCHAIR DESIGN

13. Broadly speaking, how important for you are the following characteristics of a wheelchair? (Please tick as appropriate)

<table>
<thead>
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<th>Characteristics</th>
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<th>Very Important</th>
<th>Important</th>
<th>Fairly Important</th>
<th>Not Important</th>
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<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Robustness</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Stability</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Suitability</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Reliability</td>
<td>[ ]</td>
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<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Comfort</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Aesthetic appearance</td>
<td>[ ]</td>
<td>[ ]</td>
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<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Adjustability</td>
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<tr>
<td>Portability</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Manoeuvrability</td>
<td>[ ]</td>
<td>[ ]</td>
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<tr>
<td>Ease of use</td>
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<tr>
<td>Ease of folding</td>
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<tr>
<td>Ease of storage</td>
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<tr>
<td>Ease of maintenance</td>
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<tr>
<td>Ease of repair</td>
<td>[ ]</td>
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</tr>
<tr>
<td>Ease of transport in a car</td>
<td>[ ]</td>
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</tr>
<tr>
<td>Provision of accessories</td>
<td>[ ]</td>
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</tr>
<tr>
<td>Cheap to buy</td>
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<td>[ ]</td>
</tr>
<tr>
<td>Cheap to maintain</td>
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<td>[ ]</td>
</tr>
<tr>
<td>Cheap to repair</td>
<td>[ ]</td>
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</tr>
</tbody>
</table>
14. From the 20 characteristics of a wheelchair listed in the previous question, please write down in order the three characteristics which are most important for you:

First: 
Second: 
Third: 

15. How do you rate the design of your wheelchairs in terms of the following characteristics? (Please tick as appropriate and if you only have one wheelchair only answer for Chair 1)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Very Good</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Very Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td></td>
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<tr>
<td>Robustness</td>
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<tr>
<td>Stability</td>
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<tr>
<td>Suitability</td>
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<tr>
<td>Reliability</td>
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<tr>
<td>Comfort</td>
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<tr>
<td>Aesthetic appearance</td>
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<tr>
<td>Adjustability</td>
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<tr>
<td>Portability</td>
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<td></td>
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<tr>
<td>Manoeuvrability</td>
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<tr>
<td>Ease of use</td>
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<td>Ease of folding</td>
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<td>Ease of storage</td>
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<tr>
<td>Ease of maintenance</td>
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<tr>
<td>Ease of repair</td>
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<tr>
<td>Ease of transport in a car</td>
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</tr>
<tr>
<td>Provision of accessories</td>
<td></td>
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<tr>
<td>Cheap to buy</td>
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<tr>
<td>Cheap to maintain</td>
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<tr>
<td>Cheap to repair</td>
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</tr>
</tbody>
</table>

Please turn over for Chair 2
### Chair 2

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Very Good</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Very Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
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<td>Robustness</td>
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<tr>
<td>Stability</td>
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<tr>
<td>Suitability</td>
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<tr>
<td>Reliability</td>
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<tr>
<td>Comfort</td>
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</tr>
<tr>
<td>Aesthetic appearance</td>
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<td></td>
</tr>
<tr>
<td>Adjustability</td>
<td></td>
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<tr>
<td>Portability</td>
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<tr>
<td>Manoeuvrability</td>
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<tr>
<td>Ease of use</td>
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<td>Ease of folding</td>
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<tr>
<td>Ease of storage</td>
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<tr>
<td>Ease of maintenance</td>
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<tr>
<td>Ease of repair</td>
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<tr>
<td>Ease of transport in a car</td>
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<tr>
<td>Provision of accessories</td>
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<tr>
<td>Cheap to buy</td>
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<td>Cheap to maintain</td>
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<tr>
<td>Cheap to repair</td>
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</tbody>
</table>

16. Have you ever been involved in wheelchair design with a company that mass produces wheelchairs for a large market?

Yes (continue) ☐  No (go to Question 17) ☐

If yes, what was your main contribution?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

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17. Would you like to be involved, or continue to be involved, in wheelchair design with companies that mass produce wheelchairs for a large market?
   Yes (continue) ☐  No (go to Question 18) ☐

If yes, what kind of contribution do you think you can provide to wheelchair design?

18. Do you think that, in general, the wheelchairs actually in the market place are designed taking into account the range of needs of disabled people?
   Yes, why? ☐
   No, why not? ☐
   I do not know ☐

D - QUESTIONS ABOUT YOURSELF

19. Are you male or female?
   Male ☐  Female ☐

20. Which age group are you in?
   Under 16 ☐  35-44 ☐  65-74 ☐
   16-24 ☐  45-54 ☐  75 or over ☐
   25-34 ☐  55-64 ☐
21. What type of area do you presently live in?

- Rural
- Village/hamlet
- Other (please state)

22. What is your employment status?

- Employed full-time
- Employed part-time
- Retired
- Unemployed
- Other (please state)

23. Do you drive your own vehicle?

- Yes (go to Question 24)
- No (continue)

If no, are you regularly taken out (e.g. for shopping, recreation) in a vehicle and accompanied by your wheelchair?

- Yes
- No

24. Do you have a personal assistant (carer)?

- Yes
- No

If yes please give the attached questionnaire for a nominated carer.

Lastly, is there anything that you suggest that could be done to improve the design of wheelchairs in the market place?

Thank you very much for completing this questionnaire and for assisting us with our research. Would you please return the completed set of questionnaires (Questionnaire for Wheelchair User and Questionnaire for Personal Assistants - Carers) to Loughborough University in the pre-paid reply envelope provided.

The address is:

Questionnaire for Wheelchair Users
Department of Human Sciences,
Loughborough University
FREEPOST
Loughborough, Leicestershire,
LE11 OBR
16 November 1997

Dear Sir/Madam

I wonder if you could help me.

My name is Marcelo M. Soares, a Brazilian Industrial Design lecturer carrying out a Ph.D. program at Loughborough University.

The fundamental aim of my project is to examine the relationship between wheelchair user needs and product requirements from an ergonomics point-of-view. Part of this aim involves establishing whether or not various stakeholders (including wheelchair designers, therapists, rehabilitation engineers dealing with wheelchair issues, carers and wheelchair users themselves) participate in the design process. If they do participate, I want to establish their involvement in wheelchair design. If they do not, I want to establish if they would like to be involved and how.

Part of my field study was carried out last year to bring to light how a sample of designers approach the design of wheelchairs and what kind of data they need from users. For this purpose, a sample of design practitioners working in organisations in England, Scotland and Wales was interviewed. The designers who participated in this survey represent companies which provide the vast majority of wheelchairs produced in the United Kingdom.

I have also approached therapists and rehabilitation engineers partly to gain a better understanding of the prescription process, but more importantly to determine what they contribute, actually or potentially, to design.
I am now approaching wheelchair users and their personal assistants (carers). My intention is to analyse both the views of users and their carers about wheelchair design and the process of user assessment and wheelchair prescription. I would be extremely grateful if you would agree to spare about 15 minutes to answer the enclosed questionnaire.

Accordingly I am including a set of two questionnaires: the first to be answered by yourself and the second to be answered by a carer nominated by you. If you do not have a carer please ignore the second questionnaire. The answers provided by you and your carer, if you have nominated one, will be very much appreciated and valued and will help to make wheelchairs better suited to the needs of all their users. Any information provided by you and your carer will be strictly confidential.

Please find enclosed a freepost envelope to send the two questionnaires back. I would be enormously grateful if you could help me.

Thanking you in advance and looking forward to hearing from you soon.

Yours sincerely

Marcello M. Soares
This questionnaire is divided into sections dealing with different aspects of your use of wheelchairs and your characteristics. Please read each item carefully. Some questions provide a line for you to print your answer or they ask you to tick a box. Only tick one box unless you are asked to do otherwise. If you decide to change your response, please put a cross through it (e.g., $\biggr\times$) and tick your new response. Even if you are not sure about the answer, do not leave the item blank, pick the answer that is closest to what you think. It is important that you complete all the sections and answer every question.

### A - QUESTIONS ABOUT YOUR WHEELCHAIR(S)

1. How many wheelchairs do you have? (Please include those you regularly use, and any you keep if your main chair breaks down)
   - One
   - Two
   - Three
   - Four or more

2. For about how long have you used a wheelchair?
   - Under a year
   - 1-2 years
   - 3-5 years
   - 6-10 years
   - Over 10 years

3. What makes and models of wheelchairs do you use (please name no more than 2)?
   - Chair 1 (the most used):
   - Chair 2 (the next most used):
Appendix 5.5

For questions 4 to 11 inclusive:

If you have more than two wheelchairs please state your views on the two which you use most. If you have only one wheelchair please put a tick in the appropriate cell in the first column (Chair 1). If you have a second wheelchair put a tick in the appropriate cell in the second column (Chair 2).

4. Which type of wheelchairs do you own?

<table>
<thead>
<tr>
<th>Type of Wheelchair</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual self-propelled wheelchair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual attendant propelled wheelchair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powered indoor wheelchair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powered outdoor wheelchair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powered indoor/outdoor wheelchair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powered buggy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powered scooter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please give details)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. How did you obtain your wheelchairs?

<table>
<thead>
<tr>
<th>Source of Wheelchairs</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>From the NHS Wheelchair Service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bought privately</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please give details)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. For about how long have you owned your wheelchairs?

<table>
<thead>
<tr>
<th>Duration</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 1 year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 2-3 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 4-5 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 6-8 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 8-10 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over 10 years</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. Which of the following accessories do your wheelchairs have? (Please tick as many as apply)

<table>
<thead>
<tr>
<th>Accessory</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seat cushion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back cushion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specially made seating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerb climber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual elevating foot rest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powered elevating foot rest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Device to help you to a standing position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevating seat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual reclining seat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powered reclining seat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. For about how many days per week do you use your wheelchairs?

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 5-6 days a week</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 3-4 days a week</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 1-2 days a week</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less often than 1 day a week</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. For about how many hours per day do you use your wheelchairs indoors?

<table>
<thead>
<tr>
<th>Hours</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 1 hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 2-3 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 4-5 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over 5 hours</td>
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<td></td>
</tr>
</tbody>
</table>

10. For about how many hours per day do you use your wheelchairs outdoors?

<table>
<thead>
<tr>
<th>Hours</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 1 hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 2-3 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>About 4-5 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over 5 hours</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
11. Have you had any major problem with your wheelchairs in the last 12 months? (Please tick as appropriate)

<table>
<thead>
<tr>
<th>None</th>
<th>Chair 1</th>
<th>Chair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punctures</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Brake failure</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Broken footplate</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Broken frame</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Electrical failures</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Broken armrest</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B - QUESTIONS ABOUT THE PRESCRIPTION OF YOUR WHEELCHAIR

12. Do you feel that your needs and abilities were taken into consideration during the process of assessment and prescription?

Yes □ No □ Unsure □

13. Were you shown how to use your wheelchairs?

Yes (continue) □ No (go to Question 14) □

If yes, did you consider the demonstration satisfactory?

Yes □ No □ Unsure □

14. Have you received written instructions explaining how to use your wheelchairs?

Yes (continue) □ No (go to Question 15) □

If yes, do you consider that these written instructions are satisfactory?

Yes □ No □ Unsure □

15. Did you receive follow-up after your wheelchairs had been delivered to check on whether they were satisfactory for you?

Yes □ No □

16. Can you identify any weaknesses in the process by which you were assessed, your wheelchairs prescribed and the follow-up carried out?

Yes (continue) □ No (go to Question 17) □

If yes, what were they? ..........................................................................................................

..........................................................................................................

..........................................................................................................

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.............................................................................................................
### C - QUESTIONS ABOUT WHEELCHAIR DESIGN IN GENERAL

17. Broadly speaking, how important for you are the following characteristics of a wheelchair? (Please tick as appropriate)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Extremely Important</th>
<th>Very Important</th>
<th>Important</th>
<th>Fairly Important</th>
<th>Not Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robustness</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Stability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suitability</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Comfort</td>
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18. From the 21 characteristics of a wheelchair listed above, please write down in order the three characteristics which are most important for you and why:

First: ..................................................................................................................................

Why? ..........................................................................................................................................

Second: ..................................................................................................................................

Why? ..........................................................................................................................................

Third: ..................................................................................................................................

Why? ........................................................................................................................................
19. How do you rate the design of your wheelchairs in terms of the following characteristics? (Please tick as appropriate and if you only have one wheelchair only answer for Chair 1)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Chair 1 (the chair you use the most, as stated in question 3)</th>
<th>Chair 2 (the next most frequently used chair, as stated in question 3)</th>
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<tr>
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<td>Very Good</td>
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</table>
20. Is it your impression that, in general, the wheelchairs actually in the **NHS market place** are designed taking into account the range of needs of disabled people?

Yes [ ]  No [ ]  I do not know [ ]

Please explain why?

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21. Is it your impression that, in general, the wheelchairs actually in the **private market place** are designed taking into account the range of needs of disabled people?

Yes [ ]  No [ ]  I do not know [ ]

Please explain why?

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22. Have you ever been involved in wheelchair design with a company that mass produces wheelchairs for a large market?
   Yes (continue) ☐  No (go to Question 23) ☐

   If yes, what was your main contribution?
   ......................................................................................................................................................
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23. Would you like to be involved, or continue to be involved, in wheelchair design with companies that mass produce wheelchairs for a large market?
   Yes (continue) ☐  No (go to Question 24) ☐

   If yes, what kind of contribution do you think you can provide to wheelchair design?
   ......................................................................................................................................................
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D - QUESTIONS ABOUT YOURSELF

24. Are you male or female?
   Male ☐  Female ☐

25. Which age group are you in?
   Under 16 ☐  35-44 ☐  65-74 ☐
   16-24 ☐  45-54 ☐  75 or over ☐
   25-34 ☐  55-64 ☐
26. What type of area do you presently live in?
   - Rural
   - Village/hamlet
   - City
   - Other (please state)

27. What is your employment status?
   - Employed full-time
   - Employed part-time
   - Retired
   - Unemployed
   - Other (please state)

28. When you go out in a vehicle do you take your wheelchair with you?
   - Yes
   - No

29. Which forms of public transport have you used in the last twelve months (Please tick as many as apply)?
   - None
   - Intercity train
   - Local train
   - Dial-a-Ride
   - Mobility bus
   - Low floor bus
   - Other bus
   - Plane
   - Underground/metro
   - Other(s) (Please list and tick the appropriate column)
30. What is the nature of your disability (Please tick as many as apply)?

[ ] Arthritic condition  
[ ] Stroke  
[ ] Other neurological condition  
[ ] Amputation  
[ ] Cardiovascular condition  
[ ] Respiratory condition  
[ ] Ageing  
[ ] Other (please specify)  

31. Do you have a personal assistant (carer)?

Yes [ ] No [ ]

If yes please give the attached questionnaire to a nominated carer.

Lastly, is there anything that you can suggest to improve the design of wheelchairs in the market place?

Thank you very much for completing this questionnaire and for assisting us with our research. Please return the completed set of questionnaires (Questionnaire for Wheelchair User and Questionnaire for Personal Assistants - Carers) to Loughborough University in the pre-paid reply envelope provided.

The address is: Questionnaire for Wheelchair Users  
Department of Human Sciences,  
Loughborough University ,  
FREEPOST  
Loughborough, Leicestershire,  
LE11 OBR
January, 7th. 1997

Dear Sir/Madam

About two months ago I sent you some questionnaires to be distributed to wheelchair users and their carers. As you may recall, this survey, which is being conducted as part of my Ph.D. programme at Loughborough University, aims to get the views of users and their carers about wheelchair design and the process of user assessment and wheelchair prescription.

Unfortunately the number of questionnaires returned in the whole sample is still low for the purposes of my research. To help to remedy the situation I would be extremely grateful if you would be kind enough to contact again, if possible, the people to whom you distributed the questionnaires and ask them please to send the completed questionnaire back within the next two weeks. Up to the present day I have received 6 questionnaires back from the 15 originally posted to you. It is very important to the success of my survey that I get as many completed questionnaires as possible so that the responses are truly representative.

Many thanks again for your help. It is much appreciated.

Yours sincerely,

Marcelo M. Soares
Appendix 5.7

This questionnaire is divided into sections dealing with different aspects of your use of wheelchairs as a carer. Please read each item carefully. Some questions provide a line for you to print your answer __answer__ or they ask you to tick a box ☑️. Only tick one box unless you are asked to do otherwise. If you decide to change your response, please put a cross through it (e.g., ☑️) and tick your new response. Even if you are not sure about the answer, do not leave the item blank, pick the answer that is closest to what you think. It is important that you complete all the sections and answer every question. Try to answer this questionnaire using your own opinions independently of the opinions of the user.

A - QUESTIONS ABOUT THE WHEELCHAIR PRESCRIPTION

1. Did you attend the assessment with the wheelchair user?
   ☐ Yes (continue) ☐ No (go to Question 2)

   If yes, do you feel that the your needs and abilities were taken into consideration during the process of assessment?
   ☐ Yes ☐ No ☐ Unsure

2. Can you identify any weaknesses in the process by which the wheelchair belonging to the wheelchair user who you assist was prescribed?
   ☐ Yes (continue) ☐ No (go to Question 3)

   If yes, what were they?
   ........................................................................................................................................
   ........................................................................................................................................
   ........................................................................................................................................
### B - QUESTIONS ABOUT THE WHEELCHAIR DESIGN

3. How important for you are the following characteristics of a wheelchair? (Please tick as appropriate)

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<tr>
<th>Characteristics</th>
<th>Extremely Important</th>
<th>Very Important</th>
<th>Important</th>
<th>Fairly Important</th>
<th>Not Important</th>
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4. From the 20 characteristics of a wheelchair listed above, please write down in order the three characteristics which are most important for you:

First: 

Second: 

Third: 

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454
5. How do you rate the design of the wheelchair belonging to the wheelchair user who you assist in terms of the following characteristics? (Please tick as appropriate and if the person you assist has more than one wheelchair, answer this question in relation to the wheelchair which is used the most).

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<thead>
<tr>
<th>Characteristics</th>
<th>Very Good</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Very Poor</th>
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6. Have you ever been involved in wheelchair design with a company that mass produces wheelchairs for a large market?
   - ☐ Yes (continue)
   - ☑ No (go to Question 7)

If yes, what was your main contribution?

_________________________________________________________________________
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7. Would you like to be involved, or continue to be involved, in wheelchair design with companies that mass produce wheelchairs for a large market?

☐ Yes (continue)  ☐ No (go to Question 8)

If yes, what kind of contribution do you think you can provide to wheelchair design?

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8. Do you think that, in general, the wheelchairs actually in the market place are designed taking into account the range of needs of carers?

☐ Yes, why?

________________________________________________________________________

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☐ No, why not?

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☐ I do not know
D - QUESTIONS ABOUT YOURSELF

9. Are you male or female?
   □ Male   □ Female

10. Which age group are you in?
    □ Under 16   □ 45-54
    □ 16-24   □ 55-64
    □ 25-34   □ 65-74
    □ 35-44   □ 75 or over

11. What is the relationship between you and the wheelchair user who you assist?
    □ Spouse   □ Brother or sister
    □ Parent   □ Friend
    □ Other (please state) .................................................................

12. How many days per week do you assist the user in using the wheelchair?
    □ Every day   □ Once a week
    □ Over 4 days a week   □ Under once a week
    □ Under 4 days a week

Answer the following question only if you have ticked "Every day" on the previous one.

13. For about how long per day do you assist the user in using the wheelchair?
    □ All day long
    □ Over 5 hours, but not all day long
    □ Between 2-5 hours
    □ Less than two hours a day

14. How would you rate your health at the present time?
    □ Very good   □ Good   □ Average   □ Poor   □ Very Poor
15. Considering just the period when you assist the user with the wheelchair, please rate from 0 to 3 each region of your body, represented by the figure below, according to the following scale. Please write inside each box and do not leave any one blank. Though the figure is drawn solely from the back, make sure your responses relate to the region of your body whether at the front or the back.

0 = I feel no pain at all
1 = I feel a just noticeable pain
2 = I feel a moderate pain
3 = I feel an intolerable pain

Lastly, is there anything that you suggest that could be done to improve the design of wheelchairs in the market place for the carer?

THANK YOU VERY MUCH!
Appendix 5.8

This questionnaire is divided into sections dealing with different aspects of your use of wheelchairs as a carer. Please read each item carefully. Some questions provide a line for you to print your answer _answer_ or they ask you to tick a box ☑️. Only tick one box unless you are asked to do otherwise. If you decide to change your response, please put a cross through it (e.g., ☑️) and tick your new response. Even if you are not sure about the answer, do not leave the item blank, pick the answer that is closest to what you think. It is important that you complete all the sections and answer every question. Try to answer this questionnaire using your own opinions independently of the opinions of the user.

A - QUESTIONS ABOUT THE WHEELCHAIR PRESCRIPTION

1. Did you attend the assessment with the wheelchair user?
   ☐ Yes (continue) ☐ No (go to Question 2)

   If yes, did you feel that the your needs and abilities were taken into consideration during the process of assessment?
   ☐ Yes ☐ No ☐ Unsure

2. Can you identify any weaknesses in the process by which the wheelchair belonging to the wheelchair user who you assist was prescribed?
   ☐ Yes (continue) ☐ No (go to Question 3)

   If yes, what were they?
   
   .................................................................
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### B - QUESTIONS ABOUT WHEELCHAIR DESIGN IN GENERAL

3. How important for you are the following characteristics of a wheelchair? (Please tick as appropriate)

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<tr>
<th>Characteristics</th>
<th>Extremely Important</th>
<th>Very Important</th>
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<th>Fairly Important</th>
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<tr>
<td>Ease of storage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of repair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of transport in a car</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provision of accessories</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to buy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to maintain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to repair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to maintain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to repair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. From the 21 characteristics of a wheelchair listed above, please write down in order the three characteristics which are most important for you and why:

First: ..................................................................................................................................
Why? ..................................................................................................................................

Second: ..................................................................................................................................
Why? ..................................................................................................................................

Third: ..................................................................................................................................
Why? .....................................................................................................................................
5. How do you rate the design of the wheelchair, belonging to the wheelchair user who you assist, in terms of the following characteristics? (Please tick as appropriate and if the person you assist has more than one wheelchair, answer this question in relation to the wheelchair which is used the most).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Very Good</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Very Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robustness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suitability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comfort</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aesthetic appearance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portability due to size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portability due to weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manoeuvrability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of folding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of storage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of repair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of transport in a car</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provision of accessories</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to buy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to maintain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to repair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Have you ever been involved in wheelchair design with a company that mass produces wheelchairs for a large market?

☐ Yes (continue)  ☐ No (go to Question 7)

If yes, what was your main contribution?

__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
Appendix 5.8

7. Would you like to be involved, or continue to be involved, in wheelchair design with companies that mass produce wheelchairs for a large market?

☐ Yes (continue) ☐ No (go to Question 8)

If yes, what kind of contribution do you think you can provide to wheelchair design?

.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
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.............................................................................................................................................................................
.............................................................................................................................................................................

8. Is it your impression that, in general, the wheelchairs actually in the NHS market place are designed taking into account the range of needs of carers?

Yes ☐ No ☐ I do not know ☐

Please explain why?

.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................

9. Is it your impression that, in general, the wheelchairs actually in the private market place are designed taking into account the range of needs of carers?

Yes ☐ No ☐ I do not know ☐

Please explain why?

.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
.............................................................................................................................................................................
**D - QUESTIONS ABOUT YOURSELF**

10. Are you male or female?
   - [ ] Male
   - [x] Female

11. Which age group are you in?
   - [ ] Under 16
   - [ ] 16-24
   - [ ] 25-34
   - [ ] 35-44
   - [ ] 45-54
   - [ ] 55-64
   - [ ] 65-74
   - [ ] 75 or over

12. What is the relationship between you and the wheelchair user who you assist?
   - [ ] Spouse
   - [ ] Brother or sister
   - [ ] Parent
   - [ ] Friend
   - [ ] Paid carer
   - [ ] Other (please state)

13. How many days per week do you assist the user in using the wheelchair?
   - [ ] Every day
   - [ ] Once a week
   - [ ] Over 4 days a week
   - [ ] Under once a week
   - [ ] Under 4 days a week

   Answer Question 14 only if you have ticked "Every day" on the previous one.

14. For about how long per day do you assist the user in using the wheelchair?
   - [ ] All day long
   - [ ] Over 5 hours, but not all day long
   - [ ] Between 2-5 hours
   - [ ] Less than two hours a day

15. How would you rate your health at the present time?
   - [ ] Very good
   - [ ] Good
   - [ ] Average
   - [ ] Poor
   - [ ] Very Poor
16. Considering just the period when you assist the user with the wheelchair, please rate the pain (if any) you feel in each region of your body, represented by the figure below, using the scale (0 to 3) provided. Please write inside each box and do not leave any one blank. Though the figure is drawn solely from the back, make sure your responses relate to the region of your body whether at the front or the back.

\[
\begin{align*}
0 &= \text{I feel no pain at all} \\
1 &= \text{I feel a just noticeable pain} \\
2 &= \text{I feel a moderate pain} \\
3 &= \text{I feel an intolerable pain}
\end{align*}
\]

17. Please list, in order of severity, the three tasks which cause you the most difficulty when assisting the user with the wheelchair.

<table>
<thead>
<tr>
<th>Indoor tasks</th>
<th>Outdoor tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lastly, is there anything that you suggest could be done to improve the design of wheelchairs in the marketplace for the carer?

.....................................................................................................................................................
.....................................................................................................................................................
.....................................................................................................................................................

Thank you very much for completing this questionnaire and for assisting us with our research. Please hand your complete questionnaire to your wheelchair user so that he or she can return it to Loughborough University in the pre-paid reply envelope provided.
User-centred method for wheelchair design

Preliminary Strategic Planning → Approaching the Users → USER PANEL

Investigating the Problem → Product Planning

Product Planning → Concept Design → Prototyping → Testing and Verification

Product Production → Manufacture and Assembly → Market Product → Customer Support
1. Preliminary Strategic Planning

Aim

- To define a series of strategic decisions for the design of the new wheelchair.

(there is a little involvement of industrial designers in this phase)

**STEPS:**

- Definition of the business plan for the new wheelchair, e.g. investigate the business opportunity for the new product
- Indication of the relation between the new wheelchair and the company's other products, e.g. differentiation from existing products
- Definition of the costs associated with the Product Development Process (PDP)
- Establishment of a timetable for the PDP
- Establishment of preliminary guidelines for innovation
- Definition of applicable technology
- Identification of the target market
- Identification of competing wheelchairs
2. Approaching wheelchair users and other stakeholders

Aim

- To obtain wheelchair users' and carers' views on the wheelchairs in the marketplace and establish user needs

**STEPS:**

- Investigate existing information about wheelchair users and their carers
- Develop profiles of wheelchair users and their carers
- Contact wheelchair users and carers
- Select wheelchair users and carers
- Carry out focus groups
- Select people to take part in the *User Panel*
Appendix 6.1

3. Establishing the User Panel

Aims
- To select a group of about eight wheelchair users and two carers to take part in the following phases of the design process.
- To involve the group in the design process in order to use their experience as a source of information to improve the quality and usability of the product.

<table>
<thead>
<tr>
<th>STEPS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Give the participants information on how the wheelchairs are designed, manufactured and sold including the constraints imposed by the production process</td>
</tr>
<tr>
<td>Establish sessions at significant points of the design process to enable the User Panel, with the design team, to have discussions and make decisions on the future steps of the design process</td>
</tr>
<tr>
<td>Nominate a chairperson to run the User Panel meetings</td>
</tr>
<tr>
<td>Ensure the User Panel participates in task analysis, user trials, and in the evaluation of mock-ups, models and prototypes, and the instruction manual</td>
</tr>
</tbody>
</table>
4. Investigating the Problem

Aim

- To identify correctly the problems to be solved in a form to give the design team the basis to decide what to do and how to do it, considering the competence of personnel, the available knowledge and what was required by the users and the company.

**Steps:**

- Describe what is lacking in the product or situation to be analysed, in terms of fulfilling user needs, and/or what exists but actually does not perform as required to meet user needs
- Produce a *List of Problems* from the investigation of the most serious problems that immediately appear in the analysis of the situation
- Select, classify and expand the *List of Problems* identifying the ergonomic dysfunctions (e.g. interface and instrumental problems), human dysfunctions (e.g. postural and social problems) and machine dysfunctions (e.g. structural and movement problems)
- Reduce the problems to their most significant and solvable aspects considering the competence of personnel, available knowledge and what is required by the users and the company
- Build the table of *Formulation of Problems* (Table 1)
Examples of Ergonomic Dysfunction Problems which may occur in a table giving *Formulation of Problems*

**Aim**
- To reveal the most significant and soluable problems, the design requirements, user constraints, human costs, suggestions for a design solution, and system constraints.

<table>
<thead>
<tr>
<th>Problems</th>
<th>Design Requirements</th>
<th>User constraints</th>
<th>Human costs</th>
<th>Suggestions</th>
<th>System constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backrest does not support the lower back</td>
<td>Backrest profile which considers the buttock protrusion and supports the lumbar region</td>
<td>Kyphosis dorsal and flattening of the lumbar curve</td>
<td>Pain in the back</td>
<td>Provide a new backrest profile</td>
<td>Available technology Lack of interest of buyers and manufacturers</td>
</tr>
<tr>
<td>Inappropriate support to accommodate the feet</td>
<td>Considers the length of the feet of biggest users Considers the height of the legs of smaller and bigger users</td>
<td>Legs do not touch the foot support Pressure in the popliteal region</td>
<td>Discomfort</td>
<td>Provide an adjustable foot support</td>
<td>Lack of interest of buyers and manufacturers</td>
</tr>
<tr>
<td>Inappropriate location of push handles</td>
<td>Considers the height of the elbow of the biggest and smaller carers and defines the height of push handles</td>
<td>Flexion of the lumbar spine Pain in the lower back Pain in the neck</td>
<td></td>
<td>Provide adjustable push handles</td>
<td>Lack of interest of buyers and manufacturers</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inappropriate shape of the hand controls</td>
<td>Profile that does not cause pressure on the users hands</td>
<td>Pressure on specific areas of the hands Ulnar/radial deviation</td>
<td>Pain in hands and wrist</td>
<td>Provide new profile for the hand controls</td>
<td>Available technology Lack of interest of buyers and manufacturers</td>
</tr>
</tbody>
</table>
5. Product Planning

Aim
- To find information directly relevant to the design team’s activities of generating and selecting feasible solutions in the creation of new wheelchair models.

**STEPS:**
- Carry out a task analysis to obtain details on: a) the sequence in which the user uses the product; b) the place in the hierarchy of each activity; c) user-product interface requirements; d) product evaluation and decisions that must be made in design; e) task times and f) environmental conditions
- Refine user needs, translating them into the design process to produce a list of Product Requirements
- Build the List of refined user needs and their associated metrics (Table 2)
- Review the existing state of the art by: a) reviewing the literature and standards and b) analysing and evaluating competitive products based on metrics (Tables 3) and on user satisfaction (Table 4)
- Apply Quality Function Deployment (QFD) to the wheelchair development (Table 5)
- Elaborate the Wheelchair Design Specification Document
Example of a table with a partially completed
List of Refined User Needs and their associated Metrics

Aims
- To specify, in a precise and measurable way, what the product has to do to meet user needs.
- To select, categorise and order the importance of each user need which is within the designer's competence to meet, and associate each need with a corresponding metric.

Table 2

<table>
<thead>
<tr>
<th>No.</th>
<th>Subsystem</th>
<th>Need</th>
<th>Imp.</th>
<th>Metrics</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Structure</td>
<td>Reduce weight of wheelchair</td>
<td>5</td>
<td>Total mass</td>
<td>kg</td>
</tr>
<tr>
<td>2</td>
<td>Structure</td>
<td>Produce foldable wheelchair</td>
<td>4</td>
<td>Fold width</td>
<td>mm</td>
</tr>
<tr>
<td>3</td>
<td>Structure</td>
<td>Reduce vibration in the handles</td>
<td>3</td>
<td>Attenuation from push bar to main structure at 10 Hz</td>
<td>dB</td>
</tr>
<tr>
<td>4</td>
<td>Structure</td>
<td>Allow easy traversal of difficult terrain</td>
<td>4</td>
<td>Spring preload</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>Structure</td>
<td>Easy to remove wheels</td>
<td>1</td>
<td>Time to disassemble/assemble</td>
<td>min</td>
</tr>
<tr>
<td>6</td>
<td>Structure</td>
<td>A wide variety of wheels and tyres fit the wheelchair</td>
<td>2</td>
<td>Headset size</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Steer tube diameter</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wheel sizes</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Castor sizes</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maximum tyre width</td>
<td>mm</td>
</tr>
<tr>
<td>7</td>
<td>Structure</td>
<td>Easy of access to maintenance the components</td>
<td>2</td>
<td>Time to disassemble/assemble</td>
<td>min</td>
</tr>
<tr>
<td>8</td>
<td>Structure</td>
<td>Sharp edges are smoothed off</td>
<td>3</td>
<td>Sharp edges are smoothed off</td>
<td>subj</td>
</tr>
<tr>
<td>9</td>
<td>Structure</td>
<td>Easy to fit accessories</td>
<td>3</td>
<td>Time to assemble the accessories</td>
<td>min</td>
</tr>
<tr>
<td>10</td>
<td>Structure</td>
<td>Easy to manoeuvre</td>
<td>4</td>
<td>Minimum corridor width of 1000 mm</td>
<td>mm</td>
</tr>
</tbody>
</table>
Example of a partially completed

*Chart of Competing Wheelchairs based on Metrics*

**Aims**

- To use the data from the *List of Refined User Needs and their Associated Metrics* to make a comparison amongst competing wheelchairs.
- To determine the strengths and weaknesses of competing products in relation to the company’s own product.
- To clarify problems associated with existing products which must be overcome to increase the chances of success for the company’s own product.

**Table 3**

<table>
<thead>
<tr>
<th>Metric No.</th>
<th>Need No.</th>
<th>Metrics</th>
<th>Imp.</th>
<th>Units</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Total mass</td>
<td>5</td>
<td>kg</td>
<td>15.5</td>
<td>20.0</td>
<td>17.3</td>
<td>16.8</td>
<td>18.0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Fold width</td>
<td>4</td>
<td>mm</td>
<td>330</td>
<td>580</td>
<td>910</td>
<td>730</td>
<td>815</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Attenuation from push bar to main structure at 10 Hz</td>
<td>3</td>
<td>dB</td>
<td>12</td>
<td>15</td>
<td>14</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Preload on the suspension spring</td>
<td>4</td>
<td>N</td>
<td>480</td>
<td>760</td>
<td>500</td>
<td>520</td>
<td>680</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Time to disassemble/ assemble wheels</td>
<td>1</td>
<td>min/ sec</td>
<td>15m</td>
<td>38m</td>
<td>27m</td>
<td>32m</td>
<td>35m</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>Headset sizes</td>
<td>2</td>
<td>mm</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.125</td>
<td>1.125</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>Steer tube diameter</td>
<td>2</td>
<td>mm</td>
<td>254</td>
<td>254</td>
<td>254</td>
<td>254</td>
<td>254</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>Wheel sizes</td>
<td>2</td>
<td>mm</td>
<td>609</td>
<td>558</td>
<td>609</td>
<td>508</td>
<td>628</td>
</tr>
<tr>
<td>9</td>
<td>6</td>
<td>Castor sizes</td>
<td>2</td>
<td>mm</td>
<td>127</td>
<td>190</td>
<td>190</td>
<td>127</td>
<td>190</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
<td>Maximum tyre width</td>
<td>2</td>
<td>mm</td>
<td>38</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>11</td>
<td>7</td>
<td>Time to disassemble/ assemble components</td>
<td>2</td>
<td>min/ sec</td>
<td>8m</td>
<td>10m</td>
<td>12m</td>
<td>9m</td>
<td>10m</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>Sharp edges smoothed off</td>
<td>3</td>
<td>subj</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>9</td>
<td>Time to assemble the accessories</td>
<td>3</td>
<td>min/ sec</td>
<td>3m</td>
<td>5m</td>
<td>4m</td>
<td>3m</td>
<td>6m</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>Minimum corridor width of 1000 mm</td>
<td>4</td>
<td>mm</td>
<td>1125</td>
<td>1450</td>
<td>1350</td>
<td>1500</td>
<td>1400</td>
</tr>
</tbody>
</table>
Example of a
*Chart of Competing Wheelchairs based on User Satisfaction*

**Aims**

- To make a comparison amongst competing wheelchairs based on users' perceived satisfaction of the degree to which the different wheelchairs satisfy their needs.
- To determine the strengths and weaknesses of competing products in relation to the company's own product in terms of user satisfaction.

**Table 4**

<table>
<thead>
<tr>
<th>Needs No.</th>
<th>Needs</th>
<th>Imp.</th>
<th>Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>1</td>
<td>Reduce weight of wheelchair</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Produce foldable wheelchair</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Reduce vibration in the handles</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Allow easy traversal of difficult terrain</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Easy to remove wheels</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>A wide variety of wheels and tyres fit the wheelchair</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Easy access for maintenance of the components</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Sharp edges smoothed off</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Easy to fit accessories</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Easy to manoeuvre</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Lasts a long time</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Provides good stability</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Ease of kerb climbing</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Is safe</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Is not expensive</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
CONTAINS PULLOUTS
Example of a partially completed QFD table for the design of a wheelchair

**Aim**

To match the expressed needs of wheelchair users and carers to the features and functions of the product.

### Table 5

#### Technical Competitive Assessment

<table>
<thead>
<tr>
<th>Company</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
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<td>Company A</td>
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<td>15</td>
<td>1</td>
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</tr>
<tr>
<td>Company B</td>
<td>20.0</td>
<td>580</td>
<td>15</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Company C</td>
<td>17.3</td>
<td>910</td>
<td>16</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>Company D</td>
<td>16.8</td>
<td>750</td>
<td>12</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>Company E</td>
<td>18.0</td>
<td>815</td>
<td>15</td>
<td>80</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Target Value

| Target Value | 15.0 | 130 | 10 | 850 |

#### Technical Difficulty

| Technical Difficulty | 5 | 5 | 4 | 2 |

---

**Relative importance (%)**

<table>
<thead>
<tr>
<th>Units of measurement</th>
<th>kg</th>
<th>mm</th>
<th>db</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
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<td>15</td>
<td>80</td>
</tr>
</tbody>
</table>

---

**Absolute importance**

| Reduces wheelchairs weight | 5 | 9 | 9 |
| Produces wheelchair foldable | 4 | 9 |
| Reduces vibration in the hands | 3 | 1 |
| Allows easy traversal of difficult terrain | 4 | 1 | 3 |
| Easy to remove wheels | 1 | 3 |
| A wide variety of wheels and tyres fits the w/c | 2 | 1 |
| Easy to access for maintenance of the components | 2 | 3 |
| Sharp edges smoothed off | 3 |
| Easy to fit accessories | 3 |
| Easy to manoeuvre | 4 | 9 |
| Lasts a long time | 9 |
| Provides good stability | 5 | 9 | 1 |
| Ease of kerb climbing | 3 | 9 |
| Is safe | 5 | 9 |
| Is not expensive | 5 | 1 | 1 |

---

**Relative importance (%)**

<table>
<thead>
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| Sharp edges smoothed off | 3 |
| Easy to fit accessories | 3 |
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| Provides good stability | 5 | 9 | 1 |
| Ease of kerb climbing | 3 | 9 |
| Is safe | 5 | 9 |
| Is not expensive | 5 | 1 | 1 |
6. Concept Design

Aim

- To produce alternative designs of a new wheelchair in order to meet the needs of a wide range of users, exploiting to the full the abilities of sales, marketing and distribution channels, fitting in with existing manufacturing facilities and suppliers and ending up making a profit for the company.

**STEPS:**

- Generate concepts based on the *Wheelchair Design Specification Document*  
- Use special techniques for the generation of ideas such as brainstorming, brainwriting and synectics  
- Evaluate and select concepts using the *Matrix for evaluating and Selecting Concepts* (Table 6)  
- Refine concepts using the *Matrix for Refining Concepts* (Table 7) to select one or more concepts capable of being developed  
- Detail the design of the chosen concept to enable the wheelchairs to be prototyped and manufactured  
- Design the user manual and promotional material
Example of a
Matrix for Evaluating and Selecting Concepts

Aims
- To help the design team, with the participation of the User Panel, to evaluate, compare, select and eliminate different concepts.
- To produce new alternative designs arising from the combination of different features of different concepts.
- To analyse different aspects of the product (such as its subsystems, components or combinations of them) in terms of different product features, e.g. aesthetics, stability, adjustability, manoeuvrability and safety.

<table>
<thead>
<tr>
<th>SUBSYSTEM: HANDLE</th>
<th>Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection criteria</td>
<td>A</td>
</tr>
<tr>
<td>Ease of handling</td>
<td>+</td>
</tr>
<tr>
<td>Ease of use</td>
<td>R</td>
</tr>
<tr>
<td>Ease of removal</td>
<td>E</td>
</tr>
<tr>
<td>Manoeuvrability</td>
<td>F</td>
</tr>
<tr>
<td>Sharp edges are smoothed off</td>
<td>E</td>
</tr>
<tr>
<td>Reduction of vibration in the hands</td>
<td>E</td>
</tr>
<tr>
<td>Good stability</td>
<td>C</td>
</tr>
<tr>
<td>Adjustability</td>
<td>E</td>
</tr>
<tr>
<td>Help in kerb climbing</td>
<td>0</td>
</tr>
<tr>
<td>Easy to fit accessories</td>
<td>C</td>
</tr>
<tr>
<td>Wheelchair foldable</td>
<td>O</td>
</tr>
<tr>
<td>Safety</td>
<td>N</td>
</tr>
<tr>
<td>Low manufacturing costs</td>
<td>C</td>
</tr>
</tbody>
</table>

| Sum +'s | 4 | 0 | 2 | 4 | 4 | 1 |
| Sum 0's | 9 | 10 | 10 | 6 | 7 | 10 |
| Sum -'s | 1 | 3 | 1 | 2 | 2 | 2 |
| Net Score | 3 | -3 | 1 | 2 | 2 | -1 |
| Rank | 1 | 5 | 3 | 2 | 2 | 4 |

Continue? Yes No Yes Combine Combine No
Appendix 6.1

Example of a
Matrix of Refining Concepts

Aims

- To help the design team, with the participation of the User Panel, finally to select one or more concepts capable of being developed.
- To analyse different aspects of the product (such as its subsystems, components or combinations of them) in terms of different product features, e.g. aesthetics, stability, adjustability, manoeuvrability and safety.

Table 7

<table>
<thead>
<tr>
<th>SUBSYSTEM: HANDLE</th>
<th>Weight</th>
<th>Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection criteria</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
</tr>
<tr>
<td>Ease of handling</td>
<td>5</td>
<td>R    Rating 3</td>
</tr>
<tr>
<td>Ease of use</td>
<td>5</td>
<td>F    2</td>
</tr>
<tr>
<td>Ease of removal</td>
<td>5</td>
<td>E    1</td>
</tr>
<tr>
<td>Manoeuvrability</td>
<td>10</td>
<td>R    3</td>
</tr>
<tr>
<td>Sharp edges are smoothed off</td>
<td>5</td>
<td>E    3</td>
</tr>
<tr>
<td>Reduction of vibration in the hands</td>
<td>5</td>
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<tr>
<td>Good stability</td>
<td>10</td>
<td>C    3</td>
</tr>
<tr>
<td>Adjustability</td>
<td>10</td>
<td>C    4</td>
</tr>
<tr>
<td>Help in kerb climbing</td>
<td>5</td>
<td>N    3</td>
</tr>
<tr>
<td>Easy to fit accessories</td>
<td>5</td>
<td>C    3</td>
</tr>
<tr>
<td>Wheelchair foldable</td>
<td>5</td>
<td>E    3</td>
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<td>Safety</td>
<td>15</td>
<td>P    1</td>
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<tr>
<td>Low manufacturing costs</td>
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<td>T</td>
</tr>
<tr>
<td>Total Score</td>
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</tr>
<tr>
<td>Continue?</td>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>
7. Prototyping

Aims

- To help the design team in the evaluation of wheelchair performance so that the required specifications and users' needs are met.
- To reveal problems that may arise from the engineering of the product.

**STEPS:**

- Build the prototype
- Analyse if the concept represented by the prototype will work and meet the customer needs and the product specifications
- With the help of the *User Panel*, test the prototype in terms of the user-product interface (including the assembly of the wheelchair and the interconnection of all its parts)
- Check if safety and legal issues are satisfied
- Ensure that raw materials and purchased components meet performance and delivery requirements
- Check if costs and production scheduling will be within specified limits
8. Testing and Verification

Aims

- To compare objective user-performance data obtained from the test with the product specification.
- To reduce the likelihood of legal action against the product’s manufacturer.
- To contribute to the success of the product in the marketplace.

**STEPS:**

- Provide the facilities in which the tests will be carried out
- Define the resources (people, equipment, time, money, etc) that should be devoted to the testing phase
- Establish the aims of the testing (including what will be measured and why)
- Select the tasks that users will perform
- Establish subjective and objective measurements for measuring performance.
- Define the duration of sessions and tests
- Define the techniques used for observing performance and recording the result of the tests
- Carry out usability tests involving the User Panel (and others representative product users) and working prototypes
- Analyse and interpret the results making it clear if the prototype is meeting or not user needs
9. Product Production

Aim

- To establish the phases involved in the product development cycle - assembly methods, manufacturing process and material selection - based on the details obtained from the previous phases of the design process.

(this phase does not involve directly the participation of industrial designers and is not part of this thesis)

**STEPS:**

- Production development
  - Select manufacturing methods and process parameters
  - Select materials
  - Select suppliers
  - State expected costs
  - Select assembly needs and procedures
  - Execute production design documentation
  - Design technical trials
  - Conduct technical tests
  - Appraise the results of trials and modify design if necessary

- Production planning
  - Prepare production planning
  - Design jigs and tools
10. Manufacture and Assembly

Aim

- To transform raw material into the finished product according specifications.
  (this phase does not involve directly the participation of industrial designers and is not part of this thesis)

**STEPS:**

- Meet product design specification
- Meet production schedule
11. Market Product

Aim

- To use marketing and other techniques to advertise and sell the new wheelchair.
  (this phase does not involve directly the participation of industrial designers and is not part of this thesis)

**STEPS:**

- Produce product advertisement specific to the market segment
- Give training to the sale personnel
- Distribute the product
12. Customer Support

Aim
- To provide the wheelchair user with good postpurchase support in terms of maintenance and repair.
- To monitor the product's performance while being used by the customer.
  (this phase does not involve directly the participation of industrial designers and is not part of this thesis)

**STEPS:**
- Give training to users
- Provide product maintenance
- Provide repair service
- Monitor product’s performance
- Carry out user surveys
- Carry out product review
- Modify product, if necessary