Using modularity to produce more competitive assistive technology products

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Abstract

The market for Rehabilitation and Assistive Technology (RT/AT) products is expanding. Between ten and seventeen percent of the population of European Union are documented as disabled. Many companies perceive the market to be too fragmented to invest in large batch or flow production methods.

The issues of a potential high demand and necessary variety thus require a flexible solution. This paper will highlight opportunities to address these issues and provide concomitant reduction in complexity and cost through product modularity.

The concept of modularity will be defined in the context of production and product design methodologies. A case study will be used to highlight key aspects of how modularity may be applied in conjunction with user centred design methods and product engineering methodologies drawing on other examples as necessary. The paper will also highlight the flexibility of a product’s features when modularity is considered early in the design process.

1 Introduction

As more countries develop their own manufacturing capabilities, world markets are becoming more competitive. Companies involved in mass and global markets are now trying to maximise the sale potential for their products. Such companies are also looking at new markets that are smaller than previously considered viable that address specific needs. Smaller companies now compete with much larger rivals for these ‘niche’ markets.

To meet the demands of the consumer and industry, designers and product engineers must consider ways of producing new product lines from currently used materials, components and facilities. Re-engineering of existing products is no longer viable to meet the issues of
‘niche’ markets. Modularity may be one method to develop the variety of product lines, at low cost, required to be competitive in current markets.

A large market that is made up of many niche markets is that of Rehabilitation and Assistive Technology products (RT/AT products). RT/AT products lie between mainstream consumer and medical products. Examples are; walking sticks, jar openers, light switch extensions, wheelchairs, communication devices, drinking and eating aids. Mainstream products such as spectacles are also in this category.

The turnover of the market in the United Kingdom is large. One Charity, the Motor Neurone Disease Association, spent over £100,000 in 1994-1995 on the provision of assistive products for its membership of around 5,000 people. Considering the total population of the UK who are registered disabled it seems worth consideration by large companies. Over one in ten people in the UK are registered disabled with the figure ever rising due to an ageing population. [1] Even with the growing need for RT/AT products there are few companies manufacturing products for this market. The main reason for the hesitance of manufacturers of mainstream goods entering the market is the wide range of customer need to be fulfilled by the product and the way in which products are currently bought by consumers.

Young [2] identified a number of problems facing the RT/AT manufacturer. The problems included:

- Insufficient financing
- Lack of venture capital
- Inadequate knowledge of the market
- Lack research and development
- Inadequate knowledge of supply channels
- Low quality products

Looking more closely at consumer needs, the difficulties companies face can be seen. Daily living activities that people in the UK may wish to undertake are the same. Personal hygiene, eating and drinking, communicating with others and going to and from work in the house, town or country vary little between the mainstream population. The way in which a person
with a physical or mental impairment, or disability, might perform a task may be completely different to another disabled person. Accommodating all the different control interfaces into a design specification required for even a simple product, such as a saucepan, makes large batch or flow production processes uneconomic. The potentially large market is fragmented into small groups of consumers each with their own requirements for the same basic task to be performed.

The way in which consumers RT/AT products is not straight forward. A large proportion of disabled people in the UK are likely to be on low incomes or supported by Social Services. Many RT/AT products are bought by a third party, such as an Occupational Therapist or a carer. Many products are found to be unsuitable by the consumer and involve costly reimbursement via the third party or product lying in a cupboard unused.

1.1 Why should modularity be so useful in Assistive Technology manufacturing?

The design, development and manufacture of a powered arm support by the Brunel Institute for Bioengineering (BIB) will be described as an example of the advantage of using the concept of modularity. Aspects of modularity will be discussed through this example, drawing on other sources as required. The Brunel Institute for Bioengineering (BIB) is a self financing Institute affiliated to Brunel University. The Tools For Living (TFL) team are part of BIB and have been involved in the research and development of new product for disabled and elderly people since 1983. The nine-strong multi-disciplinary team of Designers, Engineers and scientists work closely with individuals and clinicians during research and developments. In order to appreciate the effectiveness of modularity a definition of the concept is required.

1.2 What is modularity?

Modularity has been described by John Young [3] as ‘Any grouping or fitting together of individual components or parts into a functional unit or sub-system.’

In terms of product design and engineering modularity may be described as a (sub) system that has a self-constrained and testable function that may be combined and configured with similar units to form a working product. With modularity clearly defined the case study may now be documented.
2 Case study: Powered Arm Support

The charity the Motor Neurone Disease Association (MNDA) asked the Tools For Living (TFL) team, at the Brunel Institute for Bioengineering (BIB), to identify and develop new assistive products for their members. Motor Neurone disease degenerative neuromuscular disease that causes progressive weakness of the person’s muscles. [4] People with MND find their ability to move body and limbs increasingly difficult. Life expectancy diagnosis can often be only three years, although some people may live for much longer. The cause of the disease is very variable, and almost any group of muscles can be affected. Typically the leg, or arm, or speech/swallowing muscles, are affected first and then the muscles in one or both of the other two areas also lose their strength. Thus some people may become wheelchair users within the first year, while others can remain walking throughout the course of the illness. [5] However, for the majority of people with MND there are many months or years during which they are unable to move their arms in a useful manner, and so cannot feed themselves or write a letter.

2.1 Identification of need

A Powered Arm Support (PAS) was one of the items identified by the members of the MNDA as a useful product not available at that time. Using task analysis, direct observation and descriptions of the clinical characteristics of the disease the designers and engineers involved were able to develop a working specification for the product. [6] A principle proving prototype was produced and tested by volunteers from the charity under the supervision of their Occupational Therapist. User trials have been found to be the most effective way of developing new assistive technology products. [7]

Results of the trial indicated the task to be performed, moving one’s arm up, down and horizontally, (Figure 1), using the product found that its use was not confined to a wheelchair mounted Powered Arm Support (PAS) as originally designed. The volunteers testing the PAS wished to use the product whilst seated at a desk, at a dining table, at home and at restaurant, indoors and out. It can be seen that a detailed functional specification was achieved quickly through working closely with the target consumer group at such an early stage of development.
Figure 1. Shows the degrees of movement using the Powered Arm Support.

The results gave a number of problems to the designers and engineers developing the arm support:

- The consumer requested to use the PAS in conjunction with a number of different chairs and wheelchair types, in various environments.
- The ability to control the PAS was variable with each individual and would change over a short period. A different control interface may be required every few weeks.
- The existing market was very small, only a few hundred in total, making continued manufacture of the product difficult without charitable funding.

It was at this time modularity was seen to offer an opportunity to optimise the potential market and provide a flexible control and support interface.

The two areas that required most consideration were:

- The use of a range of custom made and commercially available control interfaces that allow the user to switch the PAS from up to down and back again.
- The attachment of the PAS to the supporting structure (wheelchair, chair or free standing).

2.2 Modular solutions

The control switch or interface was kept separate from the main drive unit to allow a standard connection point to be used. There was a Department of Health and Social Security
guideline already in existence regarding the connection format or DIN sockets and plugs [8] that was and is widely used by the control switch manufacturers in the UK.

Many of the electrical components had already been specified through Original Equipment Manufacturers (OEM’s). The existence and expansion of OEM’s has given the designer and product engineer an opportunity to access a wide range of ‘off-the-shelf’ components. OEM components offered a number of advantages:

- They are of known performance
- They are of known reliability
- The producer of the OEM product has specialist knowledge about the component or material
- Only the required number of units needed be bought to produce the product (Just-in-Time may be applied easily)

However, disadvantages found when using OEM components were:

- Decisions regarding the design specification of the product were focused on the OEM range, limiting the design options available.
- OEM’s often work through large distribution networks, increasing the cost of the component.

An exploded view of the component parts of the PAS MkII (Figure 2) clearly shows the standardisation using OEM components (*) and critical modular connection points. (**).
Figure 2. Shows an exploded view of the PAS. * indicates OEM components, ** indicates critical modular connection points.

The attachment points of the PAS to the supporting structure was initially a prototype clamp that gave the required axis of adjustment required to adjust the arm support to accommodate the residual muscle tone in the users arm.

The clamp used in the MKI production model was a modified Mobilia clamp system to accommodate the mounting bracket. (Figure 3).

Figure 3. Shows the MkI version of the PAS version (left) and the MkII version (right) with an increased lifting stroke.
The slider support rod and tube (parts 6 and 9, Figure 2) were increased in diameter and length to offer longer stroke of powered movement. To keep the PAS unit within the same overall dimensions as the PAS MkI the slider tube was brought in line with the main housing tube. (Figure 3) During discussions with the OEM of the Linear actuators the Design Engineers at BIB found the stroke length could be increased without extra cost.

The Mobilia clamping system marketed through Quest Enabling Designs (QED) Ltd, Fareham, UK, was intended to offer a flexible mounting system for environmental control switches/interfaces. Due to the over-engineered structure of the main clamp unit it was assessed to be capable of being subjected to the extra load applied through the weight of the PAS and a user’s arm. In the MkII version of the PAS the slider tube housing, part of the main body housing (Figure 3), was redesigned. One of the reasons for the redesign was to offer a stronger clamping and slider support unit to accommodate the heavier arms of users Muscular Dystrophy. Through functional analysis the clamp component, made ‘in-house’ was designed out. The redesigned clamp bracket was designed to be directly fastened to the Mobilia clamp. (Figure 4)

Figure 4. Shows the direct attachment of the Mobilia clamp to the support bracket on the PAS.

2.3 Expanding the market

While it was convenient to buy one-off items through retailers and wholesalers, efforts were made to find the manufacturer to buy directly batches of the components to reduce cost.

The population of people with MDN in the UK is around 5,000. [9] To make feasible to buy batch quantities of components direct from the manufacturer the consumer market had to be enlarged. This was done through categorisation of the physical dysfunction clinically
diagnosed in other forms of disability. Larger groups of people with different forms for disability were identified that had similar characteristics dysfunctions such as:

- Weak grip
- Limited ability to lift the upper limb
- An inability to hold objects
- Limited movement of the joints of the upper limb

People with Muscular Dystrophy, with a population of around 20,000 in the UK, were initially identified was a consumer group with similar need. Identifying the clinical characteristics in other disabled groups in people increased the potential sales of the PAS from hundreds into a few thousand. Though standardisation of the characteristics and knowing the activities to be performed are similar, a form of modularity was applied to the identification of new markets. However, the differences in physical characteristics had to be assessed alongside the identified clinical characteristics.

The features of the PAS offered the buyer (often an Occupational Therapist) and user a number of advantages:

- The unit could be customised quickly and easily for a new client to use without specialist tools
- Control interfaces that may already be in stock with the Therapist could be used with the product
- The unit could be used with more clients due to the flexibility of control interfaces and attachment to different support structures, prolonging its useful working life.
- The unit should not be outdated within the working life of the PAS as the switch connection points are an industry standard.

The combination of options offered through the use of modular components can be clearly seen in the following matrix.
<table>
<thead>
<tr>
<th>Support type/Control Switch type</th>
<th>Free Standing</th>
<th>Wheelchair mounted</th>
<th>Chair mounted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single lever coarse action hand activated</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Single lever fine action hand activated</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rocker coarse action hand activated</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rocker fine action hand activated</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Single lever action foot activated</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Rocker lever action foot activated</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Figure 5 Shows a matrix of some of the combinations of switch and support options available to use with the PAS.

2.4 PAS Manufacture

The manufacture of the PAS was made easier due to the use of standard components and the application of modularity. The PAS was initially made by skilled engineers, whose time was very expensive. After the initial user trials the PAS was prepared for small batch production. During the development of the PAS notes were kept on the method of production and components used. The lead times on the casings and cover were found to be a critical factor in the time taken to produce a batch of PAS’s.

The production notes were used to produce production sheets for out-worker assembly, working at non-skilled worker rates. The use of out-workers was found to be slow but cost-effective as requests for the manufacture of sub-assemblies were placed in advance of orders. There was an increase in labour costs due to extra quality control checks, but it was a more effective use of skilled staff.

Modularity has allowed the sub-assemblies to be produced separately with a simple final assembly to allow quick response to orders placed. When all components are in stock the unit could be produced, tested and packaged within 1 hour.

The same DIN connectors are used on other TFL products requiring control switch interfaces, further reducing the costs through buying large batches of the same component. The cost of
tooling to drill holes and the assembly of electrical components wiring are low as the same tools are used to make a number of products.

Maintenance has been made easier through the use of standard, modular components. The working characteristics of each components are well known to TFL staff and problems can be quickly rectified by return of post or through technical staff of the care organisation concerned.

The PAS unit retails at £770.00 sterling, which includes a bought-in arm support that plugs into the PAS slider rod (part 6). Optional extras include a wrist support and cutlery set.

5 Conclusions

While modularity has been documented as useful for large companies this concept is vital to the survival of small to medium enterprises in niche markets.

Through the example shown it can be seen that modularity has many potential advantages to the manufacture and customer alike. Modularity has allowed a product to be designed to meet a wide range of customer requirements. Though the product described is for one application it is capable of dealing with a range of similar operations and with different interfaces to suit individual need. Modularity has also allowed the product to be manufactured economically with standard components and unskilled labour.

Modularity is seen as a key design tool to aid in addressing the diametric pressures of providing a variety to meet market need and standardisation and rationalisation to meet company needs.

However, designers and engineers should be cautious of the product specification being driven by the availability of standard parts. The re-design of the support clamp racket is an example of modularity driving design decisions. If standardisation and modularity are constantly used to meet new market needs through product such as the PAS the product will evolve than be designed. While evolution of a product may be welcomed, the designer should review he fundamental requirements of need before accepting a solution based on OEM components.
The novel concept of standardising the functional characteristics of different forms of
disability have helped the TFL team maximise their market and offer an appealing range of
features to the user, carer and Social Services buyer. It is hoped through the documentation
of the methods used by the Tools For Living Team that more designers, engineers will
become involved in the development of much needed products in this field.

6 Acknowledgements

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