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A Theoretical and Empirical Investigation into the Implementation of Postponement

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Finally, this thesis is dedicated to my family who always support me with love.
ABSTRACT

The concept of postponement has a long history of academic literature and practical applications. Features and benefits of postponement have also existed for many years, but postponement has only recently received more attention. This development has become mandatory to many companies in view of today's market and business environment. However, its applications are still not as widespread as expected. Therefore, I am interested in what factors enable or hinder the successful implementation of postponement.

Based on the literature review, I first conducted a theoretical study to: (1). Further develop the concept of postponement to include product development postponement, purchasing postponement, production postponement and logistics postponement; (2). Investigate the postponement implications for such issues around the supply chain as the decoupling point, supply chain integration, power and control, and capacity planning; and (3). Propose an integrated framework for postponement applications, where I am also concerned with the development of a set of general ideals upon which future work can be based.

Then, I carried out a questionnaire survey with 368 British companies in four industrial sectors (namely electronics, automotive, food and clothing industries). In doing so, I attempted to investigate the relationships among postponement, environmental uncertainty, managerial practices and company performance. The survey data was also used to gain insight to the level of postponement applications and various barriers to postponement.
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CHAPTER 1. INTRODUCTION

Postponement is not a new idea in many respects. In contrast with the old adage: why put off until tomorrow what you can do today, postponement is the philosophy of not doing today the things you can do tomorrow (when better information is available). Many people do not realise it yet, but the examples of postponement exist every day, e.g. cutting and weighing cheese to order, labelling multiple prices on food in a supermarket, and dispensing tablets as per prescription in pharmacies. In a restaurant, most of the ingredients are nearly prepared and held until a patron orders a specific meal. Then such operations as cooking vegetables and meat, and blending sauces and spices are delayed until an order has been placed. Similarly, labelling has been fully postponed in the canning industry for many years. Fresh fruits and vegetables are canned and centrally stored without labels in 'bright' cans during the harvest season. Labelling is postponed until a later time when food marketing companies buy the canned product. Then it is labelled with their own brands (at the central storage facility).

In the above examples, it looks very natural to go for postponement. This way, canning production minimises the risk of inventory mis-forecasts and economises on mass production (in a 'bright' status). However, in most cases so commonly used postponement may not be easily implemented. In the celebrated postponement example of Hewlett-Packard (HP)'s Deskjet printer, where HP realised well over $3 million/month in logistics savings (Twede et al., 2001), it necessitated the redesign of the product (externalising the power supply), the production process (enabling final assembly to be
carried out at the distribution centre) and the supply chain (introducing patented packaging and palletising process for ease of shipment and customisation). Such concurrent engineering could only be carried out through cross-functional teamwork (e.g. through the participation of R&D, manufacturing and logistics functions) and cross-border collaboration (e.g. requiring the willingness of the distribution centre to do more training) (Herer et al., 2002). This might also require the introduction of new organisational relationships and the support of key information and communication technologies, which cannot be readily deployed. Meanwhile, we are now seeing that time-to-market is shortening and windows of marketing opportunities are fleeting. Therefore, companies cannot afford simply to wait until all aspects of exact information are revealed. Otherwise, postponement may pay to procrastinate. In this regard, postponement benefits do not just happen. Conversely, postponement applications must be planned and rolled out following a carefully orchestrated implementation plan. There are many examples of failing to respond to the end customer requirements, where postponement does have a manufacturing operations basis. In a launch of a new cracker product by Nabisco in 1997, two variants of a new thin Triscuits cracker were introduced. One variant was regular-flavoured. The other was onion-flavoured which was manufactured from the former regular one but with an additional flavouring. Significant inventory of each variant was produced for the expected holiday sales. The market enthusiastically received the regular-flavoured cracker while the onion-flavoured version was not well received. Unfortunately, Nabisco was unable to fully replenish the regular-flavoured version while high levels of onion-flavoured stock remained on retail shelves until after the holiday season (Bowersox et al., 1999a). No doubt, a successful implementation of postponement requires integrating all elements of organisational capabilities (people, process and technologies). In this thesis, I am mainly concerned with the issues around the implementation of postponement.

1.1 Background to the Research
Postponement has been increasingly regarded as an important strategy in today’s business environment. According to Zinn and Bowersox (1988), Van Hoek (1998a), Bowersox et
Johnson and Anderson (2000) and Lee and Whang (2001), many reasons are offered for the growing importance of postponement strategies:

1. Product life cycles are increasingly shortening;
2. Product proliferation continues to expand;
3. Technological developments are continuing at an ever-increasing pace;
4. Customers are more and more sophisticated;
5. Success is increasingly driven not so much by cost or quality, but by speed;
6. Mass customisation and agility have been receiving increasing interest from both researchers and practitioners (Also see Subsection 2.1.1, p.12-15); and
7. The potential afforded by e-commerce is felt to be wide-reaching and thus there are opportunities to re-engineer existing supply chains or design new supply chains using postponement strategies (Also see Subsection 2.1.1, p.15-16).

Also, it has been concluded that the benefits of postponement include saving inventory assorting, carrying and holding costs, stock-out and obsolescence costs by delaying a product's variety, volume, weight and/or value increases.

No doubt, the need for postponement is significantly driven by market circumstances. Faced with today's constantly changing environments, producing and storing all types of finished products entirely on forecast will run high risk of stock-out or and obsolescence, as suggested by the following question from Womack and Jones (1996) 'why make anything and push it to the market when you don't know whether customers are willing to buy the product at all?'. It is ideal for a company to wait for the customer order to arrive before activating the whole design-make-ship cycle. No incorrect product is thus produced, but this is at the expense of the customer who has to wait an excessive time for the product. That is, lead times often make it impossible to go for an engineer-to-order strategy (highest level of postponement). In practice, most companies carry out some early steps based on forecasts, e.g. stocking some raw materials and semi-finished goods. The remaining customisation steps are delayed to as late a time as possible, e.g. upon customer order.
The postponement concept has long been in the literature (e.g. Alderson, 1950; Bucklin, 1965) and its applications can also be dated back to the 1920s (CLM, 1995). However, currently the application of postponement is still not as widespread as expected (Van Hoek, 1997; Bowersox et al., 1999a; Battezzati and Magnani, 2000; Brown et al., 2000). Thus, my interest is in how postponement strategies can be successfully implemented.

1.2 Aims and Objectives of the Research

My research attempts to investigate the implementation of postponement from both theoretical and empirical perspectives. A considerable number of studies were conducted on various aspects of postponement strategies. However, there is still much to know about postponement. My theoretical investigation is focused on a conceptual development of postponement, postponement implications for the supply chain, and an integrated framework for implementing postponement (see Chapter 3). This way, I aim to increase my understanding of postponement strategies and explore new areas for postponement applications. Undoubtedly, this will also generate new ideas and create new research opportunities for academia.

Meanwhile, postponement applications are still much less than expected, although research addressing the issues of postponement has significantly increased in recent times. Van Hoek (2001) states that, notwithstanding all recent attention, insights in postponement appear to be underutilized. What is more, as most empirical postponement research was based on case studies, it is still unclear which elements are the generic postponement enablers/barriers. More details about the current status of research methods in postponement research are presented in Chapter 4. Accordingly, another attempt of this research is an empirical investigation of postponement strategies in British companies using multi-item measurements, namely, engineer to order, make to order, manufacturing to order, labelling/packaging to order, and ship to order (see Subsection 5.1.1, p. 113). Very few studies are concerned with postponement applications in the UK in the areas mentioned. For example, a recent study by Lowson (2001) is mainly concerned with an empirical taxonomy of operational strategies (leading to a total of 13 operational strategies including postponement) and only focuses on the retailers within
fast-moving consumer industries in the UK. The data used in the present study are drawn from a questionnaire survey across four industries in the UK. In this regard, the value of this research stems from its attempt to investigate what factors facilitate or hinder the successful implementation of postponement within a much broader context, in order to bring the theoretical benefits of postponement a step closer into practice. Postponement requires a company to change or modify its operating procedures, production system and its organisational culture. Companies are recommended to take into consideration many aspects arising from the findings of the study related to environmental uncertainty, performance measurement, managerial practices and barriers to postponement. For example, beyond the issue of whether a company should or should not adopt postponement strategies, I empirically investigate how adopters of a high degree of postponement differ from adopters of a low level of postponement. That is, should companies adopt postponement strategies because this may lead to better performance? The output of this research may also help a company discover the degree of fit between the business opportunities inherent in postponement and its organisation's ability to capitalise on the opportunity. Despite focusing only on British companies, it may be expected that some generalisation can be made from my data that would equally well apply to those companies in other countries.

1.3 Research Approach

To propose my initial research questions, a comprehensive literature search was conducted on theoretical and empirical studies on the subject of postponement. I also conducted a theoretical study reported in three sections in Chapter 3: conceptual development of postponement, postponement implications for the supply chain, and an integrated framework for postponement applications. Then, Section 3.4 (p. 81) presents five hypotheses that not only follow directly from the perspective on my research question presented in Section 2.3 (p. 37) and but also in the light of my theoretical study.

Before further developing the methodology, Section 4.1 reviews the methods that have been used in postponement research. Section 4.2 includes a detailed discussion of the methodology employed to gather empirical evidence for testing my hypotheses. Namely,
I conducted both e-mail (when personal e-mail contact addresses were available) and mail questionnaire surveys in British companies. The results and discussion are reported in four sections in Chapter 5. Although a variety of different research designs (e.g. observation, case study, and in-depth interview) could have been used in this research, self-administrated questionnaire was felt to be the most appropriate (see Section 4.2). For example, in-depth interviews were not used in this research because they are constrained by time and cost, and certain groups (such as executive managers) may not be able to devote the necessary time for interviews. Self-administered questionnaires have been preferred for collecting data for a variety of reasons:

1. Ideally the value or utility of management strategy promotion should be measured quantitatively, preferably using such financial measures as cost-benefit analysis (Pointon, 1978). However, it has long been established that part of the neglect in postponement applications may be due to the absence of effective means for assessing the feasibility of postponement before implementing it (e.g. Bucklin, 1965; Zinn, 1990b; Ernst and Kamard, 2000);

2. The sample companies are located in different areas of the United Kingdom, so e-mail or postal questionnaires are considered to be a better communications medium than other methods. Also, Wass and Wells (1994) argue that if the number in the organisational sample to be surveyed exceeds 30, it will be more efficient to use a questionnaire rather than interviews. The sample used in the study consists of 368 companies;

3. A questionnaire is appropriate in this case because much of the research is being conducted to ascertain the importance of a set of factors, e.g. in performance measurement and barriers to postponement implementation. Saunders et al. (1997) state that questionnaires can be used for research that is undertaken to discover attitudes and opinions;
4. The survey focuses on managers at specific levels in companies, who may be more prepared to complete questionnaires rather than set aside time for interviews; and

5. The reason for using questionnaires in this study is also because of the current status of methodology in postponement research (as will be seen in Section 4.1).

1.4 Overview of the Thesis

As shown in Figure 1.1, this study is presented in six chapters including an introductory chapter. Following the aims, the statement of objectives, the scope and importance of the study, the relevant literature is reviewed in Chapter 2. This chapter begins with an overview of the opportunities that drive researchers and practitioners to utilise postponement strategies. It identifies marketing drivers (engineer-to-order, mass customisation, agility and e-business) and discusses their implications for adopting postponement strategies. Then, the related issues (leagility and glocalisation) are also investigated. Following this, the literature review of postponement is conducted from three perspectives: logistics, manufacturing and supply chain. It provides a detailed understanding of the current state of postponement in terms of its research and its applications within industries. I also summarise the literature and present the opportunities and challenges in postponement research. From here, I move a first step to proposing my research questions. Finally, the chapter concludes with a discussion of justification for my theoretical study in the next chapter.

Before refining my research questions and developing my hypotheses, a theoretical study has been conducted and accordingly is divided into three parts in Chapter 3. The first part extends the concept of postponement to include product development postponement, purchasing postponement, production postponement and logistics postponement. The second part investigates postponement implications for the issues around the de-coupling point, supply chain integration, power and control, and capacity planning in the supply chain, in order to extend the significance of postponement toward the perspective of a holistic supply chain context. The third part presents an integrated conceptual framework.
for postponement implementation in the light of the literature review. Finally, the initial research question (proposed in Chapter 2) is refined and 5 hypotheses are proposed.

In Chapter 4, the methodology utilised in this research is discussed. Here, various procedures employed, such as the formulation of the research design, alternative methods that might be used in the research, the design of the questionnaires, the research sample, reliability and validity, and data collection procedures are described.

The results and discussion are reported in four sections in Chapter 5. Section 5.1 deals with questionnaire design and addresses some measurement issues raised in my pre-test of the questionnaire. Section 5.2 is concerned with the description of the sample including demographic data and response rate. Before further analysing my data, Section 5.3 focuses on preliminary analysis by primarily assessing data reliability, content validity, construct validity and criterion-related validity. The results relating to testing hypotheses and barriers to postponement are reported in Section 5.4. The analysis of the survey data was performed using the Statistical Package for Social Scientists (SPSS Version 11.5 for Windows). Statistical techniques that have been used for data analysis include parametric and non-parametric tests such as percentage, mean, and simple/multiple regression analysis. My findings indicate statistical support for four of the five hypotheses.

In Chapter 6, the nature of the contributions (derived from the results of the theoretical study in Chapter 3 and empirical study in Chapter 5) is summarised. The other aim of this chapter is to determine limitations of this research and to make suggestions for future research.

The appendices present the questionnaires (including the cover letter) that were used in my survey.
Today's competitive environment is dynamic, global, and customer driven. Product life cycles are increasingly shortening and product proliferation continues to expand. Technological developments are continuing at an ever-increasing pace. All of these factors contribute to the extending application of postponement (Zinn and Bowersox, 1988; Van Hoek, 1998a; Johnson and Anderson, 2000; Twede et al., 2000). In recent times the amount of research addressing postponement has greatly increased. At the same time, this concept is being used by companies as diverse as Hewlett-Packard (HP) Company, Dell Computer, Motorola, National Bicycle Industry Company in Japan (NBIC), Toyota Motor Corporation, the Gillette Company, Levis-Strauss, and Benneton. This might also be a reflection of the increasing interest in engineer-to-order, mass customisation, agility and e-business, as I will show in Subsection 2.1.1.

Faced with constant changes like volume change and variety change, forecasting and planning becomes very complex. Producing and storing all types of finished goods based on forecast will run high risk of stock-out and/or obsolescence while lead times often makes engineer-to-order impossible. Thus, it is a natural option for a company to seek opportunities for delaying some activities like the final processing or manufacturing of product to as late a time as possible and hence reduce the risk. The concept of postponement is about delaying activities until the exact attributes of demand can be identified. Postponement is attractive in principle, but its application is not as widespread as expected and still at an infancy stage (Van Hoek, 1997; Battezzati and Magnani, 2000;
Brown et al., 2000). Little is known about the implementation of postponement (Droge et al., 1995; Van Hoek, 1997; He et al., 1998). Thus my interest is in how to implement postponement. This chapter reviews different perspectives on postponement in the literature, serving as a foundation for my research questions. The review adopts the following category of different postponement strategies (Bowersox and David, 1996): (1). time postponement (the delaying of activities until orders are received in time); (2). place postponement (the delaying of moving goods downstream in the chain until orders are received, thus keeping goods centrally and not making them place specific); and (3). form/manufacturing postponement (the delaying of activities that determine the form and function of products until orders are received). Time and place postponement, when applied in combination, are referred to as logistics postponement. In the next chapter, I will further review and develop the concept of postponement.

2.1 WHY POSTPONEMENT

I first focus on the following question: what opportunities are driving researchers and practitioners to go for postponement strategies? This section identifies marketing drivers (engineer-to-order, mass customisation, agility and e-business), and discusses their implications for adopting postponement strategies. I also look at the related issues (leagility and glocalisation), with a view to taking full advantage of the possibilities offered by postponement.

2.1.1 Marketing strategy
Perhaps the most topical driver for looking to postponement strategies is manifested by practitioners and researchers’ interest in combining the power of the Internet with engineer-to-order (ETO), mass customisation and agility.
ETO and Mass Customisation

Every company wishes to produce exactly what customers want at the proper place and time they wish to consume (Ballou, 1999). Ideally, they trigger the entire design-make-ship cycle only when a clear demand signal is available. This may be classified as the highest level of postponement, which enables companies to maximise their profits through fully understanding real customer requirements. In reality, it may be impossible to develop such a postponement strategy in many instances because of the tolerance time that the customer is willing to wait. However, many companies are exploring ways toward this in response to constantly changing demands. For example, if customers demand delivery with a short lead time, having modules with standardised interfaces might be a desirable option. Combining standard modules into customer-specific finished products has been mentioned as one of the most efficient options of achieving the required amount of customisation in the literature. In other words, final customisation is postponed until customers specify the exact mix and match. This allows a manufacturer to achieve the marketing benefits of customisation while reaping the cost benefits of standardised production in anticipation of future customer orders (Lampel and Mintzberg, 1996). Such strategy is called mass customisation, where the key is postponing the task of differentiating a product for a specific customer until the latest possible point (Feitzinger and Lee, 1997). Not surprisingly, in the literature of mass customisation research, many authors view postponement as a practical method to move toward mass customisation (e.g. Kotha, 1995; Lampel and Mintzberg, 1996; Feitzinger and Lee, 1997).

The demands of managing global product offerings have pushed companies in many industries to seriously consider postponement as a supply chain strategy for mass customisation (Feitzinger and Lee, 1997). Although there is more postponement towards mass customisation, it always remains the challenge to find an optimal balance in which upstream activities in the supply chain are standardised and downstream activities are postponed until customer orders are received (Van Hoek et al., 1999a). I will take a closer look at this issue in Subsection 2.2.3 and Subsection 3.2.1.
Since Ford moved their assembly line to make use of standardised and interchangeable parts in the 1910s, mass production has supplanted craft production in most locations. Mass production emphasises cost efficiencies through economies of scale and the manufacture of large volumes of product, leading to producing to forecast and then eventually selling whatever was produced. A second paradigm shift occurred with the advent of the Toyota Production System and its diffusion in the form of lean production that emphasised the elimination of waste and good functional quality. In addition to the strategic emphasis on low costs and efficiency, quality became an important competitive priority in the marketplace of the 1970s. In the 1980s, competition intensified such that companies targeted at offering low-cost, quality programmes with greater reliability or dependability which concerns delivery and price promises. Then, as a result of factors such as technological developments resulting in both product innovations and manufacturing process improvements, increased global competition, more sophisticated customers (e.g. in demanding more product variety and customisation) and shortened product life cycles, companies began to concentrate on agility as a competitive priority in order to positively respond to and take advantage of the changes. Agility was originally defined as ‘The ability to thrive and prosper in a competitive environment of continuous and unanticipated change and to respond quickly to rapidly changing markets driven by customer based valuing of products’ (Iacocca Institute, 1991). Since then, a number of publications on agility in the literature have focused on formulating the concept of agility. However, there has not been a unified definition on agility. Sometimes this confusion is so great that agility is used as a catch-all-phrase to describe all the various changes and ideas being promoted such as lean production, business process re-engineering, time compression and so on. On the other hand, the literature seems to agree that agility is a multi-dimensional concept and can be achieved through the strategic integration and utilisation of available managerial and manufacturing methods and tools (e.g. Gunasekaran, 1998; Vokurka and Fliedner, 1998; Meredith and Francis, 2000). For example, Vokurka and Fliedner (1998) suggest that the efforts to improve agility should be supported by continued efforts to improve quality, dependability and flexibility. They warn that companies which focus on promoting agility without consideration of the other
performance capabilities will likely fail. Similarly, in their agile reference model for small- and medium-sized enterprises, Meredith and Francis (2000) establish the 16 interdependent components such as flexible assets and systems, fast new product acquisition, rapid problem-solving, rich information systems, deep customer insight, allied suppliers, performing partnerships, multi-skilled people, and continuous learning. They insist that if any of the 16 components is under-developed then the company’s agile capability is weakened. Companies may pursue various combinations of strategic initiatives/practices toward the attainment of agility.

However, 'just as army generals have realised that wars are won through superior competence in the chaos of battles, not in the elegance of their plans' (Meredith and Francis, 2000), no matter how sophisticated the strategy is, its imposition can not guide the success of a company in increasingly changeable markets. Even though many companies share the idea of a need for agility, they have not yet found a way to actually make the transition (Van Hoek, 2000a). The implementation of agility is highly context dependent in that different companies in different industries will experience different sets of changes and different levels of pressures resulting from the changes. They have to respond by considering strategic capabilities, which suit them and correlate to their specific circumstances. Therefore, a company looking to agility may first need to identify their agility need levels, which can be classified into four categories (Zhang and Sharifi, 2000): (i) The company does not need to be agile; (ii) The company is agile enough to respond to changes it might face in the future; (iii) The company needs to take actions to become agile but not as an urgent agenda; and (iv) The company needs to be agile strongly and urgently. Then the question is how a company could identify the necessary tools and techniques and acquire the relevant capabilities and abilities to become agile. Agility capabilities may be sought from four major areas, i.e. organisation, people, technology, and innovation (Zhang and Sharifi, 2000). Among those, postponement is increasingly raised as an effective way in meeting the requirement of the growing product variety and quick response to customers' needs (Lee et al., 1993; Battezzati and Magnani, 2000) and has been considered as an important approach for contributing to the attainment of agility (e.g. Fiedner and Vokurka, 1997; Van Hoek, 2000a). With a high
degree of conformance to the customers' ultimate requirements, postponement can contribute to agile capabilities, e.g. through its contribution to: (1) The customisation of products and services; (2) The use of customer order information through the supply chain; and (3) The cross functional efforts (Van Hoek, 1997). Some researchers even state that postponement, together with rapid response and forecasting capacity, is a vital element in any agile strategy (e.g. Van Hoek, 1997; Gunasekaran, 1998; Christopher, 2000).

E-business

The potential afforded by e-business is felt to be wide-reaching, for example in new cyber retailer Amazon.com and business-to-business online procurement network General Electric Global eXchange Services, and thus there are opportunities to re-engineer existing supply chains or design new supply chains using postponement strategies (Lee and Whang, 2001; Yang and Burns, 2003). E-business may offer a company the ability to more efficiently capture and move information as well as making it available more widely among supply chain partners. However, certain supply chain areas such as physical flow of goods are hardly benefiting directly from e-business. For example, there is still a need for companies to keep surplus finished inventory to meet any unanticipated online demand. Agrawal and Pak (2001) also note that although business-to-business electronic marketplaces can help companies realise certain purchasing and transaction-processing benefits in the short term, broader improvements (particularly reductions in inventory and faster time to market) are harder to achieve. In recent years, the collapse of many dot.com companies might suggest that, while more and more companies may easily afford and use the information and communication technology, the technology alone will no longer be a competitive differentiator. In the end, real-time information flow further requires a heightened awareness of the importance of timely and cost-effective delivery of individual orders (Lee and Whang, 2001). One lesson is from the 1999 Christmas season in USA (Anonymous, 2000) when many online orders were not shipped in time for Christmas. It has now been a big challenge for e-business companies to match material flow to information flow. To address this, recent literature points out that e-business companies are a big user of postponement (Richardson, 2000; Twede et al., 2000).
Typically finalised products are stocked at a central location or at a small number of strategically located sites and directly distributed on demand (Twede et al., 2000; Lee and Whang, 2001).

2.1.2 Leagile Supply Chain
The lean and agile paradigms, though distinctly different, can be and have been combined within successfully designed and operated total supply chains. Combining agility and leanness in one supply chain has been termed 'leagility'. In the leagile supply chain paradigm (see figure 2.1), lean and agile are combined within a total supply chain strategy by positioning the de-coupling point to best suit the need for responding to a volatile demand downstream yet providing level scheduling upstream from the de-coupling point (Naylor et al. 1999). Adopting such an approach will ensure that customer service levels are improved whilst lead times and costs are greatly reduced. To introduce this concept, the following definitions of agility and leanness were developed to emphasise their distinguishing features (Naylor et al., 1999):

- Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place.
- Leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule.

![Decoupling Point Diagram](image)

**Figure 2.1 Leagile Supply Chain**

Another assumption for leagility might be that agility and leanness cannot be employed at the same point. Obviously, leagility hinges heavily on the identification of the decoupling point. The positioning of the decoupling point must be strategic in order to establish the required lead times. This, in turn, is a manifestation of the role of postponement which may move the decoupling point closer to the end user increasing the efficiency and effectiveness of the supply chain (Naylor et al., 1999). However, since it
is possible that there are several postponement points existing simultaneously in the same
supply chain, there is enough room for lean thinking between different postponement
points if an enterprise can reconfigure its structure quickly enough. So the question is: is
it too simple only to use one point to separate lean from agile? I will further discuss the
leagile strategy from a postponement perspective in Subsection 3.2.4.

2.1.3 Glocalisation
The longer and wider the supply chain, the greater the potential benefits of postponement
(Twede et al., 2000; Richardson, 2000). Postponement is increasingly explored in the
practice of international business (Twede et al., 2000). Here I explore the role of
postponement in a global strategy by investigating the relationship between the
implementation of postponement and glocalisation (the simultaneous implementation of
globalisation and localisation).

Companies are now facing increasing globalisation, competitive intensity and market-
turbulence. They are increasingly spread across international markets in an atmosphere
of interdependency and specification. In terms of economies of scale, if products could
be sold worldwide, fixed costs of design, tooling, and equipment could be amortised. The
world-wide market also attracts companies to seek out labour markets to reduce cost and
build new markets to enhance profits. Through a strong centralisation of assets at a
global level, companies are able to achieve a mass scale in production of a standard or
base component or partly finished product, ensuring efficiency and cost leadership.
However, while markets are more and more global, there are still significant local
differences in customer requirements such as different tastes, languages and technological
specifications (Christopher, 1992). Local responsiveness requires local establishments to
be more autonomous and flexible in order to effectively respond to local demands,
probably less in the direction of corporate strategy. Developed knowledge also has to be
modified to suit local markets. That is, companies have to compete on multiple
dimensions of international strategy, resulting in simultaneous targets for local
responsiveness, global efficiency and worldwide learning (Bartlett and Ghoshal, 1989).
As a result, a careful balance between globalisation and localisation must be achieved.
Postponement is closely related to a global strategy, particularly relevant in global markets where local forecasts will be less accurate than a forecast for the worldwide volume. The split of functions on a global basis is reflected through delaying product finalisation as close to the market as possible, centralisation of production, decentralisation of distribution combined with reduction of the number of distribution points, increased outsourcing, etc. In line with the principle of glocalisation, the ideal application of postponement is to manufacture a standard or base product in sufficient quantities (based on forecast) to realise economy of scale while delaying finalisation of features until customer commitments are received. For example, in postponed manufacturing systems customisation of products can be separated from the primary processing or manufacturing of base materials. The separation enables basic processing to focus on large economic runs of standard products or base materials (the centralisation of production at a continental or international level), while finalisation of features may be positioned downstream to the distribution channel (more localised in multiple market areas) and delayed until customer commitments are received (Feitzinger and Lee, 1997; Van Hoek, 1999).

Companies at different starting points, like the existing industry structure and initial conditional capabilities, may choose different paths to their global strategies. For example, one company may target at global efficiency in the mass production of generic components, while the other may aim at downstream localisation (customisation) in response to customer orders. Accordingly, there exist different postponement strategies toward globalisation. Table 2.1 identifies a set of operational characteristics (the type of final manufacturing operations, and the type of product and market) as criteria for assessing the viability of different types of postponement in products with a global brand (Cooper, 1993; Van Hoek, 1997; Pagh and Cooper, 1998).
Final Manufacturing Structures | Characteristics | Postponement Strategies
--- | --- | ---
Unicentric manufacturing | Integrated manufacturing in a global manufacturing plant, distribution to order, for global brands with standard formulation and peripherals, for example CPUs. | Time postponement
Bundled manufacturing | Forecast-driven final manufacturing in a continental plant, for products with a global brand, standard peripherals and different formulation, for example TVs | Manufacturing postponement (postponed assembly and other manufacturing activities)
Deferred assembly | Order-driven final manufacturing or processing in the international distribution channel, for products with a global brand and different formulation and peripherals | Manufacturing postponement (postponed assembly)
Deferred packaging | Packaging and configuring shipments in a local warehouse, for products with a global brand, standard formulation and different peripherals. | Manufacturing postponement (postponed labeling /packaging)

Table 2.1 Postponement Strategies in Different Final Manufacturing Structures (adapted from Van Hoek, 1997)

2.2 POSTPONEMENT IN LOGISTICS, MANUFACTURING AND SUPPLY CHAIN

In recent times, postponement has received more and more attention in both research and practice. However, this does not mean postponement is a new concept or just a theoretical concept. In fact it was introduced in the literature in 1950 (Alderson, 1950) and its application can also be dated to the 1920s (CLM, 1995). This chapter reviews various perspectives on postponement in the literature in order to understand the current state of its research and its applications within industries. More specifically, I hope to find multiple insights into various factors for the implementation of postponement.
Postponement can change the differentiation of goods (form, identity and inventory location) to as late a time as possible and thus could be used to promote the efficiency of a marketing system, since every differentiation makes a product more suitable for a specified segment of the market and less suitable for other segments. Alderson (1957) stated that postponement can achieve savings both in costs related to uncertainty and in the physical movement of the goods. However, he did not consider the other impacts of postponement, for example, without effective supply chain management, the use of postponement might cause less certainty of delivery time. Alderson's concept of postponement was visionary for its time since long lead times in production and distribution made it difficult to rely on postponement. With the development of technology, especially information technology, transportation technology and manufacturing technology, postponement is increasingly appealing and available (Van Hoek et al., 1998). The application of postponement has gradually extended to the whole supply chain. Postponement has now become a marketing, manufacturing, logistics and supply chain concept. Not surprisingly, sometimes it is under the different labels like late customisation/configuration, delayed customisation/configuration and delayed product differentiation in the literature. Nevertheless, the logic remains the same.

2.2.1 Logistics
Logistics is a pivotal area in postponement research (Van Hoek, 2001). Postponement in logistics enables a company to keep its options open where inventory should be finally deployed, thus greatly reducing the risk of wrong time and place utility of products (Bowersox et al., 1993). The benefits of postponement also include reducing inventory levels across the supply chain while improving customer responsiveness. In fact, logistics costs, including inventory, transportation, warehousing, and the like, can make up 10 percent or more of putting a product in a customer's hand (Davis and Sasser, 1995). Reducing logistics costs is often the central goal of companies implementing postponement. In one of the early successful application of postponement, Hewlett Packard realised over $3 million/month in logistics savings from their DeskJet printers (Twede et al., 2000).
Postponement was originally applied in the distribution channel, involving the delay of the forward movement of inventories (Bucklin, 1965). Bucklin (1965) views postponement as a means by which a supplier may shift risk to the buyer and he extends it to the postponement-speculation principle. He focuses on where and by which player in the distribution channel inventory should be positioned. Bowersox (1978) points out that knowing the exact level and location of the demand prior to product shipment offers the potential to reduce distribution cost. In Zinn and Bowersox's (1988) category of time postponement, it is suggested to maintain anticipatory inventory at one or a few strategic locations. In recent literature, postponement further calls for stocking differentiated products at the strategically central location to achieve a balance between inventory cost and responsiveness (Bowersox and Closs, 1996). In the distribution channel, postponement is also involved in the repositioning of manufacturing activities, not limited to the relocation of inventories. This thinking is not surprising when it is considered that the success of postponement strategies, in part, depends on where in the process generic products should take on the form of specific end products. Postponement may relocate final configuration from manufacturer plants closer to the end-use customer, allowing for rapid delivery of customised products and quick responsiveness to changes in display mixes. For example, packaging/labelling (as one of the variables in differentiating generic goods for different brands and geographic markets) may be delayed until customer commitments are received and be better carried out by local based distributors before distribution and delivery to the customer. Based on the type of manufacturing operations postponed, Zinn and Bowersox (1988) define four types of postponement (labelling, packaging, assembly and manufacturing) and provide insight on how they can be applied to improve the productivity of the physical distribution system. According to their analysis, the implementation of postponement results in lowered inventory carrying costs, lower costs of lost sales, lowered transportation costs and increased processing costs. In addition, local based distributors have a real advantage in offering the flexibility to fit the changes in the local market, since they are already closer to the market. This is reflective of Ferdows's (1997) view that a plant (or distribution centre) located near important customers may be selected for customisation to contribute to local responsiveness.
Another issue is related to Bucklin's (1965) hypothesis that high value and lower volume/weight products are more likely positioned in a segment with a higher level of postponement. Taking this into consideration, it is viable to delay a product's variety, volume and weight increases through the implementation of postponement to save on transportation, inventory assorting and storage costs (Zinn and Bowersox, 1988; Van Hoek, 1997). The implementation of postponement is also affected by the factor of value profile. Operating structures of high value products are expected to include more postponement to save on inventory/interest expenses and obsolescence risks (Zinn and Bowersox, 1988; Pagh and Cooper, 1998). In building nuclear reactors, for example, the purchasing of the critical components has to be postponed because they have exacting specifications that result in very high costs, which makes them too expensive to hold as inventory (Waller et al., 2000). In a case study in the wine industry, Van Hoek (1997) concludes that the value of the products makes inventory in progress an important concern, offsetting the advantage of lower levels of postponement under a deferred bottling structure through diseconomies of scale from decentralised inventory keeping. Yang and Burns (2001) argue that, not only the nature of product flow, but also the structure of the routing influences the extent to which postponement should be explored. Billington and Amaral (1999) also state that postponement is valuable when capacity is unresponsive (supplier lead times are long, production scheduling is inflexible, or manufacturing volumes are constrained).

In many cases, postponement in logistics requires a fast and responsive transportation system and it can thus lead to a significant increase in transport cost (Christopher, 1998). Its applications are also constrained by time windows specified by the market. However, it is substantially applicable in all situations and sectors (Twede et al., 2000; Battezzati and Magnani, 2000). Its maximum benefits are obtainable when the distribution is not only physical transportation but also contains a product customisation component (Battezzati and Magnani, 2000). There is evidence that postponed configuration and shipment, achieved largely through logistics is the most prominent application of postponement at the present time (Van Hoek, 1998a).
2.2.2 Manufacturing

The concept of postponement, as applied to manufacturing, retains the product in a neutral and non-committed status as long as possible in the manufacturing process, usually resulting in redesigning the products and/or the processes. Since manufacturing postponement allows companies to operate with no finished inventory, companies may benefit from maintaining the bulk of their inventories in the cheaper and/or pre-customised form (in anticipation of an order) by delaying expensive operations and point of product differentiation. It also decreases the costs of complexity by reducing the variety of components and processes within the system (Garg and Tang, 1997). The inventory is generic, and because of this its flexibility is greater and the same components, modules or platforms can be embodied in a variety of end products. Thus, postponement is one of the most beneficial strategic mechanisms to manage the risks associated with product variety and uncertain sales (Aviv and Federgruen, 2001). In the international business, manufacturing postponement may also be relevant in those countries where the tariffs and taxes incurred on finished products are higher than for semi-finished products.

The key to postponement in manufacturing is to decouple the process to at least two subprocesses, separated in time and place (Feitzinger and Lee, 1997; Van Hoek, 1998a). Bucklin (1965) also hypothesises a role for the operating characteristics of lead time requirement. Van Hoek (1997) further states that very short lead times may make manufacturing postponement impossible, because of cycle time restrictions. The complexity of delayed manufacturing activities, like special knowledge and high technological contents, is another relevant operational characteristic for the implementation of postponement (Van Hoek, 1998b; Twede et al., 2000) in that it might not allow manufacturing postponement without diseconomies of scale or quality. Lee and Tang (1997) formalise three basic approaches to implement postponement: standardisation of components, modular design and re-sequencing of operations. Standard design is about using common components and processes and may invoke re-engineering changes to substitute a group of given parts or subassemblies by common
ones. Zinn (1990a) also points out the role of the commonality of modules in the viability of postponement. Due to the risk-pooling effect from demands of different end products, the commonality results in lower safety stocks of common components, in comparison to storing all different types of finished goods at sufficient levels to ensure accuracy in delivery (Van Hoek, 1998a). Leveraging commonality in parts may further enable purchasing postponement (see Subsection 3.1.2). Following this strategy, Dell do not buy monitors for its PCs until a customer order has been placed. In fact, monitors do not have to be shipped first to Dell. Instead, United Parcel Service (UPS) gets an e-mail from Dell and pulls a monitor direct from supplier stocks and coordinates it to reach the customer along with the PC. It is estimated that this postponement strategy saves freight costs of $30 per display unit (McWilliams, 1997). However, the use of standardised components may increase the cost of materials (Feitzinger and Lee, 1997). Further, introducing too much commonality, like part standardisation which is easily perceived by the customer, can reduce product differentiation leading to a cannibalisation effect (Swaminathan, 2001). In general, one wants to commonise/standardise features that have long lead times early and differentiate late those that have short lead times closer to the customer. Recent years have seen that short lead-time customisable features are postponed in the clothing industry such as printing logos with T-shirts. Modularity means building a complex product or process from smaller subsystems that can be designed independently yet function together as a whole (Baldwin and Clark, 1997). A fully modular architecture means that a change made to one component does not require a change to other components (Ulrich, 1995). A high degree of product modularity coupled with component-process flexibility could render postponement possible and effective (Ulrich, 1995). Van Hoek (1997) further concludes that without modular product design, final manufacturing is not possible in postponement applications without huge cost penalties. Apparently, the production process must allow for a flow of discrete steps in order for postponement to take place. In this regard, a prerequisite to manufacturing postponement is modularity in production (decoupling the process in at least two sub-processes, separated in time and/or place) (Feitzinger and Lee, 1997; Van Hoek, 1998a). Lee (1998) states that both product and process modularity support postponement. Furthermore, modular design might enable production of the modules to be carried out concurrently
and then significantly reduce production cycle time (Feitzinger and Lee, 1997). In addition, postponement can be achieved by re-sequencing processes each of which is associated with a separate attribute. For example, in the case of Bennetton, they applied postponement by re-sequencing knitting and dyeing. Using mathematical modes, Lee and Tang (1998) characterise the impact of re-sequencing two consecutive stages of the process. Yang and Burns (2001) also examine the relationship between postponement through re-sequencing sub-processes and the location of the customer order de-coupling point (CODP).

A supplier network that can supply parts and services is a critical success factor for postponement applications (Feitzinger and Lee, 1997). In the postponed manufacturing operation, semi-finished products and parts can be sourced from all over the world in anticipation of customised final manufacturing. The application of postponed manufacturing also facilitates outsourcing to third parties (Van Hoek, 1999; Feare, 2001; also see Subsection 3.2.3, p. 63-64). In doing so, companies can concentrate on their core competencies where they are able to expand a competitive advantage and outsource other operations (e.g. logistic, manufacturing and transport services) to capitalise on others’ expertise. Many third-party providers are now capable of performing operations like light manufacturing and final assembly at a very competitive price and quality (Pagh and Cooper, 1998). Outsourcing final manufacturing operations is a logical extension of the relationship with service offering those operations. However, Van Hoek (2000b) states that third parties are involved in relatively simple postponed customising activities such as packaging but far less in final assembly and related activities. For manufacturers, outsourcing postponed manufacturing can result in a loss of contact with the final customer, cutting off a channel of market signals of use in the manufacturer’s future product development and marketing (Van Hoek and Van Dierdonck, 2000). Production control, quality control and the need to maintain secrecy are all reasons to keep postponement in-house. Since postponement timing can be a competitive advantage, some companies also want to keep it under their own control (Twede et al., 2000).
Postponement requires making an intensive amount of coordination regarding structural, infra-structural and inter-functional elements in manufacturing and high levels of collaboration among supply chain partners (Lee, 1998). To take advantage of postponement, companies must be able to exchange information frequently and reliably with customers and partners. Even shippers must share more market and customer information with the carrier than they have in the past. The coordination also takes place between customer services in multiple markets. For example, if sales in one region were down somewhat, then semi-finished products could be routed to another region where sales might exceed normal expectations.

Postponement in manufacturing can be successfully applied when it is vital to have inventories close to the customer destination market, and to the extent that no specialised manufacturing capabilities or highly restrictive economies of scale is required (Bowersox and Closs, 1996). Its application is a logical extension of initially implementing logistics postponement (Battezzati and Magnani, 2000; Van Hoek and Van Dierdonck, 2000). Using survey data from U.S. manufacturing companies, Rabinovich and Evers (2003) also suggest that the implementation of logistics postponement supports the adoption of manufacturing postponement. In the meantime, competition in the global business environment has forced companies to recognise that efficiencies in logistics have now become as important to strategic planning as improvements in manufacturing and marketing (Ernst and Kamrad, 2000). Accordingly, postponement strategies are moving towards integrating both logistics and manufacturing activities (Pagh and Cooper, 1998). Van Hoek (1997) also notes that the integration of manufacturing postponement into logistics postponement has been coming to the forefront as an innovative supply chain arrangement in a multitude of industries.

2.2.3 Supply Chain

Over time, the scope of postponement consideration expanded from marketing to the whole supply chain, including purchasing, manufacturing, order processing, inventory management, warehousing and distribution. For example, in new product development, a design company was asked to develop a single integrated circuit. During the design
process, the micro-processor, which is crucial to the design, was improved by the manufacturers so that it ran at a 50% higher clock rate. This change resulting from technology shift led to a complete redesign which eventually added 15% to total development time (Thomke and Reinertsen, 2000). In this case postponement should be considered not directly with regard to customer needs, but technology evolution during the design process. Rao (1997) also describes how IBM applied postponement in designing asynchronous transfer mode (ATM) networking switches regarding the uncertainty about standards and protocols, as the industry had not yet fully developed standards and protocols at that moment. Thus, companies should first consider every postponability along the supply chain and then balance the trade-off not from an individual player, but the whole supply chain. Accordingly, a perspective spanning the length of the supply chain should be applied in studying postponement (Van Hoek, 1999). Employing postponement and combining it with a holistic view has enabled some companies to improve the performance of the supply chain (Pagh and Cooper, 1998).

The viability of postponement is determined by the structure of the supply chain characteristics (Battezzati and Magnani, 2000). On the other hand, postponement fosters a new way of thinking about the supply chain design. The application of postponement often leads to the reconfiguration of the supply chain (Van Hoek, 1998b) and postponement has been identified as an important characteristic of modern and competitive supply chains (Van Hoek, 1999). I summarise a literature review of postponement in the supply chain in table 2.2. Postponement was visionary when it was originally introduced to reduce the risk and uncertainty costs tied to the differentiation (form, place and time) of goods in the marketing literature (Alderson, 1950). Bucklin (1965) extends it to the speculation-postponement strategy applied to the distribution channel, mainly questioning where, when and who to hold inventory in order to reduce the cost and risk. He states that postponement needs to be combined with speculation, since long lead times in production and distribution have made it difficult to rely on postponement. Speculation holds that changes in form and the movement of goods should
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<th>Author(s)</th>
<th>Focus Area</th>
<th>Description of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alderson (1950)</td>
<td>Marketing channel</td>
<td>Original introduction of the concept of postponement.</td>
</tr>
<tr>
<td>Bucklin (1965)</td>
<td>Distribution channel</td>
<td>Further conceptual development from postponement to speculation-postponement strategy.</td>
</tr>
<tr>
<td>Shapiro (1984)</td>
<td>Logistics pipeline</td>
<td>Integration of speculation-postponement to different breadth of product lines.</td>
</tr>
<tr>
<td>Christopher (1992)</td>
<td>Supply chain</td>
<td>The role of postponement on the configuration of the global supply chain.</td>
</tr>
<tr>
<td>Naylor et al. (1999)</td>
<td>(Leagile) Supply chain</td>
<td>Use of postponement to move the decoupling point closer to the end user and increase the efficiency and the effectiveness of the supply chain.</td>
</tr>
<tr>
<td>Ernst and Kamrad (2000)</td>
<td>Supply chain</td>
<td>Conceptual framework to evaluate different supply chain structures based on the different degrees of modularisation and postponement</td>
</tr>
</tbody>
</table>

Table 2.2 Review of Literature on Postponement in the Supply Chain

be made at the earliest time. Speculation basically facilitates capturing of scale economies, but it may lead to substantial inventories. Shapiro (1984) further studies this strategy in the context of where in the logistics pipeline inventory is to be carried. Building on the different degrees of postponement and speculation integrated to different breadth of product lines, four generic modes of operation are proposed: full service, full line/long lead time, narrow line/short lead time and low cost. The supply chain can also be constructed by the different combination of postponement and speculation, which is often designed and managed autonomously (Pagh and Cooper, 1998). Speculation relies on forecasts of coming demand and therefore might be seen as a push-approach, while postponement enables the customers' needs or requirements to affect product design and production process and thus might be described as a pull-approach (Shapiro, 1984).

Traditionally, speculation has dominated the supply chain. With more changeable market demands and the development of technology (e.g. new production and information technology), postponement is increasingly appealing and available. It can thus be expected that postponement will play an increasing role in the supply chain. Pagh and Cooper (1998) focus on the downstream part of the supply chain (from factory level to end customer) and propose four generic supply chain speculation-postponement strategies.
through different combinations of manufacturing/logistics and postponement/speculation (see figure 2.2). In another related paper, Ernst and Kamrad (2000) introduce a conceptual framework to evaluate different supply chain structures (rigid, modularised, postponed and flexible) based on the different degrees of modularisation and postponement. They simplify the supply chain into three steps: manufacturing, assembling and packaging, and associate manufacturing with modularisation and packaging with postponement.

<table>
<thead>
<tr>
<th>Logistics</th>
<th>Postponement</th>
<th>Speculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make to inventory</td>
<td>Decentralized inventories</td>
<td>Centralized inventories and direct distribution</td>
</tr>
<tr>
<td>Make to order</td>
<td>The full speculation strategy</td>
<td>The logistics postponement strategy</td>
</tr>
<tr>
<td>Make to order</td>
<td>The manufacturing postponement strategy</td>
<td>The full postponement strategy</td>
</tr>
</tbody>
</table>

**Figure 2.2 Four Supply Chain Postponement-speculation Strategies (Source: Page and Cooper, 1998)**

Taking the above points further, the different degree of combining speculation and postponement can be connected to a continuum of customisation and standardisation (Lampel and Mintzberg, 1996). In figure 2.3, I summarise this relationship, with six stages in the supply chain (Hoekstra and Romme, 1992; Van Hoek, 1997) and different postponement strategies mainly in terms of postponed activities. In mass customisation, customisation begins downstream in the supply chain depending on the need for customisation, while standardisation begins upstream in anticipation of future customer orders (Lampel and Mintzberg, 1996). The dotted line in figure 2.3 divides not only speculation and postponement activities, but also standardisation and customisation activities. It also reflects how postponement is associated with the customer de-coupling point (CODP) (Van Hoek, 1997). It should be noted that figure 2.3 mainly focuses on the
spatial/functional dimension of the supply chain. In the international supply chain, the related proposition is that postponement can contribute to 'glocalisation' through globalising/centralising upstream activities to alleviate high production costs and localising/de-centralising downstream activities to alleviate market mismatch costs and reduce lead times (see Subsection 2.1.3).

According to market needs, a company can determine optimal postponement by examining the associated costs within various supply chain configurations. To select an appropriate postponement strategy, companies may also need to take into account different phases of the product life cycle. Bowersox et al. (1999a) investigate the role of postponement in the new product launch (the introduction stage), and conclude that postponement enables better management of inventory levels, and improves replenishment times and in-stock availability of products. Postponement can also reduce launch inventory exposure to cut losses in product launch failure. Twede et al. (2000) state that postponement may be best during the growth stage in the product life cycle.
They also notice that currently HP (as an early successful adopter of postponement) mainly applies postponement strategies for new products during the growth stage of the product life cycle. However, considering the downstream part of the supply chain (from factory level to end customer), Pagh and Cooper (1998) propose that starting from the full speculation strategy will be more appropriate in the introduction and growth stages, while starting from the full postponement strategy will be more appropriate in the maturation and decline stages. I argue intuitively that postponement might not always be relevant during the decline stage. For example, companies may make a downward substitution offer (providing the customer with one of the available models that has a superset of features required by the customer) (Swaminathan, 2001). In this way, companies may reduce the negative impact of customisation related to product proliferation both in terms of reducing costs for managing existing products (e.g. inventory reductions) and the number of product design changes over the life cycle. Therefore, it may be worth further investigating the issues around postponement in different product life cycles. Further, if a company has a distinct supply chain management capability, then it can coordinate appropriate changes in postponement with various members of the chain (Waller et al., 2000). Also, different postponement strategies may be simultaneously explored when a company is a member of several supply chains and manages several product groups (Pagh and Cooper, 1998).

2.2.4 Summary
In this section, I summarise the results from the literature review, and describe the opportunities and challenges in postponement research. The literature has generated multiple insights into various factors for the implementation of postponement, which was originally undertaken by Alderson (1950). There are particular conditions where the adoption / implementation of postponement is more likely to be successful.

*Market characteristics*

1) High sales fluctuations. This may mean unpredictability about product specifications and product volumes, such as unpredictable weather effects on demand for ski equipment.
2) Short product life cycles. This may be further compounded by the fragmentation of market and distribution channels, and short and reliable lead-times requirements. In some situation, product life cycles are even shorter than the production cycle. For example, Benetton would not be able to run its full regular production cycle after finding out which sweater colours will be sold best in the season. Time postponement and packaging/labelling postponement might be applied in more fragmented distribution channels, in order to improve targeting, segmentation, and positioning of products and sales.

3) Product differentiation. This is associated with distinct customer segments that require the company to provide a product line in which the products have different performance characteristics (e.g. different performance, technological or legal requirements on the same product in different countries).

**Product characteristics**

1) Customisation. Too often, it is difficult to forecast demand on highly customised end products on a product basis. It is also usually difficult to find alternative uses for them (resulting in high cost of obsolescence). Therefore, it makes sense to defer those operations, which are associated with the most significant impact on customisation of the product (point of product differentiation), for the products in the product line.

2) Commonality/modularity. Component commonality results in inventory pooling effects (e.g. lower inventory levels and reduced risk of obsolete inventories) and shared production process steps. The component commonality can be taken one step further in the modularity concept, where the composite of products in a limited set of generic modules or base materials to be combined into a wide variety of finished products.
Production process characteristics

1) Decouplability of production process. Postponement is dependent on the possibility of decoupling the process into at least two discrete sub-processes, separate in time and/or place (Feitzinger and Lee, 1997). For example, the viability of postponement is limited in such industries as chemical and other processing industries, where many processes do not allow for the decoupling of production processes into a primary and a secondary phase. This also raises the issue of modularity further towards the implementation of postponement.

2) Weight/Volume/Value increase. It makes economic sense to postpone a significantly high weight/volume/value added step (or a particular component) in the production process. For example, postponement would be preferable in products with high value density in that they have high pipeline expenses (e.g. inventory storage costs) and high cost of obsolescence. Further, if this postponed activity is also related to final configuration, it will avoid the risk of performing it for products that will never be sold.

3) The complexity of customising operations. Postponement might lead to an increase in lead time and limited loss of economies of scale in productions. Therefore, the complexity of technology and the scope of the postponed activities are limited to relatively easy to perform (e.g. not labour intensive or time consuming). For example, a high technological content of final manufacturing might not allow for postponement without diseconomies of scale or quality risks. In addition, short lead times may influence the scope of postponement opportunities (e.g. in final manufacturing operations because of additional cycle times of final processing).

Since to what degree and to what extension postponement can be applied are related to specific market, product and production process characteristics, companies at different starting points require different postponement strategies. Differences in the internal
organisation and the external demands for product specificity require different postponement strategies. Unfortunately, some key questions have yet to be answered, e.g. how can the appropriate type/level of postponement be determined for a specific product, like customised design, fabrication, or assembly? There could be a limit to which type of postponement should be applied in a specific situation. However, existent postponement strategies are mainly concerned with the narrow scope of manufacturing and logistics while postponement has gradually been applied throughout the whole supply chain. This is in part reflected by the fact that most authors cite the seminal work by Bucklin (1965), while more recent publications are referenced less often. Therefore, there is a need for a further conceptual development of postponement. For example, I may need to develop postponement strategies appropriate for new product development, where postponement might enable designers to incorporate the most current technological advances and user needs as these co-evolve with the development process. What is more, because most of the study was based on case studies from different industries, it is still unclear which elements are the generic postponement enablers. There is little effort to present a comprehensive analysis of postponement, both from a strategic perspective and enablers points of view in order to motivate the practitioners.

In recent times, postponement has been used as a supply chain concept. This further emphasises that the implementation of postponement requires a supply chain wide perspective. On the logistics side, for instance, postponement usually shifts the risk of ownership of goods to the most appropriate player in the supply chain to minimise the overall channel costs. It requires a high level of trust among all players in the supply chain, which may mean there is a need to consider those issues related to social factors besides costs/benefits of postponement. For example, manufacturing postponement means a change from stocking finished products to stocking semi-finished products. This may create some nervousness among those staff who deal with customers’ orders (Brown et al. 2000). Little study has been carried out on it. Another trend in the research on the role of postponement in the supply chain seems only to hinge on the de-coupling point, as I demonstrated earlier in this chapter. However, there is still an open question how to position the decoupling point. The literature has identified the factors influencing the
location of the DP, but little attention has been directed to how these factors can be balanced. Further, the implications of postponement for the supply chain should be further clarified. For example, the implementation of manufacturing postponement may lead to repositioning final manufacturing downstream into the distribution/retailer centre (closer to the local markets) from a manufacturer. Since retail/distribution locations are typically not owned by the manufacturer, postponement might raise the issue of outsourcing, which may be also related to power and control of the supply chain. Outsourcing is basically the reallocation of tasks to another unit within an organisation or another organisation, normally separated by ownership. It is a decision about organisational architecture and about the drawing of the boundary of the company. It might result in lower utilisation of the manufacturer's own equipment. It is also possible to simply go for downsizing, resulting in internal organisation resistance, because of the effect that it has on labour, capabilities and power. At this point, the implementation of postponement may impact not only product and production designs.

In the literature, it has been concluded that the benefits of postponement include saving inventory assorting, carrying and holding costs, stock-out and obsolescence costs by delaying a product's variety, volume, weight and/or value increases. For example, by being able to postpone the production to the point when the demand is better known, the company can greatly improve its forecasting abilities and will run a lower risk of losing sales due to unavailability. Delaying expensive operations and point of product differentiation also enables the company to maintain the bulk of their inventories in the cheaper and/or pre-customised form. As a result, a company will achieve the benefits of a larger inventory buffer (pooling effect) without having to carry the full cost of it. Further, postponement enhances companies' flexibility to respond to changes in customer demands and thus can reconcile the needs of high variety and quick response (Lee et al., 1993). However, postponement is not viable for all products, processes and organisations. Such factors as product characteristics and organisational traditions may limit the feasibility of postponement. The results from some surveys indicate that an organisation's administrative heritage in managing the change process can be major bottlenecks. Negative effects are associated with the implementation of postponement as
well. For example, postponement can reduce the risks associated with differentiation while postponement reduces the possibility to capture similarities among activities. This means that the possibilities to capture economies of scale become circumscribed. Some other cost increases can be caused by the changes in product design, production and distribution processes with the consequent impact on the infrastructure and resources (including labour). For instance, HP printers for multiple voltage/frequency networks had higher unit cost than printers that were designed for one network only. This impact is sometimes not limited to the company implementing postponement, but affects the other players in the supply chain. Manufacturing postponement may require the distribution centre to take on additional responsibilities, having an impact on the knowledge and skills the employees will need to possess, like new skills to assemble the products. Therefore, companies need effective tools for assessing the feasibility of postponement before implementing it. In this regard, I suspect many postponement supporters' view that when viewed in the context of the whole supply chain, the operational cost implications of postponement may be less relevant. Instead, I think that part of the neglect of postponement applications may be due to the absence of effective tools for assessing the feasibility of postponement. Further research should establish analytical modes to try to quantify the costs and benefits of postponement.

2.3 RESEARCH QUESTION

A thorough literature review on various aspects of postponement was carried out. It provides a detailed understanding of the current state of postponement in terms of its research and its applications within industries. Based on this, here I try to develop the research idea and establish the basis for identifying the true nature and extent of the research.
In the literature, much is written to generate insights into the benefits of postponement and the relevance of various factors for the implementation of postponement from different perspectives. With increasingly demanding markets and the development of technology, postponement is increasingly appealing and available. It has been expected that postponement will be increasingly implemented. However, currently its applications are to a lesser extent than expected and still at an infancy stage (e.g. Van Hoek, 1997; Brown et al., 2000). This raises the question of what factors are responsible for successful postponement strategies. By answering this question, I hope to help companies in further applying the concept of postponement. However, it is obvious that the research topic would need to be narrowed at this stage, as the scope is still too broad to be investigated in the original form. The investigation needs to be narrowed to allow the work to be practically undertaken by a single researcher within the time allocation permitted for a PhD. Therefore, before further developing my research questions, I feel that I need to do some theoretical study on the following issues (in Chapter 3).

1) Conceptual development of postponement. The conceptual development will facilitate my future empirical study on postponement. Companies might have used some approaches like late configuration and late/delayed differentiation even without knowing the concept of postponement. I thus need to make sure that the appropriate terminology and relevant postponement activities (which companies may consciously and deliberately apply into their business, or they just happen to use such as food supermarkets labelling discount prices on food the day just before the best used date) will be included in my study. I also hope to develop postponement strategies to include product development and purchasing, not limited to manufacturing and logistics.

2) The implications of postponement for the supply chain. By investigating this issue, I hope to facilitate establishing my research questions. It has been well documented that postponement implementation requires a complete supply chain view. Postponement applications so far mainly involve downstream activities in the supply chain. Existing literature also appears to only emphasise the role of
postponement in the decoupling point in the supply chain. I will further investigate the implications of postponement not only for the decoupling point, but also for supply chain integration, control of the supply chain and capacity planning issues. The objective is also to extend the significance of postponement towards the perspective of a holistic supply chain context.

3) An integrated framework for prompting and progressing the implementation of postponement. Successful postponement applications lie in realigning company strategy, capabilities, processes, resources and infrastructure, in such a way that the customisation differentiation of a product is made as close to the point when the demand is known as possible. This may imply redesigning products, giving priority to commonality of part and modularity of manufacturing steps, i.e. embedding postponement in the product structure. This may mean the reconfiguration of assets and capabilities, e.g. investment in (re-)location of establishments closer to the customers. This may also require suppliers' reliability and timeliness and improvement in information flow (e.g. order taking). By developing the integrated framework, I hope to find the issues which might serve to further develop my research questions.
CHAPTER 3. THEORETICAL STUDY

Over time, the scope of postponement consideration has expanded from marketing to the whole supply chain, while existing postponement strategies in the literature are mainly concerned with the narrow scope of manufacturing and logistics. Therefore, this chapter first develops the concept of postponement to include product development postponement, purchasing postponement, production postponement and logistics postponement. Then, I rethink the supply chain from a postponement point of view. Implications of postponement are highlighted in relation to the decoupling point, supply chain integration, control of the supply chain and capacity planning issues. This is followed by an integrated framework for prompting and progressing the implementation of postponement. Finally, keeping my preliminary research question (see Section 2.3), I summarise my theoretical study and further develop my research questions and hypotheses.

3.1 CONCEPTUAL DEVELOPMENT OF POSTPONEMENT

Simply put, the concept of postponement is about delaying activities (e.g. as to the form and/or place of goods) until the latest possible point in time (e.g. when exact attributes of
demand can be identified). The logic behind postponement is that the delay leads to the availability of more information and thus the risk and uncertainty of those activities can be reduced or even eliminated. This concept was first proposed by Alderson (1950) from a marketing management perspective. Fifteen years later, Bucklin (1965) extended it to the distribution channel in the context of shifting risk. Since then, increased attention on postponement has been noted in the literature (e.g. Zinn and Bowersox, 1988; Feitzinger and Lee, 1997; Pagh and Cooper, 1998).

Over time, the scope of postponement consideration has expanded from marketing to logistics, manufacturing, purchasing, distribution and promotion processes. To extend the insight into where and when postponement is applied, a variety of postponement strategies have been proposed (as illustrated in table 3.1). Pull postponement is defined as moving the decoupling point upstream to configure to order (Lee, 1998). Most of the other postponement strategies are in line with Bowersox and Closs's (1996) category (see Chapter 2, p.11). As can be seen from table 3.1, existing postponement strategies are mainly concerned with the narrow scope of manufacturing and logistics while the term of upstream or downstream postponement (Waller et al., 2000) is too broad to be followed. Here I extend the concept of postponement to include product development postponement, purchasing postponement, production postponement and logistics postponement. I restrict the scope of the latter two postponement strategies by assuming that: (1) Production postponement differs from purchasing postponement in that the necessary raw materials and components have been purchased for initiating production in anticipation of orders; and (2) Logistics postponement applies only if there are finished products. The first assumption means that production postponement will not appreciably reduce the risk of obsolete inventory as much as purchasing postponement. This is because on the manufacturer side, components or base products produced or purchased based on forecast in production postponement are as likely to suffer from obsolescence as finished products (Chiou et al., 2002). The latter assumption eliminates the possible overlaps of logistics postponement (combination of time and place postponement) and other postponement strategies, e.g. the possible overlap of logistics postponement and manufacturing
postponement (since manufacturing/form postponement must take place either in place utility or time utility).

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Classification of Postponement Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinn and Bowersox (1988)</td>
<td>Form postponement (including manufacturing, assembly, packaging and labelling postponement and time postponement)</td>
</tr>
<tr>
<td>Bowersox and Closs (1996)</td>
<td>Logistics postponement (combination of time and place postponement and manufacturing/form postponement</td>
</tr>
<tr>
<td>Lee (1998)</td>
<td>Pull postponement, logistics postponement and form postponement</td>
</tr>
<tr>
<td>Wailer et al. (2000)</td>
<td>Production postponement, upstream postponement and downstream postponement</td>
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</tbody>
</table>

Table 3.1 A Literature Review of Classification of Postponement Strategies

3.1.1 Product development postponement

Faced with a high level of uncertainty where information becomes obsolete quickly, it is difficult to finalise specifications early and keep them frozen for the rest of the development process. For example, companies could lack the power to resist changes in design specifications because of changes in customer needs and the advent of new technology or regulatory standards (Kalyanaram and Krishnan, 1997; Thomke and Reinertsen, 2000). In a recent study in the computer industry by Rosas-Vega and Vokurka (2000), it has been found that changes in customers’ demands lead to 25 percent of the delays in new product introduction. For example, Microsoft delayed the launch of Windows 98 from the first quarter to the second quarter of next year, because customers and resellers wanted both upgrades (from Windows 3.1 and Windows 95) to be available simultaneously. Since early entry of new products has now become crucial to gain or sustain competitive advantage (e.g. Brown and Eisenhardt, 1995; Rosas-Vega and Vokurka, 2000), companies have to search for new ways for coping with uncertainty to step up the pace of new product introduction while enhancing the likelihood of new product success. Some companies like Sony even sacrifice their own market-leaders by introducing new models to prevent competitors from launching comparable products (Saisse and Wilding, 1997). In the literature of new product development (NPD) research, it has been established that such strategies as quality function deployment
(QFD), concurrent engineering, process management (usually associated with manufacturing processes), cross-functional teams and stage-gate approach, are strong correlates of NPD success (e.g. Takeuchi and Nonaka, 1986; Hauser and Clausing, 1988; Cooper, 1990). The latest technological development also enables new methods such as virtual prototypes, web-based voice-of-the-customer methods, web-based conjoint analysis, and automated and distributed service exchange systems to provide information to the product development team almost instantaneously and thus develop products faster and more profitably (Howe et al., 2000). However, in Mullins and Sutherland’s study (1998) in rapidly changing markets, it is concluded that the above tools share an inadequacy to deal with an uncertainty.

In NPD literature, some authors have focused on the concept of delaying commitment (e.g. Ward et al., 1995; Kalyanaram and Krishnan, 1997), similar to simply holding semi-finished products until the order has been placed in the manufacturing context. Not surprisingly, Kalyanaram and Krishnan (1997) comment ‘Although delaying commitment would have been undesirable in the past because of the potential delay in launch, we note that a firm can offset the delay by using established project management techniques such as crashing and concurrent development’. However, capabilities to deal with uncertainty increase with early enablers of postponement in NPD, not necessarily meaning an increase in lead times. In this regard, the convergence of postponement with NPD is much less understood and appreciated. In product development postponement, such information as customer requirements and the available technologies drives all the development process. This leads to a significant reduction in lead times with fewer costly redesigns, especially those resulting from major changes later in the development processes. At Toyota, the implementation of product development postponement looks at first sight to be ‘expensive, clumsy and inefficient’ but it does enable Toyota to design better cars faster and cheaper (Ward et al., 1995).

For postponement to work, companies first need to anticipate the areas in which the change will occur and leave adequate margin for these changes if they materialise (Thomke and Reinertsen, 2000). It is very difficult, if not impossible, to acquire
information about the future in the face of high uncertainty. However, even the most uncertain environments contain a lot of strategically relevant information (Courtney et al., 1997). Companies can make specification decisions which are more likely to remain stable. In the meanwhile, certain decisions are deferred until late in the development process when better information is available. For example, Toyota first manage to anticipate the extent of uncertainty and accordingly provide their suppliers (designers) with only the degree of constraint in which they are confident (avoiding future changes). Toyota delay the decision on critical dimensions about the vehicle until the last possible moment, ensuring that their suppliers have deeply and simultaneously explored broad regions of the design space. At the same time, throughout each stage, they continue compiling information on the environment, the market, technological developments expanding the known feasible region, and various constraint and trade-offs between alternatives. In the end, Toyota gradually narrow the set of possibilities, converging slowly toward a single solution (Ward et al., 1995). Product development postponement also calls for structuring design tasks. The product development process is typically partitioned into smaller tasks (e.g. concept development and concept implementation). Minimising interdependencies among sub-tasks can significantly prompt the application of postponement. With low interdependencies among sub-tasks, companies may segregate and delay those sub-tasks sensitive to changes inherent to uncertain environments. In designing a printer, for instance, design tasks may correspond to the paper size specification, printing speed specification and printing resolution specification individually. If there are no interdependences among those tasks, the development team could arrange design tasks according to the degree of uncertainty facing the corresponding specification. In this case, the development team might do the paper size design task first, as paper size is tightly constrained by industrial standards and its uncertainty is much less. Ideally product development postponement will take the most viable portion of functionality and move it outside the system boundary, e.g. personal customised interfaces implemented by the end user (via menus or record macro operations) in the software industry (Thomke and Reinertsen, 2000). This is also how Societe Micromecanique et Horlogere (SMH), Switzerland’s largest watchmaker, were able to introduce many versions of their watches rapidly in the 1980s to recover markets
lost earlier to Asian imports. They first developed a reliable quartz time-keeping core and then rolled out a continuing stream of attractive and unique watches under the Swatch label. All unique features of these fashionable timepieces were added at the end of the development and assembly process.

In extremely uncertain markets, companies may have to accept and acknowledge the uncertainty and find ways to quickly adapt to the need for product modifications, rather than trying to build the perfect product and then get it just right. Consider how IBM coped with uncertainty about consumer preference in their IBM personal computers. During the design of the PC, there were two viable design solutions for long-term storage: a cassette recorder and a floppy disk drive. Both technologies were accepted in the marketplace, and it was unclear if either would become dominant. Therefore, IBM’s PC offered both a cassette port and a floppy drive. As the market developed, consumers expressed a clear preference for the easier-to-use floppy disks and the cassette port was eliminated in IBM’s next product, the IBM PC-XT (Thomke and Reinertsen, 2000). However, time to market is now falling and the product life cycle is reducing. It is no longer the case that a business can create a product, sell it for a few years while it develops the next one and then launch that as a replacement. What is more, customers dislike having to choose from many options. Companies such as Toyota and Nissan have experienced a backlash in fast introduction of an array of products, as customers were confused by many choices (Pine II, 1993; Lau, 1995). In practice, some companies ‘make a little, sell a little’ to quickly get the product to market and then adapt the product as necessary as market penetration grows (Mullins and Sutherland, 1998). The idea is to make a product in a small way (instead of developing marketing campaigns or launching on a large scale) and get it in the hands of customers, and then attain feedback from real users. As such, companies can modify the new product idea early in their product development to better meet customers’ needs. However, such a postponement strategy may need a small facility to be built in order for employees and customers to come in and use prototypes of proposed new products still in their infancy (Mullins and Sutherland, 1998). Furthermore, this approach takes on the risk of rushing a new product to market without due diligence.
3.1.2 Purchasing postponement
At a high level of uncertainty, companies cannot forecast the aggregate demands of their products. Early purchasing under this condition might lead to ownership of assets that become obsolete quickly. A better choice would be to minimise component and raw material inventories by purchasing components as close to the point of manufacture as possible. Purchase can be postponed until actual usage in production, leading to raw materials and components, instead of finished products, spending more time in the supply chain and thus much lower total inventory costs. More importantly, the benefits of purchasing postponement result because raw materials generally have a lower obsolescence cost than finished goods as they tend to have a wider range of potential applications (Clarke, 1998). Purchasing postponement is likely for raw materials and components which are expensive and fragile and come in many different sizes and shapes. According to a recent study by Hersch (1998), purchasing postponement not only enables Dell Computer to save their costs in inventory and obsolescence, but also enables them to realise lower costs for parts due to their reduced exposure to declining components prices.

Purchasing postponement can also be selectively applied to a product range, as a company does not have to treat all items in a similar manner. It especially holds true under the situation where companies can separate demand patterns into ‘base’ and ‘surge’ elements (Gattorna and Walters, 1996). Base demands can be produced in advance based on long-term forecasts while decisions on product quantities for surge demands (with a higher level of uncertainty) have to be delayed until further information on market demand is available. Therefore, for surge demands, manufacturers can wait to order raw materials from suppliers until they receive customer orders. Such a strategy is increasingly being employed in the fashion industry. For example, in the classical postponement example in Benetton (Benetton, 1985), 90% of its sales are of standardised items with a seven month advance committed order while the remaining demand pattern of 10% is unpredictable and hence is postponed to manufacture just five weeks before delivery. This offers the company strategic and operational flexibility. Quite often, the
above different arrangements for dealing with base and surge demands lead to a hybrid strategy using lean supply chain and agile supply chain at the same time (Christopher and Towill, 2001), or using mass production and mass customisation simultaneously such as National Bicycle Industry Company in Japan (Kotha, 1995). It should be noted that surge demand might be provided through higher cost processes compared to level demand, in order to maintain the lead time. In the case of Benetton, they subcontract the base part of a product's demand to low-cost sources that have long lead times while they produce the surge part of the demand in their own flexible facilities which are 10% more expensive but have shorter lead times. To achieve a timely and reliable delivery of raw materials and components, some companies like Toyota and Honda also choose suppliers which are close and geographically concentrated (Turnbull et al., 1992), often leading to the creation of supplier parks adjacent to their factories. In the case of SmartCar, the use of postponement leads the suppliers to take over part of the assembly factory, where they supply components directly into the final assembly line from their workshop adjacent to the factory (Van Hoek, 1998a). At this point, postponement also gives rise to a need for more strategic use of geographical proximity and outsourcing (e.g. providing additional services such as technical and project management support), although they are often justified on the basis of cost reduction effectiveness (e.g. with suppliers often paying lower wages, achieving greater economics of scale and lowering transportation costs). This is also partly echoed by Sako (2002), who comments that the geographical proximity, either on a supplier part or as part of a modular consortium where the module supplier has the responsibility to assemble the module directly on the automotive manufacturer's assembly line (Collins and Bechler, 1997; Doran, 2003), is combined with tight synchronisation of operations between the assembler and suppliers, putting pressure on the exploitation of such cost reduction as lower wages of suppliers (since the proximity might make wages differentiations to close). Close proximity can also be important for new and/or complex products that require a high level of interaction between the manufacturer and their suppliers.

In purchasing postponement, it is crucial to achieve a high level of collaboration between manufacturers and suppliers. In recent times, independent, buyer- and supplier-sponsored
business-to-business (B2B) e-markets are being rapidly established for such coordination between manufacturers and suppliers (see figure 3.1). Beyond only sharing real-time information, these online markets offer to streamline market inefficiencies by bringing together far-flung suppliers and buyers. Manufacturers are not always using the e-markets to force suppliers to compete on price but rather to improve performance by providing demand data for better forecasting and production and scheduling and replenishment strategies. For manufacturers, this enables postponed purchasing leading further towards engineer-to-order. For example, suppliers like Sony even allow Dell to ship monitors directly from the supplier to the customer, resulting in eliminating warehousing costs and the delays associated with additional inventories. However, purchasing postponement brings a new challenge to manufacturer-supplier relationship in B2B e-marketplaces. The literature has well documented the benefits of established long-term relationships between suppliers and buyers. Since this relationship with current business suppliers is difficult to change, a manufacturer may be loyal to a supplier with a strong and long-lasting relationship, rather than the most appropriate one to meet a particular requirement (Tucker and Jones, 2000), even under the situation where, using intelligent agent technology the manufacturer can easily find a wide range of potential suppliers. It is not surprising to find that short-term or ad hoc relationships are typical of electronic marketplaces. As demonstrated before, purchasing postponement is under a highly competitive and uncertain environment and thus the purchase is more likely to be ad hoc, which might put the long-term buyer-supplier relationship under increasing stress.

In addition, purchasing postponement is often involved in the shift of owning goods, since in practice, very few raw materials remain in the constant ownership of one player.
from their source to the time they are sold to the manufacturer (Berry and Towill, 1992). On one hand, high level of collaboration among all players in a supply chain is often perceived as a requirement for successful postponement implementations. From a supply chain wide perspective, postponement shifts the risk of ownership of goods to the most appropriate player in the supply chain to minimise overall channel costs. On the other hand, it should be recognised that every company in a supply chain is seeking to appropriate value for itself from participation and business success can be sustained only by having the ability to appropriate value from relationships with others (Cox, 1999). When a manufacturer has a dominant power relationship with its suppliers, it is inclined to aggressively leverage its relatively dependent suppliers to allow for a maximum appropriation of value for itself. This implies that the dominant manufacturer may postpone its purchase decisions until the latest possible time to diminish its own risk and uncertainty costs (e.g. in speculative inventories) inherent in a volatile market (Bucklin, 1965; Zinn and Levy, 1988). In this situation, the dependent suppliers are forced to bear the burden of costs induced from speculating the end consumer demand (e.g. inventory holding costs), possibly on a manufacturer’s behalf. This is consistent with Bucklin’s (1965) view on postponement as a means by which a buyer (or supplier) may shift risk to the supplier (or buyer). Similarly, in retailer-led supply chains, retailers can postpone the purchasing of goods and push all the demand uncertainty back to manufacturers by asking instant delivery within very short time scales, without adequate support in forecasting demand.

3.1.3 Production postponement
Nowadays, companies are increasingly producing products which are highly customised to meet customer needs to thrive in the turbulent and dynamic environment. Any single product may have multiple product derivatives, due to different language, technological specifications, local culture, or government regulations in different markets. This results in demand uncertainty for each type of products. As the product variety increases, it is not feasible to make finished products based on forecast. Based on the belief that forecasts are more accurate at the component level than at the finished product level, production postponement reduces the risk associated with holding finished goods
inventory, by starting to produce the generic semi-finished products and retain this generic status as long as possible in the production process. It also makes more economic sense to postpone a significantly high weight/volume/value added step in the production process. In production postponement, manufacturing, assembly, packaging, and labelling are options in which companies initially manufacture products to an intermediate or neutral form with the intent to delay final configuration until specific customer orders are received. Production postponement can be successfully applied when no complex delayed manufacturing activities (e.g. specialised capabilities) or highly restrictive economies of scale are required (Bowersox and Closs, 1996).

A key decision in production postponement is where postponement should be implemented. The implementation of production postponement may lead to a downstream positioning of production activities from a manufacturer. It can be done by the retailer at the point-of-delivery site or by the customer on his/her own site. For example, a customer may have a computer assembled at the retail shop to meet his/her individual specification. A customer may also buy a do-it-yourself (DIY) furniture in a slim box and assemble it at home using the tools provided. This greatly reduces the inventory and carrying costs. Those savings can usually make up for the extra costs in tools and a detailed assembly guide needed for a customer in the final assembly. Final manufacturing may also be postponed and performed in the distribution channel. In this situation, base products are shipped in bulk to a distribution centre with final configuration on demand. It also may involve forward deployment of materials or components to support final production. In the international business, shipping generic base products in bulk might mean significant cost savings in inventory. In 1997, Polaroid has saved over $5 million in inventory for promotional packaging around the world through packaging postponement, in which film is shipped in bulk and configured in language-specific or promotion-specific packages at local distribution centers until the demand is more certain (Twede et al., 2000). Since retail/distribution locations are typically not owned by the manufacturer, production postponement might raise the issue of outsourcing. It is important to choose the appropriate degree of outsourcing for postponement production (See Subsection 3.2.3). In fact, from successful examples of
outsourcing production postponement such as in Gillette (Gander and Whitworth, 2000) and Hewlett-Packard (Twede et al., 2000), it is clear that those manufacturers are dominant players in the supply chain, and what they outsource in production postponement are those supply chain resources that are highly contested and which have low barriers to market entry. However, sometimes postponed production has to be done in centralised facilities owned by the original manufacturer because of the need for controlling the operation.

Additionally, production postponement consideration should only be made to attributes which can be better decided when exact information on demand is revealed and therefore production postponement may be attribute-specific rather than for every attribute. Also production postponement often calls for base products or generic modules to be produced more efficiently (e.g. via centralised production plants). That is, it does not necessarily mean an increase in lead time. However, in implementing production postponement, certain levels of capacity and resources are required to be reserved for those activities that benefit most from the additional information gained by the delay. For example, viable/optional production (e.g. by asking employees to work overtime a certain period) is needed to provide responsiveness, which may be very costly. Therefore, the success of production postponement depends on the balance between the potential sacrifice that customers make for production postponement (e.g. how much delay will customers tolerate, and how much will they pay for higher production customisation), and the company’s ability to produce individualised products within an acceptable time and cost frame.

3.1.4 Logistics postponement
Logistics postponement is like just-in-time delivery reducing obsolete inventories and improving customer responsiveness by avoiding wrong time and place utility of products. Without logistics postponement, the uncertain nature of customer demands would require considerable inventory stocked in numerous locations. In contrast, logistics postponement calls for stocking differentiated products at the strategically central location (postponement in place utility) and delaying the downstream shipment (postponement in
time utility) to achieve a balance between inventory cost and responsiveness (Bowersox and Closs, 1996). For example, for a high-value product, a widely distributed network of stock would not be economical. If the cost of shipping the product is low, then it makes economic sense to ship it from one source to all customers directly. In practice, it has been found that international companies reduced their several regional warehouses in Europe to one European Distribution Centre (EDC) (Van Hoek et al., 1998). Companies even start to skip their country distribution centre and ship directly from EDC to sales outlet. Typically, its benefits can be reflected by its implementation in new product launch. In new product launches, an appropriate inventory stock level and deployment plan to support anticipatory launch is difficult, if not impossible, as the product is new. Errors here inevitably lead to stock-out or obsolescence. Thus, it is common for retailers and wholesalers to be given slotting and stocking allowances to allocate warehouse and retail shelf space to the new products, or even for companies introducing the product to guarantee sales and/or reclamation of inventory to their retailers and wholesalers if the product is a complete or even partial failure (Bowersox et al., 1999a). Alternately, logistics postponement offers an alternative way to support successful new product launch and cut losses in product launch failure by reducing launch inventory exposure in that it is involved in controlling the efficient and effective flow/storage of goods (conforming to customer requirements) (Bowersox et al., 1999a).

With a trend toward more frequent smaller sized shipments over long distances in e-business, companies are also increasingly resorting to logistics postponement (Lee and Whang, 2001). In e-business, real-time information flow further heightens the importance of physical logistics. It has now been a big challenge for e-business companies to match material flow to information flow. This is where logistics postponement has an important role to play (see Subsection 2.1.1, p. 15-16). Its benefits will enhance when the distribution centre also implements labelling, packaging, assembly or manufacturing postponement strategies (by building-to-stock basic common components and performing final configuration in response to individual online orders), given the time lag between order receipt and product delivery. This also suggests that there is a strategic need for formulating the relationship between online and offline
operations. For some companies, clicks-and-mortar systems may be based on existing distribution and warehousing infrastructures for bricks-and-mortar to provide multi-channel environments (see figure 3.1, p. 47), as individual customers may seek different channels that best serve their needs. In this way, manufacturers who do not have direct contact with customers in traditional retail channels can reduce handling costs by passing distributors/retailers and selling directly to customers. However, it should be noted that some companies (in particular such manufacturers as Hewlett-Packard, Compaq and IBM) may not pursue this online postponement opportunity (such as in Dell's direct sale mode) to avoid the channel conflict and protect their distributor/retailer partners, because they need a presence in brick-and-mortar stores (Pyke et al., 2001). In this situation, the scope of postponement implementation will be limited by the production abilities of distributors/retailers.

In many cases, logistics postponement can lead to a significant increase in transport cost (Christopher, 1998), although transportation between warehouses and factories might be avoided by shipping products directly to the end customers in its implementation. Therefore, logistics postponement is often more relevant when products are more sensitive to inventory than transport costs (e.g. higher value added products with large product variety) (Van Hoek, 2001). It may also favour the development of distribution centres based on cross-docking (with only small amounts of warehousing), to improve vehicle utilisation and reduce the number of trips. Automatic identification techniques are often used to sort out the products in a cross-docking situation (Twede et al., 2000). In practice, a variant logistics postponement, the rolling warehouse, has further been developed (Lee and Whang, 2001). For example, when a company ships products, the products on the truck are not pre-assigned to a destination. With the help of real-time demand information (monitored closely and sent usually by satellite), the truck driver is instructed how much to unload at each destination to cope with a change in demand before the time of unloading. That is to say, unloading decisions are postponed until arrival rather than departure. In this way, this truck is running very much like a rolling warehouse.
3.2 IMPLICATIONS OF POSTPONEMENT FOR THE SUPPLY CHAIN

Nowadays the battle for competitiveness is increasingly fought between supply chains, not companies (Christopher, 1992). With the increasingly sophisticated customer’s demand (e.g. product variety and customization), supply chains have to be responsive to constantly changing markets. As a result, postponement has been increasingly used as an important supply chain strategy (Feitzinger and Lee, 1997). The implementation of postponement often leads to the reconfiguration of the supply chain. For example, postponement application has resulted in a blurring of warehousing, assembly and retail operations, and the warehouse is often the place where final assembly, labelling and packaging are processed. More importantly, postponement fosters a new way of thinking about product design, process design and supply chain management. For example, it encourages companies to decide which components will be modular, standard and customisable, which parties are best suited to each task, where and when inventories are justified and what activities are based on forecast (or order). This part discusses the implications of postponement for the supply chain, with a view to extending the significance of postponement towards the perspective of a holistic supply chain context.

3.2.1 The decoupling point (DP)

The decoupling point is an important element in the supply chain and how to position it is a crucial decision in designing the supply chain. In the literature, this point usually corresponds to the order penetration point (OPP) (Sharman, 1984) and the customer decoupling point (CODP) (Hoekstra and Romme, 1992). This is the point where in the supply chain the customer order penetrates and that distinguishes forecast and order-driven activities. The DP depends on a balance between the product type, market, process and stock characteristics. Product and market characteristics include required
delivery reliability and time, predictability of demand, and specificity of demand. Process and stock characteristics include lead times and costs of steps, controllability of manufacturing and procurement, costs of stock-holding and value added between stock points, and risk of obsolescence (Hoekstra and Romme, 1992). For example, when deciding on the location of the DP companies usually have to consider the lead times imposed by the market and the inventories. If the lead time from the DP to the customer is longer than the market delivery time, companies will tend to react by moving the DP closer to the customer (Andries and Gelders, 1995). An optimal DP will change as market and industry conditions change. If retailers increase their leverage within a distribution chain, manufacturers will often need to redesign their products as well for easier handling or more economical storage (Sharman, 1984). Postponement is closely linked with the DP (Heskett, 1977) and requires very careful thought as to the location of the DP (Mason-Iones and Towill, 1999). The level of postponement can also be related to the DP (Van Hoek, 1997). There are two different flows in the supply chain, known as information flow (the order information transfer from point of sale to raw materials suppliers) and material flow (the product transfer from raw materials to end customers). In return, different reasons can be stated on how postponement can help locate the DP from both information flow and material flow perspectives.

An information flow perspective
Postponement offers a potential core basis for making the most of information flow in the supply chain. Information flow affects the performance of the whole supply chain. One lesson comes from a company which strove to reduce manufacturing cycle times by just one day while it did not attempt to tackle two to three week ordering delays (Braithwaite, 1993). Timely information flow may enhance information sharing across the supply chain to match supply chain strategies with customer needs. The question is how far into the supply chain the customer order information is shared and linked to specific (semi-finished) products and operations (Van Hoek, 2000a). Mason-Jones and Towill (1999) propose that the further the marketplace order data penetrates upstream the better the improvement in the dynamic behaviour of the supply chain. However, since an order has many attributes (e.g. items shapes and colours, packaging, assortment variety, and
delivery sequence) and these attributes are often created by different points and/or different players in the supply chain, different players in the supply chain may need different aspects of the customer order (Bowersox and Morash, 1989). In other words, a customer order does not have to be fully specified at a single point in time. This also gives customers the freedom to specify certain details of their order and later then on other details, which may mean that the benefits of postponement will go to the customer side as well, especially when it is difficult for customers to accurately specify their needs at the outset of a design project system. Furthermore some players in the supply chain even need information on ongoing demands, not the order itself. For example, Benetton will order and weave un-dyed yarn all in advance of the actual requirement being known, given that they can forecast aggregated demands of certain size. This reflects how postponement works. Postponement may correspond to details of certain attribute(s) not of the whole order. Generally the logic behind the concept of postponement is: (1) The overall demands (the aggregate items number) are relatively easy to accurately forecast; and (2) Accurate information on demand for every product variation in every sales location (further details about other order attributes) is available in the delay period. The DP does not have to be the same point at which postponement is applied in theory (Van Hoek, 2000a). In addition, to correspond to several attributes of the demand, there might be several postponement points in the same supply chain.

Postponement application may also be a reasonable starting point for making a decision on how to locate the DP. Postponement reallocates time along the supply chain or even changes the time sequence to arrange the steps along the supply chain in the most efficient sequence. The rationale of the postponement is to delay some activities after some information about the customers' demands is known. Thus those information related activities are often placed behind the DP through postponement. It is intuitive that the DP is used to separate postponable activities from non-postponable ones. Are all existing processes behind the DP closely associated with the customer order? If not, can they possibly be moved before the DP? Are all existing processes before the DP not associated with the customer order at all? If yes, can they possibly be moved after the DP? Consider the old and new manufacturing processes in the case of Benetton (figure 3.2).
Their marketing and product processing is based essentially on colour, and thus the DP is really positioned at the dyeing process (Andries and Gelders, 1995). Traditionally, the yarn is first dyed into different colours and then knitted into finished garments, which is a lengthy process. There were always too many garments in colours customers did not want, whereas colours in demand were always sold out. To cope with long production lead-times and fickle fashion trends, Benetton changed the order of the dyeing and knitting sub-processes since they can forecast aggregated demands of a certain size (related to knitting) more accurately. They first knit garments using bleached yarn and postpone dyeing until a later stage, either when they receive an order or when they have a better idea of the popular colours for a season. This change leads to inventory reduction, better customer service and fewer write-offs (Lee, 1998).

A material flow perspective
As significant weight or volume increase usually leads to higher inventory carrying and holding cost and products with high unit value also have high cost of oversupply, it makes sense to delay a significantly high weight/volume/value added step in the material flow. In this sense, postponement may help locate the DP in order to improve the nature of product flow and the production routing. Postponement means that some phase, which usually precedes the point of differentiation, is prolonged. In terms of inventory costs, companies may tend to apply postponement upstream, because raw material inventories...
are usually cheaper than end item inventories. At this point, the best location for postponement might be at the convergence of the bill of materials in that it is the place in the supply chain where the amount of parts, components, sub-assemblies or assemblies is the lowest (Andries and Gelders, 1995). This might also be the best location for the DP, where a strategic stock is established at the product differentiation point that acts as a planned buffer in the supply chain. In table 3.2, I present the possible choices for postponement and DP location in different product types. ‘V’, ‘A’, ‘T’ and ‘X’ stand for different product types (e.g. Umble, 1992). In ‘V’ type products, a single piece of material can be processed and transformed into a very large number of distinct end products. In ‘A’ type products, a relatively large number of component parts and materials are purchased. Many of these materials are further processed, fabricated and combined to make subassemblies, which eventually converge to form unique end products. ‘T’ type products are made from a few common raw materials or component parts and at a single point in the process can be converted into a number of end products. ‘X’ type of products have many raw materials (or components) and fewer sub assemblies or modules which can then be configured in a wide variety of permutations. It should be noted that the choices in table 3.2 should be traded off against other factors. For example, in case of ‘V’ products, requirements in lead time often make it impossible to put postponement and the DP at the very beginning of the whole process.

<table>
<thead>
<tr>
<th>Product type</th>
<th>Location of DP and choice of postponement</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>V</td>
<td>Levis’s customer-fitted jeans are made to order (manufacturing postponement) from a small number of raw materials.</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
<td>A very limited range of Henry Ford’s T automobiles was made to stock from a greater number of components.</td>
</tr>
<tr>
<td>T</td>
<td>T</td>
<td>Lots of Gillette’s pack variants are packaged to order (packaging postponement) from a limited number of razors.</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>Dell computers with lots of different specifications are assembled to order (assembly postponement) from a large number of parts through a small number of assemblies.</td>
</tr>
</tbody>
</table>

Table 3.2 A choice for the DP and Postponement Location

Finally, as many of today’s products offer variations, options and customised features, there might be several points of product differentiation which can be determined by
multiple product attributes, the target market segments and sales regions. For example, general base products may be first variegated into families and later into individual end products. Companies may simply hold the products in the unfinished state at the first product differentiation point until a customer order arrives. In other words, the first product differentiation point is delayed in time and merged with the DP. However, since customers are not willing to wait too long, companies have to move the first point of differentiation downstream (closer to the customer) and further merge with the DP, often by restructuring the supply chain. One of the classic examples of postponement is the Deskjet-Plus printer in Hewlett-Packard (HP) (Lee et al., 1993). HP originally produced different versions of finished printers for the US markets, European markets and Far East markets in Vancouver, because of different power supply standards in different countries. Thus the first product differentiation was at the point of installing the power supply, which was performed at the factory in Vancouver. Through redesigning the printer, HP first produced the standard common core printers without power supply and final power supply assembly was delayed and finished by the distributors. Thus, HP can make finished printers only as needed, and do not need to hold the finished products in inventory in anticipation of customer demand. It should be noted that, for postponement to work, companies have to balance it against other factors. For example, postponement may result in costs to modify the sequence of a production process, the patterns of material flow through the supply chain or the product’s design. In addition, postponement can change the location of the DP directly (e.g. final configuration of products by customers) or indirectly (e.g. re-sequence activities) and thus should consider the effects of its upstream and downstream shifting (See table 3.3).

<table>
<thead>
<tr>
<th>Effects</th>
<th>Upstream Shifting</th>
<th>Downstream Shifting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>• Reduce the reliance on forecasts</td>
<td>• Reduce the customer lead time</td>
</tr>
<tr>
<td></td>
<td>• Reduce or eliminate buffer inventories</td>
<td>• Process optimisation</td>
</tr>
<tr>
<td></td>
<td>• Reduce the risk of obsolescence of inventories</td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td>• Longer delivery lead times</td>
<td>• Rely more on forecasts</td>
</tr>
<tr>
<td></td>
<td>• Reduced delivery reliability</td>
<td>• Higher risk of obsolescence</td>
</tr>
<tr>
<td></td>
<td>• Reduced process efficiency due to reduced possibilities for optimisation</td>
<td>• Reduce the product range</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increase products-in-process</td>
</tr>
</tbody>
</table>

Table 3.3 Effects of Upstream and Downstream Shifting of the DP (Source: Olhager, 1994)
3.2.2 Supply chain integration

Rapidly evolving technologies, increasingly competitive intensity, turbulent markets and increased supply chain complexity have contributed to an increase in uncertainties in industries as diverse as cars, chemicals, and electronics (e.g. Wilding, 1998; Prater et al., 2001). Examples of this include those uncertainties from future demand and a supplier’s ability to meet a delivery promise. Supply chains thus need to be engineered to manage, reduce or entirely eliminate the impact of uncertainties, in order to best service consumer requirements (Davis, 1993; Fisher, 1997; Christopher and Towill, 2001). To address this, supply chain integration is a desirable goal (Stevens, 1989; Towill et al., 2002).

Postponement is also used by companies to restructure the business processes that underlie their supply chains to better cope with uncertainty. In an environment of extreme demand uncertainty, for example, a manufacturer may derive significant economic benefit from using faster manufacturing/distribution processes, and/or locating production geographically closer to customers, to postpone production in time. The logic behind postponement is that additional information can be collected to reduce uncertainty during the delay. There may be little value in applying postponement in easily predictable environments. The important issue is what the relationship between postponement and different uncertainties is. Here I discuss postponement and uncertainties in the context of improving supply chain integration.

According to Towill et al. (2002), the best way to cope with uncertainty is to understand and tackle the root causes in the supply chain. Generally there are four different sources of uncertainty (e.g. Davis, 1993; Mason-Jones and Towill, 1998) that plague supply chains: supply side (e.g. uncertainty in schedule adherence and supply quality), process side (e.g. uncertainty in yield ratios and cycle times), control side (e.g. uncertainty in internal decision making) and demand side (e.g. uncertainty in turbulent market demands and changeable customer buying behaviours). As can be seen from figure 3.3, it requires a growing level of reduction to achieve functional integration (focusing on goods inward and reaction toward customers), internal integration (emphasising all work process integration and the role of the customer in supplier planning), and external integration (implying synchronised material and extended enterprise structure) individually (Towill
et al., 2000). In the meantime, control uncertainty is assumed to go over the whole supply chain integration, as control uncertainty is concerned with how internal decision making affects the ability to transform customer orders into activities in the supply chain (e.g. supply raw material requests) (Towill et al., 2002).

For postponement to work, uncertainties in the supply chain also have to be reduced as much as possible. The reduction in control uncertainties has received much attention towards the implementation of postponement. For example, postponement calls for reducing the uncertainty induced by the bullwhip effect (Lee et al., 1997) through advanced information technology (e.g. Robinson and Elofson, 2001) and more willingness to share information and jointly make some decisions between players in the supply chain (Towill, 1996; Mason-Jones and Towill, 1999). At the same time, figure 3.3 shows that there are different ways to adopt postponement with a growing level of requirement in uncertainty reduction:

![Figure 3.3 Postponement and Uncertainty in Improving Supply Chain Integration](image)

(1) The first step in postponement application is to reduce process uncertainty because a company's own processes are the most visible and accessible area to influence (Towill
et al., 2002). Strategic initiatives can lessen the process uncertainty, like change to more reliable transportation and a new product design to stabilise manufacturing processes (Davis, 1993). To maintain the timing of postponement, it may be involved in combining two processes into one, eliminating some processes, doing some processes in parallel, re-sequencing processes or reducing a cycle time within a subprocess, which in turn contributes to functional integration. This continues until manufacturing or logistics postponement is reached, which makes it possible to concretely demonstrate feasibility and benefits deriving from the postponement implementation, thus creating the necessary positive climate in the supply chain towards the further use of postponement (Battezzati and Magnani, 2000). Companies may centralise inventories in a limited number of centralised inventory-keeping points in the chain (postponement in place utility) and delay the downstream shipment (postponement in time utility). Postponed assembly (form postponement) is relatively feasible in a given industry, like automotive and computer, because of the use of standard components or product modules. Sometimes postponement goes so far that the final manufacturing step is done by the end user such as in the do-it-yourself furniture (see Subsection 3.1.3, p. 49);

(2) The second step is to reduce supplier induced uncertainty towards both manufacturing and logistics postponement. A supplier network that can supply parts (e.g. generic base product, standard and modular components) and services (e.g. meeting supply quality and delivery promise) is crucial for postponement applications (Feitzinger and Lee, 1997). This implies improving flow of material across business functions, consistent with internal integration. Suppliers may further be involved in product development (e.g. specifying the overall product architecture) as a strong input at the level of modules and components (Van Hoek, 1998a). As postponement is increasingly employed in the international businesses, activities like sourcing or supplier management are being globalised or pan-regionalised in response to strong economic drivers. In addition, postponement requires the situations where there are a few barriers to transportation and thus its implementation has a major impact on international transport; and
(3) The final step is to reduce demand uncertainty to extensively implement postponement throughout the supply chain. Reduction in demand uncertainty here, similar to external integration, requires more focus on customers. In dynamic environments, customers shopping and buying behaviours, buying criteria and segments change frequently. Deep penetration into customers’ perception can reduce those kinds of uncertainties towards extending the postponement implementation. Not all products should be provided at the same level of customer service. For example, in some situations, customers do not favour the speed of delivery and are even willing to sacrifice certain benefits such as short waiting time for more options (Waller et al., 2000). Companies may not afford to miss such postponement opportunities. Further, extensive application of postponement requires full integration of customers and suppliers and co-operation among the cross-functional and cross-organisational processes (Van Hoek, 1998a). This thus leads to a fully integrated supply chain with low uncertainty in process, supplier, demand, and control sources. Nowadays, constantly changing competitive environments force companies to develop strategies that incorporate demand uncertainty as an opportunity and not a problem. Most authors think that postponement is such a powerful strategy to deal with those uncertainties induced from turbulent market demands. However, I emphasise that, only after this final step has been completed, can postponement be effectively used to respond to demand uncertainty with the maximum flexibility and without substantial cost increases.

3.2.3 Control of the supply chain

Control of the supply chain is a prerequisite for postponement applications. Proposed approaches to tighten the control include adopting information technology to link operations to suppliers and customers and better controlling in-house activities. Across most industry sectors, there is a distinct trend towards increasingly employing postponement. Unfortunately, extensive implementation of postponement often leads to the relocation of specific inventory holding, production activities and knowledge management to other players in the best position in the supply chain and brings a new
challenge to the control of the supply chain. As most often manufacturers specify the overall product architecture significantly affecting the level of postponement applications, here I discuss the control of the supply chain from a manufacturer perspective.

Postponement and outsourcing

One crucial decision for companies is whether to outsource parts of the product (Prahalad and Hamel, 1990). In deciding whether an activity should be outsourced, the company should assess whether the activity is essential to perform within the company in order to sustain its competitive advantage. The danger is that the company outsources its key expertise, only to find later that it is squeezed out of the market by its erstwhile supplier (Anumba et al., 2000). In the meantime, with the constantly changing competitive environment and increasingly complex management in a more dynamic business environment, it is also dangerous for a single company to maintain full capacities to take every market opportunity. Thus many companies are focusing on their core business activities where they are able to expand a competitive advantage and contracting out their non-core activities to capitalise on others' expertise, resulting in a greater reliance on suppliers and alliance partners. Small companies look to outsourcing also because they do not have enough skills or internal resources.

The implementation of postponement facilitates outsourcing to third parties. In the case of Gillette's razors, they postpone packaging to satisfy their many geographical markets, resulting in far more contracting out of packaging operations (Gander and Whitworth, 2000). In the UK, Gillette ship from their factories in Isleworth and Berlin only in bulk, with retail packaging contracted out to a dedicated Hemel Hempstead operation run by Low & Bonar. Most often final configurations of products are applied in the distribution channel (see Subsection 2.2.1, p.21-22). In the HP DeskJet Printer postponement example, they outsource the final customisation of the DeskJet printers, in which HP have no direct ownership of the facilities or operations. In a recent strategy change, HP even outsource the full production of some products (built to HP specifications) to the third-party contractors who come up with more efficient methods of operation (Twede et al., 2000). At the same time, some third-party service suppliers are targeting final
postponement activities as an extension of their portfolio of services (Van Hoek, 2000b). This move facilitates postponement-oriented strategies. For example, the logistics division of the Barilla industrial group, the largest producer of pasta and baked products in Italy, made itself independent from Barilla and became a new company called 'Number One' in Spring 1999. The large volumes handled by Barilla and the high number of delivery points have been strong assets which can guarantee the economies of scale. The new company is extending to offer manufacturing postponement services in the packaging and co-packing field to help its customers improve the management of product varieties (Battezzati and Magnani, 2000). Furthermore, some leading third party logistics suppliers are now forming partnerships with industrial subcontractors to offer postponed manufacturing services (Van Hoek, 2000b), which are outside their primary core competencies. Initiatives of this kind can support their upgrading from low interest-low involvement to a higher value service, resulting in broader and stronger supply chain capabilities.

**Power shift and control**

The above trend to outsourcing postponement activities creates evident problems for the control over the supply chain. For manufacturers, this can lead to less contact with final customers. Further, this may contribute to the power shift in the supply chain from manufacturers to distributors and retailers. Sharman (1984) noticed that in the market for colour television sets, retailers other than brand image and product features were the dominant influence on the consumer's buying decision. More recently, the scale and scope increase in distributors and retailers, like giant retailer Wal-Mart in USA, can enable them to squeeze and pressure the branded-goods manufacturers to take expensive actions such as lowering prices, accelerating delivery times, offering special allowance, or carrying extra inventory (Anderson and Day, 1997; Bloom and Perry, 2001). Van Hoek (1998a) states that the extent to which the manufacturer is squeezed out of the physical flow of goods in the postponement applications is notable. Some distributors and retailers can even take over some of their suppliers (manufacturers)' activities, or directly displace them with their own products.
To defend themselves, manufacturers have to keep critical production/skills in-house and well-guarded. Building on their core manufacturing capabilities, manufacturers are also moving downstream in the supply chain to exploit many downstream opportunities (Wise and Baumgartner, 1999). In this context, it is noteworthy that Dell was appointed the best PC-dealer in Sweden in 1998. Further, manufacturers can achieve the control over the supply chain by specifying the overall product architecture and mastering the flow of information, rather than through ownership (Van Hoek, 1998a). In the meantime, with the development of e-commerce, manufacturers may look to more assembly, packaging and labelling postponement by building-to-stock basic common components and performing final configuration at the latest possible time, given the time lag between when an order is placed via the Internet and filled. This move obviously enables manufacturers to bypass distributors/retailers and directly contact customers. According to Wise and Baumgartner (1999), it may be the only option for manufacturers to bypass distributors via the Internet (or some other new channel) in the supply chain controlled by big and consolidated distributors. However, no matter who is a dominant player in the current supply chain, possibly another trend one cannot ignore is that ‘both manufacturers and retailers have lost power to the consumer’ (Anderson and Day, 1997).

3.2.4 Capacity planning
The implementation of postponement is involved in product, production and supply chain designs and thus it can be seen a method that helps build the multidimensional strategic capabilities (Van Hoek et al., 1999a). Postponement centres on delaying the final customisation or forward positioning of finished goods until the final market destination and/or customer requirement is known. Such strategy often requires acceleration of production and/or premium movement (e.g. changing the mode of transportation from rail to motor carriage) of specific components or finished products through the system. Therefore, part of postponement is the allocation of assets or resources to the appropriate location in the supply chain to better satisfy customers’ demands (Van Hoek et al., 1999a), thus leading to capacity utilisation improvements. Considering the implementation of postponement, there are different ways to be exploited to help with capacity planning.
Postponement implies an approach to achieving the leagility via capacity calculation. The current definition of leagility emphasises that lean and agile are different or might be complementary mainly in that lean and agile deal with level demands and volatile demands respectively. Mason-Jones et al. (2000a) note that, lean means that companies operate with little spare capacity, while agile means that the maximum capacity level is higher than the average demand. What may be regarded as ‘waste’ in lean may be essential in agile, because the customer reserves capacity that may additionally need to be made available at very short notice. This suggests that lean may be a prerequisite for agile, which can be enabled by initially engineering lean and then adapting it by improving the capacity limitation. Also, this can be reflected by the leagile supply chain in which lean precedes agile both geographically and temporally (Mason-Jones et al., 2000b). I argue that, if companies cannot manage to deal with level demands, how can they deal with volatile demands. Facing constant changes, some activities have to be postponed until more information is available in the lean supply chain. In this situation, agile distribution or/and agile manufacturing are introduced to maintain or even shrink lead times, leading to a supply chain paradigm very much like leagility.

Pareto’s law (or the 80/20 rule) in postponement may also make capacity planning significantly simplified. For example, 20 percent of capacities will generate 80 percent of the total products. Companies may have to stabilise the use of those capacities and allocate them to non-postponable activities, which suggests that companies might look for postponement opportunities outside of those capacities. In the late nineteenth century, Pareto analysed the distribution of wealth in Italy and concluded that 80 percent of the country’s wealth was owned by 20 percent of the nation’s population. This law can be applied to a lot of fields, e.g. the product mix of a facility in many manufacturing companies. The significance of this for postponement is that a small percentage of the total capacities are responsible for the majority of the total products. That is to say, Pareto’s law could be used to identify the capacities for postponable activities and those for non-postponable activities. In a similar sense, postponement should also consider the structure of the routeings, in particular relating to a bottleneck capacity, as it might be
problematic to postpone any steps that need to be executed by a bottleneck resource. In fact, bottleneck resources need to be utilised to the full, as otherwise loss of throughput results that can never be made up.

3.3 AN INTEGRATED FRAMEWORK

As I discussed before, part of the neglect of postponement applications might be because there is little effort taken to comprehensively analyse postponement, from both a strategic perspective and enabler points of view in order to motivate the practitioners. In this regard, I propose an integrated framework (as illustrated in figure 3.4) for prompting and progressing the implementation of postponement based on the literature review.

![Figure 3.4 An Integrated Framework for Postponement Application](image)

3.3.1 Preconditions

Before embarking upon postponement, companies need to identify and fully understand the marketplace requirements. There are certain conditions and situations where the
implementation of postponement is more likely to succeed. Its benefits vary with the competitive environment. Although highly competitive markets and short product life cycles rarely make sense to use stocks to buffer supply/market uncertainty, some manufacturers are forced to do so (rather than looking to postponement) in order to remain competitive with other manufacturers who are able to offer shorter lead times and/or variety (Newman et al., 1993). The degree of uncertainty is significant for selecting an appropriate postponement strategy. The strength of postponement lies in its capability of coping with those uncertainties inherent to dynamic and changing markets, which companies may have to accommodate in their business strategies (Yang et al., 2004). According to Galbraith (1973), uncertainty is the difference between the amount of information required to perform a task and the amount of information possessed by the organisation. Facing uncertainty, companies may not have enough information and be less willing to make resource commitments (Kim and Hwang, 1992). Alderson’s (1950) original concept provides a basis for understanding how to cope with the uncertainty (imposed by the customer demands) by postponing the variant differentiation of a product (form, identity and inventory location), since every differentiation makes a product more suitable for a specified segment of the market and less suitable for other segments. In easily predictable environments, there may be very little value in applying postponement. The higher the uncertainty in customer demand, the more important it is that companies will look into more postponement opportunities. Through postponement, more activities are now based on real market demands. In this regard, both agility and mass customisation imply a postponement mindset. The need for responsiveness to dynamic markets (demand-related items) is another important driver of postponement applications (Van Hoek, 1998a). In new product development, postponement is favourable due to uncertainty about customer requirements and technical evolution during the development process. For innovative products, the supply chain should respond quickly to unpredictable demand in order to minimise stock-outs, forced markdowns, and obsolete inventory (Fisher, 1997). In this situation, it will be appropriate to postpone the final manufacturing and logistics operations (Pagh and Cooper, 1998).
For postponement to work, companies need to first figure out what can be well forecasted and what can not be forecasted. Postponement considerations are then only given to those decisions about unpredictable items. That is, postponement is a strategy to intentionally delay the execution of a task instead of starting it with incomplete or unreliable information input. At this stage, it is essential to anticipate the extent of the variability of those unpredictable items, leading to an exhaustive set of solutions in the sense that any future changes of solutions (responding to real demands) fall within its boundaries. The logic behind this is to defer commitment of the most uncertain items to a later time when these could be defined more efficiently in response to such possible major changes in customer needs, technologies and competitors' action. In this way, postponement maps various decisions to different time horizons and alleviates the need to make some decisions prior to the availability of adequate information. In this context, postponement is relevant to the principle that, in general, short-term forecasts for an item are more accurate than long-term ones. For global products tailored to local markets, it is increasingly difficult to forecast demand for every product variation, which results from technical requirements and customer preferences, in every sales location. However, once companies choose to target certain markets, the extent of product variability is clear and forecasting is easier at the generic level than at the level of the finished item (Christopher, 1998). As often cited in the literature as the practitioners of postponement, HP have to forecast total demand of printers and Benneton must forecast aggregate demand for garments of a certain size.

Further information (e.g. information on local demands) must be available in the delay period. Postponement is only valuable if the information about the customers' needs can be captured quickly and accurately (Lee, 1998). Postponement does not necessarily rely on advanced IT (Van Hoek, et al., 1999b) and companies can combine postponement with simple information sharing to achieve low supply chain costs and high customer service level (Billington and Amaral, 1999). However, latest information technology may extend the application of postponement or even enhance the value of postponement. The information for postponement, in many cases, does not only refer to the customer's order information which is transmitted in a timely manner without distortion from the players.
closer to the customers. Companies sometimes need some information about ongoing
demand. Precision is a major concern for this kind of information. The internet provides
a way for richer understanding of customers’ requirement. An electronic broker can
increase the precision of demand information and thus enhance the value of postponement
(Elofson and Robinson, 1998; Robinson and Elofson, 2001).

3.3.2 Approaches
Considering the application of postponement, there should be postponable points. At
these points, companies have to examine product/production characteristics and analyse
the costs and benefits of postponement. Not only should companies stay with product
and process (re-) design for postponement in end units or finished goods, but also they
should look at ways to improve the nature of product flow and the production routeing.
Analytical models are often powerful as a means to help motivate or justify postponement
(Lee, 1998).

Once postponable points have been chosen, companies can begin to create those points.
Modular and standard design is a powerful tool to create postponable points (see
Subsection 2.2.2). Through standard design, increasing the level of part commonality
from initial stages of the manufacturing process may delay the differentiation of the
products until after these early stages (Lee, 1996). Modular designs for products or
modular processes also enable postponement (Lee, 1998). Through process modular
design, a process is broken down into sub-processes and those associated with specific
attributes might be delayed until a later stage. Through product modular design, semi-
finished products can be assembled, configured and finished to provide the high level of
variety to customers. The degree of modularity in the production development or
production cycle is a key indicator of the degree or type of postponement provided. If
product development can be divided into non-interdependent sub-processes (with high
modularity), it could achieve the high level of postponement to re-arrange the order of
sub-processes simply according to their degree of uncertainty (Yang and Burns, 2002). If
there is little modularity in product development, the entire process may not be divided
into pieces that can easily be rearranged to support different product development
options, limiting the viability of the postponement strategy. At the production level, the literature has well established that high level of modularity is a key to successfully achieving production postponement (Feitzinger and Lee, 1997). This can be reflected by relatively extensive use of assembly or manufacturing postponement in automotive and computer industries with the high level of product modules. The degree of modularity also determines the level of production postponement, ranging from manufacturing, to assembly, to packaging, and to labelling. In the continuous processing industry like the chemical industry, many processes do not allow the separation into a flow of discrete steps, leading to postponement opportunities only in labelling or packaging operations.

Since successful postponement applications first lie in organising product architecture, it is necessary to incorporate postponement thinking all the way up to product development. However, in the early phases of a product development project, detailed information on the product attributes (e.g. due to uncertainty about customer preferences and new technology) may not be available. Thus, product development may have to look to postponement in itself (see Subsection 3.1.1), avoiding major changes later in the development process (which are inherently expensive). Further, with the fleeting windows of marketing opportunities, companies may not be able simply to wait until all aspects of exact information are available. For example, facing technological uncertainties, companies may delay their commitment to a single technology by pursuing simultaneous commercialisation of two of more competing technologies, as opposed to simply waiting to enter later until the dominant design emerges (Hatfield et al., 2001).

That is, during the delay, alternative options (e.g. about technology and thus product architectures) should be seriously considered, and companies thus need to have more knowledge than needed for what they make. In doing so, companies may gain industry- and product-level knowledge and experience in applying postponement before the dominant technology emerges. However, there is a big challenge when the emphasis shifts from the capability for focused and rapid project execution to the capability to gather and incorporate new technical and market information during the course of the project itself. Not surprisingly, some projects that attempted to investigate a broad set of concept alternatives were forced to focus early and freeze the product concept (Iansiti,
In the postponement example at Toyota, Toyota relied more on its suppliers in their product development: its suppliers (designers) deeply and simultaneously explored broad regions of the design space, and provided a set of possibilities, while Toyota continuously compiled information on the market and technological developments, various constraint and trade-offs between alternatives (Ward et al., 1995). However, this co-design hinges heavily on a long term experience together (Dyer and Ouchi, 1993), where Toyota's suppliers even invest in developing ideas and plans for the next model in advance. Many companies will not be capable of such inter-company coordination necessary to implement such a postponement strategy. In fact, some authors (e.g. Hsuan, 1998) argue that the above case at Toyota may only be existing in Japanese practices where the operations and planning are highly integrated between manufacturers and suppliers. In addition, postponement implementation may have to take into account the nature of design information. Baldwin and Clark (1997) suggest that designers achieve modularity by portioning information into visible rules (e.g. an architecture and interfaces) and hidden design parameters. Companies may choose to control the visible information (e.g. by designing proprietary architectures) or design modules (where they conform to the architecture, interfaces and test protocols of others) (Baldwin and Clark, 1997). Generally visible rules affect subsequent design decisions. For example, an architecture specifies which modules will be part of the system and what their functions will be. Interfaces describe in detail how the modules will interact. Therefore, the visible design rules should be established early in a design process. Conversely, hidden elements can be chosen late and changed often and do not have to be communicated to anyone beyond the local module design team. That is, companies may look for postponement opportunities in hidden design rather than visible design.

At the same time, companies have to understand how to tackle obstacles in the way to an effective adoption of postponement. Companies generally find it difficult to change routines and knowledge that are deeply embedded in the organisation. Exploring postponement is no exception. An organisation's administrative heritage and the lack of an overall supply chain vision can be a major bottleneck (Van Hoek et al., 1999b). Also, retailers are increasingly found to process some postponed operations (Lowson, 2001).
Retail locations are typically not owned by the manufacturer or distributing company, which adds an inter-organizational dimension to postponement implementation (Zinn, 1990b). As a consequence of the traditional culture companies will deliberately distort order information to mask their intent not only to competitors but even to their own suppliers and customers (Towill, 1996). Thus, even if it is now possible for companies to capture, validate, and forward information in real time, the players upstream in the supply chain may receive distorted information. The latest techniques like the internet, electronic data interchange (EDI) and point-of-sale system may improve the information flow by reducing data collection errors and moving data quickly. However, they do not eliminate distortions or identify good information in the information flow. In this regard, it may not be enough simply to rely on the technology to cope with information distortion in the information flow, such as the bullwhip effect (reflecting that demand information becomes increasingly distorted in moving up the supply chain from the end customers). Even when market information is shared by all supply chain players in an undistorted way, the performance of the whole supply chain might still be poor (if all players do not share a common target) (Hong-Minh et al., 2000). To further enhance information flow, companies need to manage the information and be willing to act as partners in the supply chain and recognise the need for open communication (Mason-Jones and Towill, 1999). Some of the biggest improvements have occurred through a change of attitude amongst the parties involved, away from an adversarial approach to a relationship that is based upon 'win-win' thinking.

Based on the above approaches, postponement can be achieved by delaying operations or re-arranging sub-processes. When increasingly adopting strategies to improve overall supply chain management, companies may look to wider implementation of postponement (Bowersox and Morash, 1989; Davis and Sasser, 1995). Conklin (1994) asserts that no single enterprise in today's global marketplace is able to realise market opportunities in a timely and cost-effective way, mainly due to the lack of solid skills and experience bases. This assertion is consistent with the view that competition no longer takes place between individual businesses, but between supply chains. However, this does not mean that players in a supply chain may have natural tendencies to develop co-
operative (rather than competitive) relationships. In manufacturing postponement, manufacturers may require distributors to take on additional responsibilities due to the relocation of final manufacturing downstream to distributors/retailers. Manufacturers may also need to foster and develop manufacturing capabilities (e.g. skills to assemble the products) within a particular distributor/retailer, since a company’s success is partly tied to the strength of its weakest supply chain partner. However, in many industries like the automotive, aerospace and personal computer industries, many original equipment manufacturers share common distributors/retailers. The existence of common or overlapping distributors/retailers in different supply chains may limit the manufacturer's ability to invest in the related facilities and human training programmes of distributors/retailers. The reason for this is that any investment in this will provide a ‘free’ benefit for competitors (manufacturers in other supply chains) (Rice and Hoppe, 2001). Obviously, this added competitive aspect of the relationship sometimes complicates the effective employment of postponement strategies. It is also important to note that differences in the internal organisation and the external demands for products require different postponement strategies (Van Hoek et al., 1999b). Companies at different starting points require different postponement strategies. Also companies implementing postponement might modify their postponement applications according to changes in competitive environments, stages of product life cycle, technological advances and so on.

3.3.3 Fit other concepts into postponement

Finally, to accomplish postponement within time and processing cost constraints, there is a need for fitting other related concepts into postponement, as the application of postponement is going through the whole supply chain and negative effects can be associated with it. Typically the implementation of postponement leads to reducing economies of scale and increasing cycle time. A natural option is to look to economies of scale. Consolidation in transport is a related concept. In the transport cost-rate structure, consolidation by creating large shipments from small ones can effectively achieve economies of scale (Ballou, 1999). Bowersox and Closs (1996) state that time-based logistics builds on postponement and consolidation to facilitate timely performance and
reduce total cost. Bhatnagar and Viswanathan (2000) point out that companies can achieve globalisation and time-based competition simultaneously by the balance between postponement and consolidation. Competitive advantages all along the supply chain can be achieved by implementing postponement and outsourcing in an effective manner (Ernst and Kamrad, 2000). Another related concept is quick response, consisting of introducing systematic reductions in the average value and variability of lead times (Aviv and Federgruen, 2001). Postponement divides the whole process into several sub-processes and quick response may be applied into those sub-processes.

3.4 RESEARCH QUESTIONS AND HYPOTHESES

Keeping in mind my preliminary research question in the previous chapter, here I summarise my theoretical study and present various factors affecting postponement applications before further developing my research questions and hypotheses.

3.4.1 Summary of theoretical study
With increasingly demanding markets and the development of technology (e.g. information technology, transportation equipment and manufacturing technology), postponement is increasingly appealing and available. It has been expected that postponement will be increasingly implemented. Across most industry sectors, there is a distinct trend towards increasingly employing postponement, especially in the practice of international business, where companies have to simultaneously target local responsiveness, global efficiency and worldwide learning. However, currently postponement applications are to a lesser extent than expected and still at an infancy stage (Van Hoek, 1997; Battezzati and Magnani 2000; Brown et al., 2000). To address the
question of what factors are related to the implementation of postponement, one may consider this in different contexts:

1) *Exploring new postponement opportunities.* With today's increasingly demanding and changing competitive environments, companies have to develop strategies that incorporate the uncertain as an opportunity and not a problem. Mass customisation and agility are often cited to be such strategies. Mass customisation (shifting from mass production) is referred to as customising products in response to individual customer orders at the price of the comparable mass-produced products, while agility (perceived as enrichment of lean) is defined as the ability to thrive in the face of constant change. In this regard, it is a natural option for companies to turn to postponement, since postponement is an important method to contribute to the attainment of both mass customisation and agility (see Subsection 2.1.1). However, postponement implementation requires a complete supply chain view. The benefits of postponement increase with early enablers of postponement. In Subsection 3.1.1 and Subsection 3.1.2, I have extended the application of postponement to the two early upstream activities in the supply chain: new product development and purchasing. For example, I have demonstrated how product development postponement can be used to incorporate the most current technological advances and customer needs as these co-evolve with the development process. It may allow deferral of the point within the product development phase at which a generic product design takes place to the characteristics of specific end product designs, thus reducing the product development team's response time to react to late changes (e.g. in the nature of customer specifications). Unfortunately, so far postponement applications mainly involve downstream activities in the supply chain. The literature has suggested that the application of production postponement is a logical extension of implementing logistics postponement (Battezzati and Magnani 2000, Van Hoek and Van Dierdonck 2000). More recently, Chiou et al. (2002) examined the relationships among the four production postponement strategies (manufacturing, assembly, packaging and labelling postponement) in the information technology (IT) industry and indicated that the experience in implementing one production postponement strategy may lower the
cost of implementing another production postponement strategy. Therefore, to prompt
the implementation of postponement, it is tempting to investigate the relationships
among broader levels of postponement strategies. If some types of postponement tend
to move together, it makes sense to first choose the dimensions along which
companies can move towards a certain postponement strategy. This may suggest that
depending on the environment it faces, a company may require more of certain types
of postponement strategies than others. Furthermore, I show that: (1) the
implementation of postponement seems a good starting point for balancing various
factors influencing the location of the DP (see Subsection 3.2.1); (2) postponement
strategies may contribute to supply chain integration (see Subsection 3.2.2); (3)
extensive use of postponement brings a big challenge to the control over the supply
chain (see Subsection 3.2.3) while an optimal postponement strategy is driven by a
combination of market characteristics and a company's own internal and supply chain
capabilities (Waller et al., 2000), thereby creating a competitive advantage (Gagnon,
1999); and (4) when a supply chain is restructured in the way that postponement most
often will call for, its assets or resources can be allocated to the appropriate location to
better satisfy customers' demands (see Subsection 3.2.4). Therefore, I expect that
postponement will be increasingly used.

2) Managing uncertainty. It has long been recognised that one of the most important
tasks for any organisation is to cope with uncertainties (Thompson, 1967). A method
is to identify the uncertainty sources and institute approaches to reduce them (Victor
and Blackburn, 1987; Mason-Jones and Towill, 1998). In a broader context,
Childerhouse et al. (2002) also propose an integrated framework for developing
different focused demand chains based on five parameters (duration of life cycle, time
window for delivery, volume, variety and variability). There is significant evidence
that strategic initiatives in supply chain management can effectively decrease
uncertainty (Davis, 1993; Christopher and Towill, 2001). For example, Fisher (1997)
states that uncertainty can be reduced by cutting lead times and increasing the supply
chain's flexibility. Christopher and Towill (2002) emphasise that supply chain
management in the future must be on agility in response to highly uncertain demand.
Childerhouse and Towill (2002) further investigate the importance of various supply chain management factors in accordance with a composite uncertainty measure. However, Small and Downey (1996) indicate that uncertainty in the business environment has still been the main cause of failures in manufacturing industry. Furthermore, it is often unrealistic to find a solution to completely eliminate uncertainty. In recent case studies by Prater et al. (2001), it has been concluded that even if a very high degree of agility is called for in a changing international business environment, companies (even such as General Motors and Hewlett-Packard) must sometimes decrease agility because an increase of agility could lead to more complexity and uncertainty. Companies may have to choose to reduce internal uncertainty (e.g. in their more complex manufacturing task) by the controlled use of internal buffers, in conjunction with the use of dedicated technologies and centralised infrastructures, and limit the external uncertainty which they can accommodate (Newman et al., 1993). For example, if a high-fashion product is highly fashionable by its intrinsic nature, companies may have to accommodate the uncertain nature of its demands. In Subsection 3.2.2, I have looked at the relationship between postponement and different kinds of uncertainty towards supply chain integration. I think that other uncertainties (e.g. from control, supply and process sides) have to be reduced as much as possible before embarking on postponement as a way for effectively responding to uncertainties inherent in highly changing markets, which companies may have to accommodate in their business strategies. Therefore, those managerial practices towards the reduction of former uncertainties may have a positive relationship with the implementation of postponement.

3) Identifying marketing, product and production characteristics where the implementation of postponement is more likely to succeed (also see Subsection 2.2.4, p. 31-33). Marketing characteristics are significant for choosing postponement. For example, some manufacturers may not look to postponement in order to remain competitive with other manufacturers who are able to offer shorter lead times and/or variety because of their higher levels of manufacturing flexibility. In product architecture and production processes, standard and modular designs are conducive to
postponement implementation. I also emphasise the importance of this in Subsection 3.3.2. This may mean that a company must consider product families and generations and seek commonality between parts and subsystems. At this point, postponement is based on the principle of seeking to design products using common platforms, components or modules. Also product development must deliver a product design that both meets customer needs and the postponement process (e.g. capable of efficient manufacture and logistics). This may be facilitated by such tools as design for manufacturability/assembly (DFMA). Again, this directs my attention to the appropriateness of managerial practices for pursuing postponement strategies.

4) **Dealing with negative effects associated with the implementation of postponement.** Postponement is attractive in principle. However, postponement might lead to reducing economies of scale or increasing cycle time. In many cases, logistics postponement can also lead to a significant increase in transport cost. Some other cost increases can be caused by the changes in product design, production and distribution processes (e.g. the sequence of a production process, the patterns of material flow through the supply chain). This is intensified by the fact that customers are not willing to wait too long. Therefore, companies cannot afford simply to delay their activities until all aspects of exact information are available. Instead they may need to re-engineer the business process focusing on lead-time reduction. Considering fleeting windows of marketing opportunities, postponement is only valuable if the information about the customers’ needs can be captured quickly and accurately. Thus, the implementation of postponement calls for such initiatives in enriching specific information as customer-relationship management (CRM), customer-quality function deployment (QFD) (translating customer requirements into product attributes) and cross-functional teams including marketing, research and development, manufacturing, suppliers and customers. In Subsection 3.3.3, I also suggest companies to integrate other concepts (e.g. consolidation and rapid response) into the implementation of postponement. Therefore, further research may need to be conducted on the relationship between the above initiatives and postponement.
Finally, for postponement to work, there is a need to create organisational culture and structure which actively embraces change and welcomes the opportunity to apply postponement. In the application of product development postponement at Toyota, postponement seems completely inconsistent with the speed, economy, and effectiveness of Toyota’s development process. Therefore, a critical part of the manager’s job is ‘to prevent people from making decisions too quickly’ (Ward et al., 1995). Not surprisingly, engineers at one of Toyota’s leading Japanese competitors think that their own process must be more efficient than Toyota. Clearly, there is a big challenge when the emphasis shifts from the capability for focused and rapid project execution to the capability to react to newly discovered technical and market information during the course of the project itself. Therefore, companies looking to postponement opportunities may first do it selectively, e.g. start with a product line best suited for postponement, and/or focus on new products with late configuration that requires modification of a few established manufacturing procedures. Similarly, Battezzati and Magnani (2000) recommend that, before extending the postponement application to product structure and product processes, companies may need to create culture on the theme and above all concretely demonstrate feasibility and benefits from the use of postponement (e.g. by first restricting the method to the distribution channel without ‘entering factory’). In addition, unlike more rigid bureaucratic organisational forms, new postponement-based companies are more responsive to varied information, since it is possible that nowadays companies are facing information overload, impeding managers’ ability to make timely decision. Postponement heightens the importance of designing an organisational structure that is efficient in acquiring and processing information. In this chapter, I have pointed out that, with the explosive development of electronic markets, purchasing postponement (more likely to be ad hoc) might put the long-term manufacturer-supplier relationship under increasing stress (Subsection 3.1.2). In Subsection 3.1.2 and 3.2.3, I also investigated the issues around power and control in the implementation of postponement. As such, when introducing postponement strategies, companies may not ignore the soft side of business which also drives the whole business process. In this regard, I think that postponement capabilities can be difficult to imitate since they are not just present in the physical material systems, but in the organisational structure and culture developed inside the
3.4.2 Research questions and hypotheses
Based on the above theoretical study, I can now further develop my research questions and hypothesis:

1. What is the impact of uncertainty on the adoption of postponement strategy?
2. What is the relationship between postponement and other management practices (such as improvement initiatives in production, coordination with suppliers and customers, and those initiatives aiming to reduce internal uncertainties)?
3. Do companies have better performance with more postponement efforts than those with less postponement efforts?
4. To what extent is postponement currently used in industries?
5. What are the barriers to extending postponement initiatives?

H1. There is a positive relationship between the level of environmental uncertainty and postponement.
H2. There is a positive relationship between postponement and administrative factors in managerial practices.
H3. There is a positive relationship between postponement and technological factors in managerial practices.
H4. There is a positive relationship between postponement and company performance.
H5. Postponement is increasingly used in industry.

The first research question 'What is the impact of uncertainty on the adoption of postponement?' is used to examine whether or not uncertainty is one of the generic underlying elements of postponement enablers in the industry. This may also help develop the postponement strategy tailored to the specific sector of industry. Companies that experience those demands with little or no uncertainty and low product proliferation
would obviously gain very little from postponement. Instead, the strength of postponement lies in its capability of accommodating uncertainty. For example, faced with an unprecedented number and variety of products on the market, managers are finding it more difficult to predict demand and plan production and orders accordingly. If there can be a postponement strategy, companies may be able to delay decisions about their most unpredictable items until they have some market signals to help correctly match supply with demand. To answer the first research question, I test the hypothesis H1. I hypothesise that companies that are facing a higher level of uncertainty will adopt higher levels of postponement strategies.

The second question investigates how other related managerial practices influence the implementation of the postponement strategy. In the face of uncertainty, it may be a natural option to postpone activities. Not surprisingly, postponement may often not be a conscious choice. However, the implementation of postponement typically leads to reducing economies of scale and increasing cycle times. Only those activities closely associated with the customer order may be worth considering toward postponement. In the context of managing external environment uncertainties, other uncertainties have to be reduced as much as possible before companies embark on postponement strategies. Therefore, successful postponement implementation may need to re-engineer business processes from a system wide view. Little research has been directed to the appropriateness of managerial practices for pursuing postponement strategies. In this regard, I raise the second research question: what is the relationship between postponement and other management practices? That is, I attempt to investigate the implementation of postponement in terms of other managerial practices including those aiming to reduce internal uncertainties (from supplier, customer and control side) and improvement initiatives in production. For example, initiatives in enriching specific information are hypothesised to be positively related to the implementation of postponement. Hypotheses H2 and H3 will be tested together to answer the second research question.
The third question focuses on the contribution of postponement to the company performance. I attempt to answer the question of whether companies that put forth greater postponement efforts reap greater benefits. That is, are companies likely to be more successful in their more postponement efforts than those in their less postponement efforts? To address this question, I test the hypothesis H4.

The fourth research question 'To what extent is postponement currently used in industry?' is answered through the testing of the hypothesis H5. Since considerable research has suggested that postponement applications can be expected to increase, respondents are asked to specify the extent of postponement application currently, three years ago and in three years.

In the literature, while much is written to generate insights into the benefits of postponement and the relevance of various factors for the implementation of postponement from different perspective, it is much less easy to find information in empirical studies about what factors hinder the implementation of postponement. Companies may engage in postponement strategies as a reaction to competitive markets. However, the question is: are they ready for postponement? For example, I try to find if a company's organisational structure is suitable for extensive use of postponement applications. Therefore, in order to get a better impression of what factors are likely to influence the successful adoption of postponement, I am also interested in the fifth research question: what are the barriers to extending postponement initiatives? I hope to understand the obstacles that hamper the application of postponement in practice and thus minimise their damaging effect and, further prompt and progress the adoption of postponement. As I will show in Subsection 5.4.4, I will answer this question based on descriptive statistics analysis, rather than through testing a hypothesis (due to the exploratory nature of the question).
CHAPTER 4. RESEARCH METHODOLOGY

Generally, research starts with the researcher being interested in solving a particular problem through being better acquainted with the facts surrounding the problem (Walker, 1997). As a starting point, a literature review approach is the best strategy, which I have done in Chapter 2. My preliminary question is to investigate what factors are related to the successful implementation of postponement, which is descriptive in nature. A descriptive study is concerned with making complicated things understandable and sets out to collect, organise, and summarise information about the matter being studied (Punch, 2000). In this regard, theoretical study conducted in Chapter 3 is a reasonable attempt. It also justified the specific research questions that this research will attempt to address in terms of the novelty and applicability of its contribution. Research results at this stage were analysed, and some conclusions formed the basis for three journal paper submissions (Yang and Burns, 2003; Yang et al., 2003 and 2004). As such, five research questions and five hypotheses have been proposed (in Subsection 3.4.2, p. 81). A number of quite different methods can be employed in establishing the acceptability of a hypothesis, and in some cases these can be used to complement each other. To choose my research methodology, this chapter first provides an overview of ideas on how others have tackled this in the postponement research. Then I discuss general issues on the research design, and further outline and justify my research methodology. Finally, I present the design of my questionnaire survey. Specifically, this chapter describes the various procedures by which the research was carried out, such as the formulation of a research design, alternative methods that might be used in the research, the design of a questionnaire, reliability and validity, and data collection procedures.
4.1 RESEARCH METHODOLOGY IN THE POSTPONEMENT LITERATURE

The possible range of postponement methodology has grown. There is much literature in which case studies, surveys and analytical models have been used to generate multiple insights into the relevance of various factors for the implementation of postponement. I looked to the methodologies on postponement in the literature and found that most referred papers only briefly describe the chosen approach for the very specific research reported upon. Few papers provide detailed information on the adopted research methodology, as these papers are more concerned with reporting research results. However, the review here might help me in matching an appropriate existing research approach to my particular research questions and then deciding on an appropriate and defendable research methodology.

4.1.1 Theoretical and Modelling Research
The theoretical and modelling work on postponement has provided insight into numerous factors for the implementation of postponement. A review of the literature yields theoretic work on postponement originally undertaken by Alderson (1950) in the marketing literature. Articles that discuss costs associated with postponement include the work of Bucklin (1965), Zinn and Bowersox (1988), Zinn and Levy (1988) and Pagh and Cooper (1998). Bucklin (1965) categorises total storage costs into those incurred by the supplier and those incurred by the buyer in the distribution channel. Zinn and Levy (1988) present a framework to suggest conditions in which postponement is justified in marketing channels. The authors conclude that an integral supply chain perspective among players in the supply chain is a pre-requisite for the viability of postponement. Pagh and Cooper (1998) develop a framework for
classifying different postponement and speculation strategies in the mid- to down-stream stages of the supply chain. They also reflect upon the role of factors in the operating environment of companies that influence the feasibility and selection of a particular postponement application. In another related paper, Shapiro (1984) listed different degrees of postponement applications throughout the channel, from no postponement (decentralised stock of finished goods) to full postponement (no inventory carried channel). Christopher (1992 and 1998) offers a geographical classification of activities in the supply chain (from globally coordinated to localised activities) and includes postponement in the list of future directions for supply chain management.

Modelling also provides some useful indicative information on analysing the costs/benefits of postponement applications. This information is supplemented by numerous theoretical works. Zinn (1990a) uses a simulation model and develops heuristics on postponement, indicating the role of operation conditions such as volume and value in achieving the lowest logistics costs with postponement. Lee et al. (1993) simulate a postponed manufacturing supply chain, mainly focusing on inventory levels. Lee and Tang (1997) model the benefits of postponement from three different ways: standardisation, modular design, and process restructuring. Their model highlights conditions under which each method is effective. Lee and Tang (1998) focus on reversal of operations, and examine how this strategy impacts variability in production volumes in a multistage production process for the two-product case. In a model implemented using data from IBM, Swaminathan and Tayur (1998) consider postponement for an assembled product manufacturer producing multiple end products. These authors describe a phenomenon in which companies carry inventory of semi-finished goods, called vanilla-boxes, which are converted into end products by adding other components. For a given line of end products, the issue is to decide how many and which vanilla box configurations to use and how to allocate vanilla boxes to final products to minimise production and market mismatch costs, subject to capacity constraints. Swaminathan and Tayur (1999) extend this model to include one-time design costs associated with creating alternative assembly sequences for the vanilla box manufacturing process. In another modelling paper, Waller et al. (2000) use a primarily deductive theoretical modelling approach to provide a basis for more inductive empirical research concerning postponement,
product customisation, and time-based competition. It should be noted that, the use of computing simulation has also appeared in the literature to evaluate the effects of postponement.

The limitations of mathematical modelling and simulation include the fact that they are dependent upon the researchers' theoretical assumptions and the initialising values of the independent variables. Some of these concerns may be obviated by changing the assumptions of the model or by altering the initial variables or both, and performing a sensitivity analysis over the manifold versions of the model. The problems of simulations generally include, as with any abstraction, their omission of detail, limiting somewhat the complexity of individuals and decisions and processes. Additional problems include attempting to verify the models under consideration. The papers mentioned previously have examined the issue of postponement implementation primarily from a cost perspective. However, taking a broader perspective, postponement reduces lead-time for customer orders, and customers care about lead time (Fuller et al., 1993; Swaminathan and Tayur, 1998). Thus models for postponement do not currently capture the revenue impact of reduced lead-time. In some cases, revenue gains from reduced lead-times may be needed in order to justify the costs incurred to postponement. Estimating these revenue gains is largely an empirical question, and is a useful avenue for future research, as is prescriptive modelling that incorporates these revenue gains.

From the above discussion, I may classify my work in Chapter 3 as theoretical research, while modelling will not be adopted in this research since my hypotheses do not directly address the issues on the analysis of costs and benefits of postponement or its impact on lead time.

4.1.2 Empirical Research
In recent years, there has been considerable empirical research on generating multiple insights into the relevance of various factors for the implementation of postponement.

Case studies
Case studies are the preferred strategy when 'how' or 'why' questions are being posed (Ellram, 1996; Yin, 1994). This strategy has its strength in its ability to deal
with a full variety of evidence such as documents, artifacts, interviews, and observations (Yin, 1994) and it is an appropriate methodology when focusing on one organisation/entity. Moreover, this strategy enables the researcher to develop a better insight into a complex and relatively unexplored phenomenon. Therefore, it is suitable to conduct a case study to answer research questions: why postponement? And how can it be successfully implemented? For example, case studies have been used to centre on the practical experience of companies in implementing postponement (e.g. Cooper, 1993; Feizinger and Lee, 1997; Van Hoek, 1997; Van Hoek et al., 1998). In-depth studies of cost and benefits of postponement also look to case studies. Several case studies indicate that companies trade off specific postponement options against supply chain options without postponement. Thus, the trade-off studied in postponement tends to be integrated with the fundamental trade-off in configuring the supply chain. For example, Garg and Tang (1997) study two products: personal computers and hairdryers. Their findings are relevant to the decision whether to adopt postponement early (i.e. mid- or up-stream in the supply chain) or late (i.e. down-stream).

Case study research may be defined as research in which the researcher has direct contact with the participants and the participants are the primary source of the data. It follows, then, that the primary methods used in case research are interviews and direct observations. Other methods, such as experiments and surveys, separate the phenomenon from its context (Yin, 1994). Among the limitations of case studies are the lack of generalisability and the possibility of the research influencing the phenomenon under study. By contrast, statistical and mathematical generalisations can be made on the basis of modelling and surveys.

Surveys

Few surveys exist in the postponement literature. Droge et al. (1995) examine the impact of form postponement on organisational structure in terms of formal control, horizontal and vertical differentiation, and size. In another survey, Bowersox et al. (1992) link organisational characteristics to organisational capabilities in the field of logistics. Van Hoek (1998a) identifies postponement applications throughout the supply chain, ranging from engineering and purchasing to distribution and provides a statistical generalisation using factors from prior case studies and modelling studies.
More recently, Chiou et al. (2002) conduct a questionnaire survey in the information technology industry to examine the strength of the relationships among four postponement strategies (i.e. manufacturing postponement, assembly postponement, packaging postponement and labelling postponement).

In empirical studies on postponement, the less use of survey than case studies might be because, at that time, research on postponement was basically exploratory. The state of knowledge creation had not reached the stage of developing strong statistical generalisable inter-relations between constructs, or even the development of multi-item constructs at all. As the attention on postponement from both academics and practitioners has significantly increased in recent years, I expect that the use of surveys on postponement will be increased. In the same vein, with the development of research on postponement, the upgrade of the research methodology in postponement might be increasingly appealing. More recently, Van Hoek (2001) suggests that triangulation is a viable option to integrate findings from the postponement literature into a coherent research plan at a more advanced methodological level. For example, case studies in different industries are conducted to obtain a good perspective on cross-industry and cross-company variations in the applicability of postponement and in the range of possible postponed operations. Calculation modelling is also used to gain more insight into the financial effect of postponement on operating costs and on the role of specific operating characteristics. However, these insights are difficult to generate on the basis of individual case studies only (e.g. Yin, 1994), especially because it appeared difficult for case companies to estimate accurately the costs/benefits of postponed manufacturing systems. Therefore, a survey is conducted to help build statistical generalisations on the extent to which companies have actually implemented postponement in the context of operational feasibility and organisational reconfiguration. However, it should be noted that the use of a particular methodology must be based on the nature of the actual questions at hand. In essence, the next step in my research is to verify a theory. According to Punch (2000), a theory verification study aims to test a theory or, more accurately, to test hypotheses derived from the existing theory. Such a study starts with a theory, deduces hypotheses from it, and proceeds to test these hypotheses. In this context, a questionnaire survey is the most appropriate strategy to answer this research. In Subsection 4.2.2, I will further show why I chose a questionnaire survey,
rather than other methods. I will also present the triangulation thinking in my research (in Subsection 4.2.1).

**4.2 RESEARCH DESIGN**

A comparison of basic research designs is shown in table 4.1. Exploratory research is used to gain insights and ideas. It is generally used by researchers to help form hypotheses and explore the nature of a phenomenon. An exploratory design was therefore a very suitable approach for the initial investigations with this research, before the research questions were formulated. A causal (or explanatory) research design is concerned with the possible cause-and-effect relations there may be within the subject under scrutiny (Churchill, 1995). Descriptive research can be used to investigate areas of interest, with an aim of adding weight, or challenging an argument. It is used to provide a description of the situation, for example, by capturing how frequently things occur (Churchill, 1995). Typically descriptive research is also guided by hypothesising what trends are expected in the research findings. These trends may also be used to infer possible relationships between variables, and therefore to formulate hypotheses that can be tested via a causal investigation. My research questions require a descriptive research design approach as it can best explore the reality of the hypotheses.

Sekaran (1992) also provides a useful general model of a research process for basic applied research. The model clearly illustrates the process to be followed by a researcher having a rather vague idea of a potential problem worthy of research, through formulation of a working hypothesis based upon observation and review of the work of others, which may usefully contribute to the formulation of a testable hypothesis or set of hypotheses. These hypotheses are tested using an experiment designed specifically for the research question. Analysis of the experimental results provides answers to the research question together with explanations that can be
verified, adding to a body of knowledge. Following this research process, I have proposed five hypotheses in Chapter 3. The role of research design is to show how the research questions will be connected to the data, and the tools/procedures will be used in answering them. The design here is the basic plan for a piece of empirical research, and includes main ideas such as strategy, sample, and the tools and procedures to be used for collecting and analysing empirical data (Punch, 2000). Research design must follow from the questions and fit them with data. According to my research questions and hypotheses, the purpose of my research is to explore what factors are responsible for the successful implementation of postponement.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Exploratory</th>
<th>Descriptive</th>
<th>Causal</th>
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<tbody>
<tr>
<td></td>
<td>Discovery of ideas and insights (Find the problem)</td>
<td>Find out specifics</td>
<td>Investigate cause and effect relationships (Investigate the solutions/reason)</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Flexible, Versatile, Often the front end of total research design</td>
<td>Marked by the prior formulation of specific hypotheses</td>
<td>Manipulation of one or more independent variables</td>
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<td></td>
<td></td>
<td>Preplanned and structured design</td>
<td>Control of other mediating variables (must be careful to analyse random components)</td>
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<tr>
<td>Methods</td>
<td>Expert surveys, Pilot surveys, Case studies, Secondary data, Qualitative research</td>
<td>Secondary data, Surveys, Panels, Observational and other data</td>
<td>Usually experimental methods</td>
</tr>
</tbody>
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Table 4.1 A Comparison of Basic Research Designs

4.2.1 Qualitative versus quantitative research

At the point when the methodology needs to be selected, the quantitative (concerned with measurement and analysis of relationships between variables, rather than processes) versus qualitative (examining the content and context of processes and meanings in an exploratory fashion) debate begins. The choice and adequacy of whether qualitative or quantitative (in any case, a somewhat crude and oversimplified dichotomisation) embodies a variety of assumptions regarding the nature of knowledge and the methods through which that knowledge can be obtained, as well as a set of root assumptions about the nature of the phenomena to be investigated (Morgan and Smircich, 1980). Many studies begin qualitative (to find out the basics) and later develop into quantitative (after one has an idea of what questions to ask).
The focus of quantitative and qualitative methods is quite distinct (Stake, 1995). Qualitative research tries to grasp the form, content, and some constraints and reasons of the investigated phenomenon and analyse its qualitative characteristics (Lindlof, 1995), whereas quantitative research uses mathematical models and statistical tables to relate the research in impersonal terms (Denzin and Lincoln, 1994). Qualitative research offers the research an opportunity to probe and follow different lines of enquiry because it is generally more flexible than quantitative research, which typically requires answers in particular times and in specific ways. This means that qualitative research often allows for new questions and answers, while quantitative research requires pilot studies to exhaust all possible relevant questions and possible responses as they are not flexible when being administered. The basic assumption in quantitative methodology is that observations and experiments can be replicated. The rigours of quantitative methods do not allow for anything that has not been previously anticipated. Although in practice there are some variations, ideally, the path of quantitative research is traversed from observation to generation of theoretical explanation to further testing of the theory. Recently, the overall schema has been extended with exploratory data analysis, when hypotheses are formulated and reformulated during the analysis. In addition, quantitative types of research can generally be collected with minimum bias and with regular responses that can be easily compared.

Each methodology has its own set of costs and benefits and thus it is possible to develop a research schema that benefits from both methods with particular variables of interest (Seymour, 1992). Many researchers have used overlapping techniques like questionnaires, where responses may be of both qualitative and quantitative nature. In some cases, researchers may quantify qualitative data – for example, coding concepts from interviews and surveys in a manner suitable for statistical analysis. Researchers may also qualify quantitative data – for example, using quotes from complementary dialogue to support a statistical pattern derived from data collection. This raises the issues around the concept of triangulation. Triangulation is to employ a combination of research methods in the study of the same phenomenon (Denzin, 1978), typically used to gather and interpret data (Hammersley and Atkinson, 1983). The rational for triangulation is that different measures or methodologies are complementary to each other, and weaknesses of one methodology could be
overcome by strengths of another, and vice versa. For example, qualitative and quantitative approaches can be combined such that the weakness of any single method is balanced by the strengths of the other method, therefore triangulation can improve internal and external validity (Scandura and Williams, 2000). Triangulation can be applied to many elements of research, including data source (e.g. combining different data sources that are related to the same phenomenon in different contexts), investigator (e.g. examining the same phenomenon by several investigators), theory (e.g. interpreting the same results with multiple perspectives and hypotheses in mind), and methodology (e.g. using different data collection methodologies) (Denzin, 1978; Flick, 1992; Scandura and Williams, 2000). In case studies, for example, triangulation could be done by using multiple sources of data (Yin, 1994). The validity and reliability of data would be enhanced by incorporating opinions of people with different positions and from diverse standpoints. Similarly, it may be possible to triangulate on the research strategies themselves. Researchers might employ a laboratory experiment and a field experiment to examine the same research in question. However, in this case, methodological triangulation involves a complex process of playing each method off against the other so as to minimise the validity of field efforts.

Flick (1992) further argues that theoretical triangulation does not necessarily reduce bias, nor does methodological triangulation necessarily increase validity. Theories are generally the product of quite different traditions so when they are combined, one might get a fuller picture, but not a more objective one. Similarly, different methods have emerged as a product of different theoretical traditions, and therefore combining them can add range and depth, but not accuracy. What is important is to choose at least one method which is specifically suited to exploring the structural aspects of the problem and at least one which can capture the essential elements of its meaning to those involved. In this way researchers may get different sorts of data that can be related to each other and present complementary aspects of the subject under study. They may reinforce one another, enabling researchers to present results with greater certainty. On the other hand, if results conflict, it may point to a weakness in their methodology or genuine inconsistencies between what their respondents say and what they do.
As demonstrated in the next section, basically my research adopts a quantitative approach (questionnaire survey). Although qualitative techniques provide richer and more industry-specific data regarding my research, they have their limitations. Major limitations include: (a) the data are hard to analyse; (b) the analysis is susceptible to subjective interpretations due to the unstructured, non-standardized nature of the techniques; and (c) the study results are difficult to compare (Weiss, 1968). I will further analyse alternative research methods for my research in Subsection 4.2.2. According to Bourque and Fielder (1995), a questionnaire survey can be used only when the objective of the study is clear and not complex. Generally, questionnaires are used to obtain a large database of information with a low level of details. That is, breadth is often emphasised at the expense of depth. Further, it might be found that a questionnaire contains ambiguous questions or that a key question is omitted, or that an inadvertent fault in its design weakens the results (Gorman and Clayton, 1997).

To address this, I will present a clear picture of what is done to carefully design and execute the survey (in Section 4.3). At the same time, taking into account the fact that the main disadvantage (of a questionnaire survey) is the inability to probe respondents for more detailed information, such a weakness could be overcome by qualitative methodologies such as in-depth interviews, where, by not constraining the respondent to a fixed set of replies and through careful probing, an experienced interviewer can elicit a more accurate picture of the respondent’s true opinion about a certain issue. From my experience in pre-testing, I found that e-mail may be used as a qualitative method instead of in-depth interviews, not only due to resource and costs limits, but also due to the difficulty in arranging for a time in meeting top managers (even if as researchers, I tried to be flexible as much as possible). Actually, at the pre-testing stage, I have done some ‘e-mail interviews’ with respondents. Through several round e-mails, I discussed the issues around hypotheses, research questions and the whole questionnaire design (e.g. even possible difficulties in data analyses). The feedback from the pretest was extremely helpful in modifying my initial questionnaire. At the same time, ‘e-mail interviews’ offered me an opportunity to defend my research, giving added confidence in the research design. I will further discuss the issues on e-mail questionnaires in Subsection 4.3.1. After the questionnaire survey, more personal e-mail contacts were available and thus further facilitated my ‘e-mail interviews’. Some of those who participated in the
questionnaire survey were further contacted via e-mail in order to clarify and amplify the results from the survey (e.g. exploring significant findings in greater detail). An open questionnaire was derived from the responses to the survey. My follow-up e-mail questionnaire tried to find out why some responses considerably differ from my expectations with regard to postponement applications. I have received five replies out of 30 e-mail sent-outs. Due to time and cost constraints in my project, I did not try further follow-up methods. Nevertheless, those replies provided helpful input into explaining my survey data (see Subsection 5.4.3). Therefore, the research strategies adopted in this study can be characterised as triangulation methodologies. I believe that through the breadth of the study and the depth of the analysis, the results of my study will be applicable and reliable.

4.2.2 Alternative Methods

In Subsection 4.2.1, I have looked at the issues of qualitative and quantitative research, and triangulation. It should be noted that, in an attempt to answer my research questions, it is important to find a methodology that is appropriate, and achievable within the constraints of the research project. The nature of the principle research questions helped to define the instrument used, as did the nature of the population under investigation and the limitation of resources. As demonstrated later on in this section, the data collection procedure used in the research mainly involved one form of questionnaire survey. A questionnaire was felt to be the most appropriate, but a variety of different research designs could have been used in this research, namely: observation, case study, in-depth interview and self-administered questionnaire.

4.2.2.1 Alternative qualitative methods

Observation

Observation of participants is one of the best methods by which data can be collected about issues companies deal with in the implementation of postponement, in order to ascertain management behaviour, because the researcher can use this technique to produce and record data himself/herself by means of careful observation of the manager’s work as it occurs. However, the technique has not been used in this research. Apart from the limitations of costs and time, this is also because: (1). Although it is possible to collect information on the behaviour of managers, Boukersi
(1991) reports that observational techniques are ineffective in generating information about perceptions, beliefs, feelings, motivations or anticipations which, by their very nature, are impossible to observe. The great part of this research is concerned with studying the perception and beliefs of respondents (e.g. the level of uncertainty and barriers to postponement); (2). Access to organisations may be difficult. Saunders et al. (1997) report that difficulty of access to organisations is one of the barriers to using observational techniques to collect data. They also argue that participant observation has been used much less in management and business research. However, this does not mean that it has limited value to management and business researchers. Indeed, it can be a very valuable tool, usually as the principal research method, but possibly in combination with other methods; and (3). Observation requires skills and techniques that may not be available to everyone. Delbridge and Kirkpatrick (1994) note that not everyone is suited to this type of research, much of which relies on the building of relationships with others. For example, a certain amount of personal flexibility is needed in conducting the observation. As a participant observer, one has to be 'all things to all people'. His/Her own personality must be suppressed to a great extent and this is not something with which some people may feel comfortable.

Case study and in-depth interview
The case study and in-depth interview methods are also inappropriate for this study (testing my hypotheses). Studying a concrete case will have the advantage of being able to study a process in depth from start to finish (Hellevik, 1995). However, one limitation of analysing a single case is the difficulty of determining whether the patterns found are typical, making it difficult to generalise from one case. In addition, the nature of my research (e.g. attempting to identify whether or not uncertainty is a general factor for adopting postponement strategies) may lead me to investigate companies in different industrial sectors. It may not be applicable to use many case studies in my research. Further, according to Saunders et al. (1997), an in-depth interview is difficult to conduct properly, it needs high levels of competence, and there are also logistical and resource issues involved. In addition, certain groups, such as executive managers, may not be prepared to set aside time for interviews. Therefore, conducting large-scale in-depth interviews can not be used in this research, although personal interviews yield better information than that collected by mail and
telephone. However, as discussed in Subsection 4.2.1, (e-mail) interviews could be integrated into my research.

4.2.2.2 Alternative quantitative methods
There are several alternative quantitative methods that could have been used in this research, namely: telephone interviews, structured interviews, and self-administered questionnaires. Unlike a self-administered questionnaire, the former two allow the opportunity for some opinion probing. However, telephone interviews and structured interviews have not been used in the present study because they are not popular and managers may not have the time for interviews, as mentioned before. Self-administered questionnaires have been chosen here for collecting data from companies. This is considered as the most appropriate analytical approach for the study since:

1. Ideally the value or utility of management strategy promotion should be measured quantitatively, preferably using a financial measure which will provide an accurate evaluation of costs and benefits. Cost-benefit analysis (CBA) is a favoured technique best suited for evaluation (Pointon, 1978). However, it is difficult to conduct CBA of postponement. In fact, it has been long established that part of the neglect in postponement applications may be due to the absence of effective means for assessing the feasibility of postponement before implementing it (Bucklin, 1965; Zinn, 1990b; Van Hoek et al., 1998; Ernst and Kamrad, 2000).

2. Ease to use and complete. This technique is well-known by most people, so it is not difficult to use and it is easily understood. Also, a questionnaire does not take a great deal of time to answer because it does not require much writing. In addition, the survey focuses on managers at a certain level in a given company. Although members of this group may be prepared to complete a questionnaire, they might not be prepared to devote time to personal interviews.

3. The sample companies are located in different areas of United Kingdom, so e-mail or postal questionnaires are considered to be a better communications medium than other methods. This can be reflected by Dawe's (1978) view that it is possible to reach a wider geographical dispersion by using a mail questionnaire
than is practical through personal contact. Also, Wass and Wells (1994) argue that if the number in the organisational sample to be surveyed exceeds 30, it will be more efficient to use a questionnaire rather than interviews. The sample used in this study consists of 368 companies;

4. Collecting data by using questionnaires may be more suitable to this research than other techniques because of the characteristics of the research objectives. For example, the research lists a set of factors and requires them to be measured to ascertain the importance of those factors (such as in performance measurement and barriers to postponement implementation). In some sense, I try to ascertain the opinions and attitudes of respondents toward postponement implementations. Saunders et al. (1997) state that the questionnaire can be used for research undertaken to discover attitudes and opinions, for example, the use of mail questionnaires may achieve this measurement better than other methods. This may be a more valuable tool if used in combination with other methods. As discussed in Subsection 4.2.1, the development of information and communication technology enables me to look to 'e-mail interview'.

![Figure 4.1 The Maturity Cycle of Research (Source: Malhotra and Grover, 1998)](image)
5. The final reason for using questionnaires is because of the current status of methodology in postponement research, which I have discussed in Section 4.1. This is also reflective of Malhotra and Grover (1998)’s maturity cycle of research (in figure 4.1).

4.3 QUESTIONNAIRE DESIGN

Mail questionnaires have sample-related advantages: geographic coverage, larger samples, and wider coverage within a sample population. For example, researchers using surveys will gather a large amount of data from a variety of respondents within a relatively short period of time. In this study, the questionnaire survey is used to obtain information about the effects of environmental uncertainties and managerial practices in the implementation of postponement. Such data could be used to give insight into what factors are related to the successful implementation of postponement. However, apart from the disadvantages inherent to questionnaire survey (e.g. the inability to probe respondents for more detailed information), there are some challenges in conducting the survey. For example, questionnaire survey is very popular in data collection in research while it is known for low response rates. In order to help ensure success of my questionnaire survey, guidelines are sought (and partly modified) from the field of the social sciences and from the literature pertaining to questionnaire surveys previously undertaken in postponement research. Because of technological changes and other changes in society and its perceptions, the effect of a particular technique on increasing response rates to mail surveys could change over time. Therefore, I mainly look at those techniques that are presented in the last two decades, with hopes of finding the techniques that consistently lead to increased mail response rates, not only across research studies, but also over time. I also alter some guidelines according to recent findings. As Dillman (1978) argues that the mail response behaviour depends on the subjects’ own overall assessment of
all the research elements visible to them, here I try to provide a clear picture of what is done to maximise the response rate by carefully designing and executing the survey. At this point, I agree with the view that most problems with questionnaire analyses can be traced back to its design phase.

4.3.1 Response Rates

Although there is no generally accepted minimum percentage for response rates, non-response bias is always a concern for researchers conducting mail surveys. One method for testing non-response bias is to test significant differences between the response of early and late waves of returned surveys. This method is based on the assumption that the opinions of late respondents are somewhat representative of the opinions of non-respondents (Armstrong and Overton, 1977). I will further discuss this issue in Subsection 5.2.2 (p. 123-124). In addition to low response rates increasing non-response bias (Paxson, 1992), it puts generalisations from the survey findings at question (Wilson, 1999). Therefore, low mail return rates have motivated researchers over the years to search for ways to increase response rates. Possibly, the best encouragement to participate is the subject’s perception of how important the study is. To achieve a satisfactory response rate, it is ideal to ask questions which respondents are interested in. Therefore, one major concern is the balance between what I want and what companies are very interested in.

In the literature, there is a range of ways suggested and tested extensively for increasing the response rates, such as show positive regard, give tangible rewards/incentives, multiple contacts (follow-up), and make the questionnaire short, interesting and respondent-friendly. In particular, I have first considered the following two options which are consistently identified to affect the response rates positively:

1) Estimate the non-response and make allowance for it, e.g., enlarge the sample and enclose monetary incentives. As this study is a large scale survey as part of my PhD research project investigating postponement applications by companies, it is probably not wise or permissible to offer any financial incentives and thus offering any kind of allowance was rejected. Instead, I offer some non-monetary incentives to respondents, which may be sufficient enticements to motivate them.
to complete the questionnaire (which is probably a task above and beyond their typical job duties). As an incentive for companies to participate in the research, they are promised to receive a summary report at the end of study, contrasting their approach evaluating postponement strategies to that of other companies;

(2) Supplement the survey with multi-method follow-up to concentrate resources on reluctant respondents. It has been generally accepted that all follow-up techniques have a positive influence on response rates. Two or three reminders (and even more) have proven effective. In some cases those follow-up techniques may increase the cost, but they have been consistently effective in improving mail survey response rates. The special attention and effort of additional mailings or special contacts would illustrate the energy the researcher is willing to expend to get the questionnaire recipients' input, making respondents feel that their response is indeed important. However, the use of follow-up techniques has to be balanced against some factors such as the available budgets and time. To ensure a satisfactory response rate, a variation of Dillman's Total Design Method (Dillman, 1978) is used: Two weeks after an initial questionnaire (together with a prepaid self-addressed envelope if by post) is sent off, reminder letters, telephone calls or e-mail (also with an attachment of the questionnaire) will be followed, urging non-respondents to complete it if they have not done so already. Four weeks after the initial (e-) mailing, the replacement packet (as an e-mail attachment) along with a final appeal in the form of a cover letter is e-mailed to non-respondents. This might either simply indicate my commitment or make respondents think that their response is more important than they previously thought. It might also be more convenient for respondents to complete than finding the previous one, which could have been discarded or misplaced.

I also consider the following steps to encourage the respondents to complete the questionnaire:

(1) Make the most of a cover letter. Once a recipient receives my questionnaire, I may need to motivate him/her to complete it. The cover letter offers an opportunity to provide the motivation. My cover letter is short and includes the purpose and significance of my study, and assurance of confidentiality of all
information. More specifically, the cover letter starts with a mandatory and benefits appeal by reminding the recipients of some thinking referring to a prestigious (both researcher- and practitioner-oriented) book (*Lean thinking*) and an article in *Harvard Business Review*, thereby identifying the research topic as of both academic and managerial importance. Then an altruistic appeal is utilised by stating that the questionnaire is the final stage of my research requirements. Finally, an egoistic appeal is utilised by stating that their response as a manager is of importance to the research;

(2) Set up the questionnaire to justify the time and the effort involved in completing the questionnaire. Considerable care is given to ensure simple and quick completion of the questionnaire but also yielding meaningful data for the research. Since shortening the questionnaire has been identified as one of the most effective methods of maximising response (Dillman *et al.*, 1993 and 1994), I keep the length of the questionnaire as short as possible, but compatible with receiving useful information in order for respondents to take a minimum of their time. Another obvious reason for this is that longer questions might cause respondents to lose track of the questions. Most questions are multiple choice questions, with a limited number of open-ended questions to invite comments where appropriate. Through pre-testing the questionnaire, unrealistic and long-winded questions would be avoided;

(3) Make it convenient to complete and return the questionnaire. It has been indicated that a combination of online and postal approaches will positively affect the response rate and data quality. On-line surveys can be conducted through e-mail or they can be posted on the web and the URL provided to respondents who have already been approached. The major advantages of on-line surveys are (see Mehta and Sivadas, 1995; Tse *et al.*, 1995; Weible and Wallace, 1998): (1). Short response time; and (2). Saving time and resource associated with the data entry process, since data can be directly loaded in the data analysis software. The empirical research carried out on on-line surveys shows that e-mail surveys generate better rates than web-based surveys and that they provide greater research control over the sample of respondents (especially avoiding multiple entries to the survey by the same respondent). However, the safety issue is often
raised on on-line surveys, possibly disencouraging respondents from participating in the survey. Furthermore, the mode of contact also depends on whether the 'right' person's contact details are available as well as required. Quite often, there is no personal electronic contact (e-mail address) details available, therefore the 'right' person in the company can only be approached by post. Most of the time on the internet, if one does not send the e-mail to the right person, he/she does not usually have the opportunity to network to the right person. At this point, the mail survey gives respondents the choice of being anonymous, whereas e-mail always discloses the sender's identity. Thus, I mainly posted the questionnaire to all respondents, while the other questionnaires were distributed via e-mail when personal e-mail addresses are available. In the cover letter with postal questionnaire, it is indicated that they can get an electronic version of the questionnaire by e-mailing me. In this way, my survey provides both postal return (with a self-addressed postage-paid return envelope) and online return (e-mail) options.

I also take into account facts which seem to be associated with a high response in surveys, such as mailing the questionnaires midweek, giving the questionnaire a title that is short and meaningful to the respondent (since some people may discard a questionnaire based entirely on its subject or sender, particularly in an e-mail), choosing the colour of the questionnaire and indicating university sponsorship. Some concepts are defined in the questionnaire so that respondents would have a common understanding of their meanings. Recently, Sheehan and McMillan (1999) explore the impact of pre-notification of a survey on the speed of the responses, and the positive relationship is partially supported by their findings. However, doing so in a large scale questionnaire survey might mean a significant increase in time and costs and thus I have not used such additional contacts as prenotification letters and thank-you cards. In addition, deadline date is not stated in the cover letter as Diamantopoulos and Schlegelmilch's (1996) findings indicated that the creation of a sense of urgency is not likely to encourage response.
4.3.2 Identifying Respondents

The research on non-response in surveys has identified three kinds of non-respondents: (1) Those who simply refuse to supply information; (2) Those who are unable to supply answers. For example, they do not feel qualified to rate programs, or they are asked to rate programs in the area they feel is not appropriate given their field of expertise; and (3) Those whom the data collection procedures do not reach (e.g. due to wrong address). The latter two reflect how important it is to identify the ‘right person’ who is able to supply information in the survey and thus should be approached to participate in the survey. It is also favourable to avoid the ‘gatekeeper’, where the questionnaire might be completed by an individual other than the person the questionnaire is sent to.

Survey research makes inferences about some characteristic, attitude or behaviour in the population from which the sample is drawn (Creswell, 1994). As Patton (1990) outlined, ‘there are no rules for sample size in qualitative inquiry, sample size depends on what one wants to know, the purpose of the inquiry, what’s at stake, what will be useful, what will have credibility, and what can be done with available time and resources’. I determine the sample size mainly on the basis of meeting the information requirements for the research, the expected response rate, requirements for performing statistical analyses, and survey cost. In my survey, the sample companies are selected trying to maintain a balance between those where postponement is extensively applied (e.g. electronics and automotive) and those where it is less extensively applied (e.g. food and clothing). I used a pilot study to help achieve this balance. A list of companies were mainly obtained from Key British Enterprise (KBE) database, Financial Analysis Made Easy (FAME) database and from some other databases such as Kellysearch (http://www.kellys.co.uk/), Kompas (http://www.kompass.com), go4gain (http://www.go4gain.co.uk), International Product Compliance for Electrical and Electronic Products Suppliers & Services (http://www.jxj.com/suppands/ipc/index.html) and Applegate (http://www.applegate.co.uk). In addition, some companies are selected because they have experience with postponement applications. They are identified by surveying the sources of materials like newspaper, magazines and resources from researchers and organisations.
4.3.3 Reliability and Validity

Any research needs to be shown to be reliable and valid for its results to be taken seriously (Gill and Johnson, 1991; Bell, 1993). To determine the adequacy of any measures of any construct, evidence of its reliability and validity must be offered. To develop items, I adopted and adapted questions in the literature (if existing), which is one of the best methods in helping to assess reliability and validity, and assist comparison with the findings of other studies. Saunders et al. (1997) further confirm that adopting and adapting questions may be necessary if comparison with the findings of other studies is required and that this helped in assessing reliability. This is a more efficient method than tailoring questions specifically to the present study, providing that the relevant data can be collected to answer research question(s) and fulfil the objectives of the study. Also, adopting standard questionnaires to maximise close-ended questions can be effective because these questions and instructions have already undergone development and testing. Although for some questions, I have to develop specific measures for the purpose of this research (where no related literature exists), the survey instrument is tested for both reliability and validity, as will be shown in Chapter 5.

Reliability is a measure of the extent to which results of a test can be reproduced repeatedly and consistently by different researchers (Miles and Huberman, 1994). Validity is a measure of the extent to which the question or item really measures what it is supposed to measure (Oppenheim, 1966). According to Yin (1994), consideration must be given to construct validity, internal validity, external validity and reliability. Construct validity refers to establishing suitable operational measures for the concepts being studied (the logical relationships among variables and the way they are measured) (Mason and Bramble, 1989). Internal validity refers to the reliability of a study and whether the chosen items for investigation are sufficient to explain the topic under investigations (Dane, 1990). External validity is concerned with how the conclusion can be generalised to the real world.

Montoya-Weiss and Calatone (1994) investigate the threats to internal and external validity including issues that only significant correlations are reported even when a large number of constructs are included in the study, issues that respondents often are...
allowed to self-select successes and failures, and issues that much of the literature relies on respondents' perceptions rather than objective measures. Yin (1994) suggests using multiple sources of evidence as the way to ensure construct validity. Construct validity is largely achieved by basing the questionnaire used for data collection on the work of previous researchers and using sufficient piloting. Consequently, operational measures such as the percentage of make to order in my survey are identified from previous research. In order to maximise internal validity, multiple sources of data can be used. For example, multiple informants allow data triangulation – an important approach to ensuring data reliability in manager-reported research (Miles and Huberman, 1994). To improve external validity of survey results, I mainly focus on how to improve response rates, e.g. by paying careful attention to details in the questionnaire design.

The importance of multiple sources of data to the reliability of the study is well established (Yin, 1994; Stake, 1995). In discussing reliability, Fowler (1984) states that ‘one step toward ensuring consistent measurement is that each respondent in a sample is asked the same set of questions’ which is the case with this questionnaire. Fowler also states that ‘if all respondents are asked exactly the same questions, one step has been taken to ensure that differences in answers can be attributed to differences in respondents’ and that ‘the questions should all mean the same thing to all respondents’. To ensure that this is the case with this questionnaire, all questions were first pilot tested with a number of individuals with academic and/or industrial backgrounds on postponement.

In Chapter 5, I will further demonstrate how to use statistics techniques to test reliability and validity of items in a questionnaire.

4.3.4 Items Development

The objectives of the survey are to investigate the current postponement applications, and to examine the factors which influence the adoption and implementation of postponement. In addition, it is hoped that the findings could open up more possible areas for future research, and invitations to companies to participate in further studies are also included. The questions include items concerning the environmental uncertainty, postponement, management practices, company performance and barriers
to postponement. The process of item development involves several phases. The following points were taken into consideration when preparing the questionnaires, in the light of the advice of Boukersi (1991) and Bourque and Fielder (1995):

**Item generation**

The literature review and the theoretical study were conducted to determine the initiatives meaningful to the implementation of postponement. A literature search here involves reviewing all readily available materials. These materials can include internal company information, relevant trade publications, newspapers, magazines, annual reports, company literature, on-line data bases, and any other published materials. Some questions were adapted from other studies because this may be necessary in order to compare the findings of the present study with those of other studies, thereby allowing reliability to be assessed. For example, the measure of uncertainty in my questionnaire has been adapted from the one used by many researchers previously so its validity and reliability has already been tested. High degree of validity and reliability has been found. Questions were developed when no existing questions could be adopted or adapted for the purposes of the study. I will further explain how to develop all items in the questionnaire in the next chapter.

**Pre-testing (Pre-pilot study)**

The list of questionnaire items was further developed with the co-operation of several colleagues who are familiar with manufacturing management research and statistics. They have an opportunity to suggest changes to 'keep', 'drop', or 'modify' each item. They are also instructed to suggest new items if they feel that existing ones do not cover the domain of the construct. Other decisions were made on matters that have to be taken into consideration in designing the questionnaire, such as type of question, length and structure of the questionnaire. This led to a preliminary four-page (A4 size) questionnaire. Then, a group of 21 experts in academia, consultancy and management were approached to critique the questionnaire for review, comments and suggestions. Around 50 percent of respondents responded (4 academics, 3 consultants and 3 managers). This provided valuable information about the reliability and validity of the instruments in the questionnaire. The questionnaire was further refined to take the format of a ten-minute self-administered survey.
**Pilot study**

Before using a questionnaire to collect data it should be pilot tested under survey conditions. Pilot testing is a necessary and important part of survey development. It provides useful information about how the survey instrument actually performs in the field. Although it requires extra time and energy, the pilot test is a critical step in assessing the practical application of the survey instrument (Litwin, 1995). A pilot survey can serve several functions within the overall survey process. If there are problems with the questionnaire (such as poorly worded questions), which could not be easily discovered at the questionnaire design stage, they almost always show up here and can thus be recast. More importantly, a pilot survey is one method of obtaining an estimate of the population variance. The major function of the pilot survey, however, is to help 'tune' the proposed process for the main survey. I do this by using the pilot survey to find out whether the survey is going to be successful. That is, will it achieve an acceptable response rate, and provide reliable data on the relevant topics? How I conduct the pilot survey, and whether I learn the right lessons from it, are major determinants of the quality and effectiveness of the final survey. A pilot study involving 33 randomly selected companies, which will not be included in the final sample, was set up to pre-test the questionnaires. I have received 11 replies from those companies. Saunders et al. (1997) state that the purpose of the pilot study is to refine the questionnaire so that respondents will have no difficulties in answering the questions, and there will be no problems in recording the data. In addition, it enables an assessment to be carried out regarding the questions' validity and the reliability of the data collected. For most questionnaires this means that the minimum number of respondents for a pilot study is 10 (Fink 1995b).

In the pilot study questionnaire, I provided respondents with answers like ‘Don’t Know’ and ‘Not Applicable’, in case they are unsure about whether to answer a questions or which answer is the most appropriate. If a large number of respondents choose such options, I may need to examine whether the question is badly worded, or in the wrong place in the questionnaire. I also combine closed questions with space for the respondents to add comments (by providing ‘please comment/explain’), providing the best of closed and open questions. The appropriate recommendations are incorporated into the survey design before the final distribution.
4.3.5 Flow

The questionnaire consisted mainly of closed questions and began with simple ones, and then moved gradually on to more specific issues. For most questions, measurement was done on the lines of a Likert scoring system on a scale of 1 to 5. For example, when asking respondents to determine the degree of uncertainty, a 5-point rating scale is used, where 1 is extremely unpredictable, 2 unpredictable, 3 neither unpredictable nor predictable, 4 predictable, and 5 is extremely predictable. In my original questionnaire, I used a scale of 1 to 7. However, most respondents suggested that the scale in the questionnaire is difficult to be followed. Obviously, adopting a scale of five-points or fewer may make a questionnaire appear more concise and simpler. Further, it has been shown that an increase from five to seven or even nine points on a rating scale does not improve the reliability of the ratings (Elmore and Beggs, 1975; Sekaran, 1992). Fink (1995a) also reports that self-administered questionnaires and telephone interviews should probably use 4 or 5 point scales. The questionnaire consisted of six sections (including introduction part, part I-V) (see Appendix B). In the next chapter, I will present more details about the types of data provided in the questionnaire. The form was designed in this way because it was felt that respondents might become bored and be tempted to leave certain questions unanswered if the form started with more difficult questions.

The questionnaire begins with questions regarding the demographic characteristics of the respondents companies. A major reason for asking these questions was to gather certain information, such as the size of the company (as measured in the number of employees and gross annual sales), which is likely to influence the implementation of postponement. These data are also useful in helping explain the results of the survey and determining differences between the respondents. Fink (1995) reported that knowledge questions are included in surveys in order to achieve the following objectives: (1). To determine if people have enough knowledge about a topic to warrant asking their opinion about it; (2). To identify gaps in knowledge that warrant other kinds of information gathering strategies; and (3). To help explain attitudes and behaviour.

In my pilot study, some respondents suggested that this section be placed at the end of the survey. However, although it is true that respondents can read an entire mail
questionnaire before answering any of its questions, it is still believed that starting a
questionnaire with simple questions that immediately engage the respondent in the
topic will increase response rates and reduce the amount of missing data (Bourque
and Fielder, 1995). Demographic questions are easier for respondents to answer
because the information sought is well known to them. One question in this part is to
identify the respondent’s position. Actually this question might be a requirement to
improve validity, in order to establish that respondents have direct responsibility for
their company’s strategic decision-making. This is done to ensure the person
completing the questionnaire has the knowledge and ability to provide suitable
information.

4.4 SUMMARY

This chapter has presented the research methodology used to investigate the five
hypotheses. To choose my methodology, I first reviewed the research methodologies
which have been carried out in the postponement literature. In recent years, there has
been considerable empirical research on generating multiple insights into the
relevance of various factors for the implementation of postponement. This is in line
with the development of research methodology in operations management. It has
been increasingly realised that the scope of operations management can not be
captured and explained in its entirety by purely deductive tools such as mathematics
and its extension such as operations research (Swamidass, 1991). Since 1980, we
have witnessed increased deployment of empirical research designs, particularly
survey research, to better understand issues such as manufacturing strategy and
quality management (Rungtusanatham et al., 2003). Based on my review on
postponement research, I also expect that the use of surveys on postponement will be
increased.
To decide on an appropriate and defendable research methodology, I also examined such issues as the classification of basic research designs, qualitative research versus quantitative research and triangulation. It should be noted that it is also important to find a methodology that is appropriate and achievable within the constraints of an individual research project. Although a variety of different research designs could have been used in this research (e.g. observation and case study), questionnaire was felt to be the most appropriate. One of the most important reasons for using questionnaires in this research is because of the current status of methodology in postponement research (see Section 4.1).

To test my hypotheses, I chose to conduct both e-mail and postal questionnaire surveys. However, apart from the disadvantages inherent to questionnaire survey, there are some challenges in conducting it. As a result, I have provided a clear picture of what has been undertaken in terms of designing and executing the survey. For example, to maximise the response rate, I have reviewed the guidelines from the field of the social sciences, as well as from the literature pertaining to questionnaire surveys that have previously been conducted in postponement research. I will present further details on how to design the questionnaire in the next chapter. More specifically, I will address some issues raised during the pre-test of the questionnaire before conducting data analysis.
CHAPTER 5. DATA ANALYSIS AND FINDINGS

In my pre-testing, some measurement issues were raised around the questionnaire. In particular, the perceptual measures of environmental uncertainty and performance were criticised by some respondents. To address this, this chapter first presents details on how I developed the instruments of the questionnaire. The successful measure of the questionnaire survey and its outcomes relies on the use of both appropriate sampling methods and a valid research instrument. The importance of developing reliable and valid measures of constructs in any given study has been noted by Churchill (1979) and DeVellis (1991). Poor measurement can limit the validity of a study’s findings. Therefore, the methodologies and procedures in sampling, and reliable and valid instruments of measuring research variables are crucial in my data analysis. Accordingly, Section 5.2 and 5.3 provide a description of the respondent sample (including the test of non-response bias) and the validation of the survey instrument. Following DeVellis (1991) and Malhotra and Grover (1998), various data methods such as Cronbach’s coefficient alpha and exploratory factor analysis were used to assess the measure quality of respective construct, after data have been collected. The results of further data analysis are reported in Section 5.4. Following a preliminary test for multi-collinearity, I use simple/multiple regression analysis to test my hypotheses (with regard to the relationships among postponement, uncertainty, managerial practices and company performances). I also report the results of postponement applications and barriers to postponement. The analysis of the results of the survey in this chapter was performed using the Statistical Package for Social Scientists (SPSS-Version 11.5 for Windows).
5.1 QUESTIONNAIRE DESIGN

This section presents details on how I developed the instruments of the questionnaire. As mentioned before, the reason behind this is to address measurement issues raised by some respondents during my pre-test of the questionnaire. Additionally, in doing so I will add greater confidence to the reliability and validity of those measures adopted in my questionnaire.

5.1.1 Postponement applications (Part I)

The focus of this part is to identify the postponement activities which are currently used in British companies. Building on measures of postponement by Droge et al. (1995), Van Hoek (1998a) and Chiou et al. (2002), a company's extent of use of a postponement strategy is assessed by measuring the percentages of goods engineered to order, purchased to order, made to order, assembled to order, packaged to order, labelled to order and shipped to order (as shown in table 5.1). For example, to assess logistics postponement, respondents are asked to specify the degree to which shipment is undertaken after customers' orders are received. In the questionnaire, respondents were provided with the definitions of all items operationalised with postponement. Validity and reliability of this measure have been provided by Van Hoek (1998a).

<table>
<thead>
<tr>
<th>Variables in the questionnaire</th>
<th>Level of postponement applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering to order</td>
<td>Postponed engineering</td>
</tr>
<tr>
<td>Purchase to order</td>
<td>Postponed Purchasing</td>
</tr>
<tr>
<td>Make to order</td>
<td>Postponed Manufacturing</td>
</tr>
<tr>
<td>Final manufacturing/assembling to order</td>
<td>Postponed final manufacturing/Assembling</td>
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<td>Packaging/labelling to order</td>
<td>Postponed packaging/labelling</td>
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<tr>
<td>Shipment to order</td>
<td>Logistics Postponement</td>
</tr>
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</table>

Table 5.1 Operationalisation of the Concept of Postponement
5.1.2 Managerial practices (Part II)

Little research has been directed to the appropriateness of managerial practices for pursuing postponement strategies in the literature and thus there are no existing measures. I first developed the measuring items based on the literature review and the theoretical study. After my pre-testing, a total of 21 factors emerged which are classified into two groups: administrative issues and technological issues. Respondents were asked to what extent 8 statements (about administrative issues) correctly describe their company, where 1 = strongly disagree, 5 = strongly agree. Respondents were also asked to what extent 13 initiatives/systems have been implemented in their company, where 1 = not pursued, 5 = fully in place.

5.1.3 Performance measurement (Part III)

To address the company’s overall performance, I use a perceptual measure of performance because obviously many of the respondents are reluctant to disclose (objective) performance data (e.g. financial data) due to confidentiality issues (Ward et al., 1996) and the use of accounting data (to measure company performance) ignores opportunity costs and the time value of money (Chen and Lee, 1995). Many researchers have asked for the company’s gross profit level relative to its competitors in the industry as an indicator of overall company performance. However, this measure would have been of limited value in making comparisons across multiple industries, as financial measures of success vary from industry to industry (Vickery et al., 1993). Bowersox et al., (1999b) also suggest that multiple environmental factors and one-time incidents make it virtually impossible to use pure financial results as an objective measure of performance. Therefore, I adopted the perceived performance measure recently developed by Pagell and Krause (1999), which allows for different needs due to differences in industry or different strategies while still allowing some comparisons on performance. The main reason for this is that my research design intended to maximise the number of industries sectors represented in an attempt to assess which factors are generally related to the implementation of postponement. In addition, Ward et al. (1996) also show that there is a high correlation between objective data and perceptive performance measures that managers can readily provide.
I ask respondents first to rank the importance of what are generally considered the main goals for their company: quality, costs, delivery/responsiveness, and product innovation. In addition, they are given the option of including other goals that are unique to their company, and to rank goals that are not applicable as zero. Once the goals are ranked, respondents are asked to assess theirs on each goal on a 1-5 scale. I calculate performance by multiplying the rank of each goal times the level of performance on each goal, summing the total, and then dividing by the maximum score they could have achieved if all applicable categories had a score of five.

5.1.4 Environmental uncertainty (Part IV)

Environmental uncertainty has long been studied in the strategic management and organisational theory literature (Barnard, 1938; Thompson, 1967; Lawrence and Lorsch, 1967; Duncan, 1972). However, the literature in this area could hardly be described as unified, because various authors have conceptualised and measured it differently (e.g. Duncan, 1972; Wernerfelt and Karani, 1987; Swamidass and Nwella, 1987; Kreiser and Marino, 2002). Early efforts to capture environmental uncertainty tended to employ relatively simple, unidimensional measures. Over time, measures of environmental uncertainty have tended to become increasingly complex with numerous contemporary researchers utilising multidimensional tools. A number of elements can be identified as relevant to measures of uncertainty in empirical studies, such as complexity (number of elements in the environment), dynamism (change over time and in the rate of change), volatility (the extent to which changes are rapid), unpredictability, stability, diversity (variety of elements), variability and heterogeneity (e.g. Downey and Slocum, 1975; Aldrich, 1979). While so much interest has been placed on how uncertainty is conceptualised, operationalised and measured, there is little agreement on which dimensions are key. Even for the same dimension, the actual operational measures vary from study to study. Those differences might be one of the main reasons why there are inconclusive results on the uncertainty research, such as conflicting views of the relationship between uncertainty and vertical integration.
(Krickx, 2000), and the relationship between the level of uncertainty and purchasing structure (e.g. Duncan, 1972; Corey, 1978; McCabe, 1987).

I chose to use a particular multi-dimensional measure of perceptual environmental uncertainty, which includes the following elements: customers, competitors, technology and government regulations (since they are all relative to the adoption of postponement). A similar set of measures have been used by many researchers (e.g. Duncan, 1972; Swamidass and Newell, 1987; Miller, 1993; Werner et al., 1996; Lewis and Harvey, 2001). They have been tested in terms of reliability and validity (e.g. Miller, 1993; Werner et al., 1996). This measure was felt appropriate for my survey since:

(1). Multidimensional operationalisations are useful when uncertainty is one of primary interest, while simple measures are useful when uncertainty is a secondary variable of interest and only broad analyses are necessary (Kreiser and Marino, 2002). My first research question is concerned with the impact of environmental uncertainty on the adoption of postponement and thus uncertainty is a primary variable in my research. A complex (multidimensional) measure should be employed in order to ensure more precision and comprehensiveness while measuring the construct;

(2). Measures of perceived uncertainty are based on the belief that it is impossible for a company to fully acquire knowledge about its environment and this lack of information creates uncertainty for the company (e.g. Lawrence and Lorsch, 1967; Duncan, 1972). This is consistent with my understanding that, given that it is unrealistic to completely eliminate those uncertainties such as inherent to dynamic markets, postponement may be thought of as a powerful strategy to cope with uncertainty (Yang et al., 2004). Miller (1993) also found that uncertainty perceptions were consistent across industry sectors. My survey is targeting companies across four industry sectors; and

(3). Companies respond to the environment perceived and interpreted by the decision makers and thus the environmental conditions that are not
noticed do not affect management's decision making (Duncan, 1972; Sawyerr, 1993). That is, when managers perceive the environment as uncertain they will make decisions that are designed for an uncertain environment. A similar view is also explained by Hitt et al. (1982), 'the recognizable pattern of organisational responses to environmental conditions is determined not so much by the objective characteristics of the organization-environment interactions as by managerial perceptions of the strategic importance of the critical areas contained within different organizational functions'. Thus a perceptual measure is more appropriate for this research to investigate the influence of environmental uncertainty on the adoption of postponement.

I have also made some modifications to the set of items above in the literature. For example, I eliminate the item that deals with the predictability of unions, since the percentage of unionised workplaces has fallen dramatically and this would not apply to a majority of current companies. Although I recognise that there are other sources of uncertainty, I only assess external environmental uncertainty because of its apparent centrality to the adoption of postponement (Yang and Burns, 2003). Instead, I use the degree of other uncertainties to examine whether a company is ready for postponement in the questionnaire (barriers to postponement). In summary, this part of the questionnaire provides fourteen items to measure environmental uncertainty: three for competition, four for products, markets and demand, three for government and policies, and four for technology. For each item, the respondents are asked to evaluate its predictability on a five-point Likert scale where 1 = extremely unpredictable, 5 = extremely predictable.

In pre-testing the questionnaire, some respondents criticised that the use of a single respondent for each company in my survey might cause a potential bias, especially for perceptual data such as environmental uncertainty here. However, Miller and Roth (1994) note that the higher the respondents' managerial rank, the less of an issue a single respondent becomes. Because my questionnaire was distributed to top management (as will be shown in Subsection 5.2.1) at their respective business units/companies, the biases potentially introduced through the
use of a single respondent should be mitigated. Such respondents are chosen because they would have knowledge of managerial practices as well as knowledge of their competitive environment.

5.1.5 Barriers to Postponement (Part V)

In order to get a better impression of what factors are likely to influence the successful adoption of postponement, I am also interested in the barriers to extending postponement initiatives. Again, no such research has been done in the literature. In the same way as used in part II, a total of 13 factors were identified from the literature review and included in the questionnaire to measure barriers to postponement. Respondents are asked to indicate the extent those factors companies perceive inhibit the extending use of the implementation of postponement, where 1 = not relevant at all, 5 = most significant.

5.2 DESCRIPTION OF THE SAMPLE

Malhotra and Grover (1998) indicate that sample size is the most important factor in establishing adequate power for a test. In order to get precise and reliable findings, the efficient sample size should be estimated first (Fink, 1995b). The formulas for the efficient sample size in terms of means, suggested by Henry (1990) and Walpole and Myers (1993) are shown as follows:

\[ Z = \frac{\hat{\mu} - \mu}{\sigma / \sqrt{n}} \]  

(1)

\[ n' = \left( \frac{Z\sigma}{\hat{\mu} - \mu} \right)^2 \]  

(2)
Where

$Z$ is the $t$ value for the desired confidence. For the current research, the desired confidence level is set as 95% and therefore the $t$ value for the desired confidence is 1.96, i.e. $Z = 1.96$.

$\sigma$ is standard deviation estimate. Usually, the standard deviation of the variable can be estimated from a previous study (Henry, 1990). Based on similar studies, the biggest standard deviation is estimated as 1.00. The $\sigma$ in this study is thus set as 1.00.

$\mu$ is the sample mean, $\mu$ is the population mean, $\mu - \mu$ is the tolerable error.

The literature on postponement survey has not provided such information. Therefore, from a conservative point of view, I set the tolerable error in this study as 5% of the largest measure score 5 in my 5 point scale, i.e. $\mu - \mu = 0.25$.

$N$ is the population size. The population size in the current study is 7680 (see table 5.5).

$n'$ is the sample size without the finite population correction; $n$ is the sample size with the finite population correction.

From formula (1), (2) and (3), I have

\[
n' = \left( \frac{Z\sigma}{\mu - \mu} \right)^2 = \left( \frac{1.96 \times 1}{0.25} \right)^2 = 61.5
\]

\[
n = \left( \frac{n'}{1 + \frac{n'}{N}} \right) = \left( \frac{61.5}{1 + \frac{61.5}{7680}} \right) = 61
\]

Therefore, the theoretical sample size in my research is estimated as at least 61. That is, the current research will be 95% confident that the estimate of the mean
will fluctuate within 5% of the largest measure score above or below the true mean. To obtain this level of precision, a sample size of 61 is needed after taking the finite population correction into account. Considering the fact that 20% response rate is usually satisfactory (e.g., Yu and Cooper, 1983; Malhotra and Grover, 1998), a target sample of about $61 / 0.2 = 305$ was considered desirable for this study. In this study, I surveyed 368 manufacturing companies.

5.2.1 Demographic data for the respondents
The current research focused on four different industry sectors, namely food, clothing, automobile and electronic industries. The rational for selecting those four industries is that they provide a balance between industries where postponement is extensively applied (electronics and automotive) and industries where it is less extensively applied (food and clothing) (Van Hoek, 1998a). The companies surveyed in this study represent the following UK SIC (2003) codes: 1593 (wine), 1596 (beer), 174 (made-up textile articles, except apparel), 177 (knitted and crocheted articles), 181 (leather clothes), 341 (motor vehicles), 3541 (motorcycles), 3542 (bicycles), 2971 (electric domestic appliances), 3002 (computers and other information processing equipment), 323 (television and radio receivers, sound or video recording or reproducing apparatus and associated goods), 332 (instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment), and 334 (optical instruments and photographic equipment). According to UK National Statistics (2003), there are 7680 such manufacturing companies in UK (only those companies classified into the above SIC codes have been counted), which constitute the entire research population of this research.

The self-reported titles/positions held by responding individuals in 76 usable responses are summarised in Table 5.2. As can be seen, for the most part, key decision-makers in the responding companies completed the questionnaires. The majority of respondents held top management or executive positions: about 53 percent (41 respondents) were presidents, chairman, owners, or managing directors. Other directors (rather than managing directors) account for around 29 percent of the respondents (22 respondents). Importantly, those respondents were in positions that assumed both the greatest familiarity with their companies’
manufacturing activities and involvement in business policy decision making, suggesting that they provided information that is within the domain of their responsibility. Those key informants assure the reliability of the information provided (Huber, 1985). Phillips (1981) and Schwenk (1985) report that key informant bias would not have occurred as top management responded to questions within their level of responsibility.

<table>
<thead>
<tr>
<th>Title/Position</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managing Director</td>
<td>34</td>
<td>44.74</td>
</tr>
<tr>
<td>Other Director</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial Director</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Operations Director</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Technical Director</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Finance Director</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Sales &amp; Marketing Director</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Not Specified</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Manager</td>
<td>8</td>
<td>10.53</td>
</tr>
<tr>
<td>General Manager</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Technology &amp; Quality Manager</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Marketing Manager</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Plant Manager</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Owner/(Vice-) President/(Vice-)Chairman</td>
<td>7</td>
<td>9.21</td>
</tr>
<tr>
<td>No title reported</td>
<td>5</td>
<td>6.58</td>
</tr>
<tr>
<td>Total companies</td>
<td>76</td>
<td>100*</td>
</tr>
</tbody>
</table>

Table 5.2 Position/Title of Respondents (Self-reported)
* Column sums to 100.01% because of rounding error

With regard to company size, there is no single universally accepted measurement, and several criteria have been suggested in the general literature. For example, Robinson and Pearce (1984) found that company size is typically defined on the basis of either annual sales or number of employees. However, Agarwal and Ramaswami (1992) argue that most indicators of company size are likely to strongly correlate. In the present study, the total number of employees has been selected as a measure of company size because the pilot test suggested that employment data would be more readily available, as opposed to alternative size criteria, such as sales volume. Furthermore, Katsikeas et al. (1997) state that employee numbers are relatively stable because they are not influenced by price levels. In this study, the number of the companies’ employees (in 76 usable responses) ranged from less than 50 employees to over 500 employees, as shown in table 5.3. Those companies with 500 employees and less were classified as small and medium-sized companies, while those with more than 500 employees...
were classified as large companies. Demographic data indicated that in terms of employment, the majority of the respondents were small and medium-sized companies. More than 74% of respondents had 500 employees and less.

<table>
<thead>
<tr>
<th>No. of Employees</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-50</td>
<td>12</td>
<td>15.8</td>
<td>16.2</td>
<td>16.2</td>
</tr>
<tr>
<td>51-100</td>
<td>24</td>
<td>31.6</td>
<td>32.4</td>
<td>48.6</td>
</tr>
<tr>
<td>100-500</td>
<td>19</td>
<td>25.0</td>
<td>25.7</td>
<td>74.3</td>
</tr>
<tr>
<td>501-1000</td>
<td>7</td>
<td>9.2</td>
<td>9.5</td>
<td>83.8</td>
</tr>
<tr>
<td>Over 1000</td>
<td>12</td>
<td>15.8</td>
<td>16.2</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>74</td>
<td>97.4</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>2</td>
<td>2.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>76</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.3 Company Size (number of employees)

5.2.2 Response rates

From the 368 subjects in the target sample, a total of 106 responses were received (see table 5.4). Of these, seventeen responses indicate that the target respondents elected not to participate. Six mail responses were returned without completing the questionnaire, where one company was no longer in business, two responses were determined to be incomplete or not relevant for further analysis, and three respondents had moved from their original locations and left no forwarding addresses. Seven e-mail responses were created automatically via computer e-mail systems because of unknown user names or user names not being listed in public name and address book. Consequently, there were 76 usable responses obtained from a population of 368 companies, representing an overall response rate of 20.7%. There appears to be no generally accepted minimal percentage for response rates (Fowler, 1993). However, it is argued that this response rate is acceptable because:

<table>
<thead>
<tr>
<th>Survey procedures</th>
<th>Usable</th>
<th>Not usable</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>The original (e-)mailout</td>
<td>48</td>
<td>20</td>
<td>68</td>
</tr>
<tr>
<td>Following up by reminder (e-) mail**</td>
<td>20</td>
<td>8</td>
<td>28</td>
</tr>
<tr>
<td>Following up by another e-mail questionnaire***</td>
<td>8</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>76</td>
<td>30</td>
<td>106</td>
</tr>
</tbody>
</table>

Table 5.4 Questionnaire's Respondents

* The targeted companies totalled 368, excluding 33 companies used in the pilot study.
** A copy of questionnaire is attached to every e-mail reminder.
*** Considering the time and cost constraints, I did not conduct second-round mail follow up.
a. The distribution of the sample obtained in the study by industrial sectors reflects very closely the population as a whole. The frequencies of companies within particular industrial sectors and subsequent response rates are summarised in Table 5.5, demonstrating that the sample is representative of the whole population. As shown in Table 5.5, the whole population of British manufacturing companies in this study totalled 7680 companies. There were 76 respondents (excluding those used in the pilot study). The largest number of participating sector was the electronics sector, which has 4445 companies and represents 57.88 per cent of the whole population. There were 45 respondents in this sector, which represent 59.21 per cent of the total respondents. The second largest sector represented in the survey was the clothing industry, representing 27.62 percent of the whole population (2170 companies). There were 21 respondents (27.64 percent of the total respondents) in this sector. The automotive sector and the food sector are the two smallest ones, consisting of 640 companies (8.33 per cent of the whole population) and 425 companies (5.53 per cent of the whole population) individually. There were six respondents (7.89 per cent of the respondent companies in the survey) in the automotive industry and four respondents (5.26 percent of the respondent companies in the survey) in the food industry.

<table>
<thead>
<tr>
<th>Variance</th>
<th>Companies responding*</th>
<th>The whole population**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>Frequency</td>
</tr>
<tr>
<td>1.33</td>
<td>59.21</td>
<td>45</td>
</tr>
<tr>
<td>-0.63</td>
<td>27.63</td>
<td>21</td>
</tr>
<tr>
<td>-0.44</td>
<td>7.89</td>
<td>6</td>
</tr>
<tr>
<td>-0.27</td>
<td>5.26</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>76</td>
</tr>
</tbody>
</table>

Table 5.5 Comparing Respondents With the Total Population of Manufacturing Companies in UK

* Excluding 33 companies used in the pilot study
** Source: UK National Statistics (2003)

b. Researchers have noted that one sure way to decrease non-response bias (the difference between the answers of non-respondents and respondents) is to attempt to increase the response rates (Armstrong and Overton, 1977), since the larger the bias, the more caution researchers should exercise in
generalising results of the respondent sample to the entire population (Lambert and Harrington, 1990). As I demonstrated in Chapter 4, all efforts have been made to maximise the response rate, such as using incentives for responding and follow-up techniques. Another approach to testing the non-response problem is to sample non-respondents. This approach was dropped because of time and financial constraints in my research. The third approach is to estimate the effects of non-response utilising extrapolation method. This method is based on time trends, e.g. persons responding later are assumed to be more similar to non-respondents. In other words, the opinions of late respondents are somewhat representative of the opinions of non-respondents (Ferber, 1948-1949). For the current study, potential non-response bias was assessed by comparing early and late waves of returned surveys in accordance with the theory of Armstrong and Overton (1977). Thus, the data were divided into two groups of 20 based on early and late questionnaire return times. Using t-tests, the latest 20 responses were compared with the earliest 20 ones. The overall pattern of responses between them was not significantly different among the survey items tested (in the analysis at the 5 % level) on key characteristics, such as company size, the level of environmental uncertainty and postponement applications. I thus concluded that the data contained no major problems with respect to non-response bias. This gives added confidence to the view that the sample actually obtained in my survey is in fact representative of the population as a whole.

c. Apparently, more follow-ups of a personally addressed research instrument would have been much more appropriate, as it probably would have raised the total response rate to an even higher level. However, time and financial constraints did not allow me to implement this option. While the higher the response the better, response rates under 20 % are extremely undesirable (Yu and Cooper, 1983). The response rate for this research was only 20.7 %, but this is within the 10-30 % of the historical average (Flynn et al., 1990). Additionally, this response rate is higher than the previous published studies (on postponement) in the literature. For example, Van Hoek (1998a) and Chiou et al. (2002) obtained only 15 % and 17 % usable responses respectively in their postponement surveys.
d. Given the extensive (and relatively complex) nature of the questions (spanning from business processes to information systems areas), a response rate of over 20 per cent was considered satisfactory. Furthermore, research as a whole is not believed to be important in companies, perhaps because of a lack of awareness of its value - only three respondents expressed a wish to participate in further studies (presumably reflecting a low level of interest in the postponement area). This is also born out by such responses from my survey as follows:

_I am sorry that I am unable to complete the questionnaire, as I am totally unaware of 'postponement' as a modern management phrase._

5.3 VALIDATION OF THE INSTRUMENT

The need for developing a validated scale in empirical operations management research has been noted in the literature (e.g. Flynn et al., 1990; Malhotra and Grover, 1998; O’Leary-Kelly and Vokurka, 1998; Hensley, 1999). It is suggested that a thorough measurement analysis on scales should be conducted after the data are gathered. In this way, it provides confidence that the empirical findings accurately reflect the proposed constructs. Additionally, empirically validated scales can be used directly in other studies in the field for different populations (Ahire et al., 1996).

5.3.1 Reliability
Reliability pertains to the consistency or stability of a set of measures which make up a construct (Churchill, 1979). Usually, stability is assessed by taking repeated measures from the same sample at various times. Practical reasons limit the use of stability measures in the social sciences because of time requirements and the
difficulty of finding subjects who are willing to be involved in a longitudinal study. An alternative method is to measure the internal consistency of each item compared with other scale items and is used to provide a measure of the internal homogeneity of the items comprising the scale (Churchill, 1979). Usually, internal consistency is measured by computing Cronbach’s coefficient alpha (Nunnally, 1978), which measures the degree of inter-item correlation in each set of items. High inter-item correlations suggest that all the items in a set of items are measuring the same construct or factor (DeVellis, 1991). Coefficient alpha can range from 0.00 to 1.00 and DeVellis (1991) suggests that alpha levels below 0.60 are unacceptable. For each of the scales that had coefficient levels near or just below 0.60, individual items could have been eliminated to increase the alpha level for the remaining set of item. The Cronbach’s alpha levels of the constructs in this study were higher than 0.70 (ranging from 0.75 to 0.83) (see table 5.6), indicating that the testing items within each construct converged on a common construct. This was considered adequate evidence of internal consistency reliability and scale unidimensionality for this study according to Nunnally (1978).

The output in the table accompanying coefficient alpha also includes the effect of dropping each individual item on the coefficient alpha for its respective scale.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Alpha</th>
<th>Research variables</th>
<th>Scale mean if item deleted</th>
<th>Scale variance if item deleted</th>
<th>Corrected item total correlation</th>
<th>Alpha if item deleted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postponement Applications (5 items)</td>
<td>.75</td>
<td>Q11 9.60</td>
<td>31.29</td>
<td>.39</td>
<td>.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q12 9.92</td>
<td>31.84</td>
<td>.49</td>
<td>.72</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q13 9.01</td>
<td>34.38</td>
<td>.20</td>
<td>.79</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q14 9.84</td>
<td>29.51</td>
<td>.62</td>
<td>.69</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q15 9.67</td>
<td>24.99</td>
<td>.75</td>
<td>.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q16 9.01</td>
<td>26.88</td>
<td>.56</td>
<td>.70</td>
<td></td>
</tr>
<tr>
<td>Managerial Practice 1 (8 items)</td>
<td>.83</td>
<td>Q21 25.71</td>
<td>26.42</td>
<td>.51</td>
<td>.81</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q22 26.30</td>
<td>23.25</td>
<td>.75</td>
<td>.78</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td>Q23 26.25</td>
<td>25.60</td>
<td>.54</td>
<td>.81</td>
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<td>Q24 26.30</td>
<td>25.52</td>
<td>.59</td>
<td>.81</td>
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<td></td>
<td></td>
<td>Q25 26.42</td>
<td>25.71</td>
<td>.46</td>
<td>.82</td>
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<td></td>
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<td>Q26 25.88</td>
<td>25.89</td>
<td>.62</td>
<td>.80</td>
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<td></td>
<td></td>
<td>Q27 26.82</td>
<td>24.34</td>
<td>.50</td>
<td>.82</td>
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</tr>
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<td></td>
<td></td>
<td>Q28 26.68</td>
<td>23.37</td>
<td>.55</td>
<td>.81</td>
<td></td>
</tr>
<tr>
<td>Managerial Practice 2 (13 items)</td>
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Table 5.6 The Reliability Analysis for All Constructs – Scale (Alpha) (Number of cases = 76)

5.3.2 Validity

Validity is defined as the extent to which the instrument captures what it is intended to capture (Churchill, 1979). Assessing the validity of an instrument involves an examination of three primary characteristics: content validity, construct validity and criteria-related validity (Flynn et al., 1990).

5.3.2.1 Content Validity

Content validity refers to the construction of an instrument and whether the items adequately capture the construct domain or essence of the domain (Churchill,
1979). In this study, as indicated in Chapter 4, the initial measurement items were either produced on the basis of an extensive review of literature or modified from previous related research. In addition, all the measurement items were examined by a selected number of experts (academics, managers and consultants) in the postponement field to ensure that the item appropriately measured the key elements in my research. I also had the contents reviewed by industry experts who filled out the initial survey and made recommendations to reduce extraneous items and to use more precise wording in order to ensure consistency in data collection. Based on this feedback from consultants, managers and academic experts, I modified the survey instrument. Since all this involved field-based content validation of this research, the measures could be generally considered to have content validity (Malhotra and Grover, 1998).

5.3.2.2 Construct Validity
Construct validity is a measure of the degree to which the scale measures the abstract or theoretical construct it is intended to measure (Churchill, 1979). That is, construct validity requires that a scale be an appropriate operational definition of an abstract variable or construct and can be inferred by the relationship the construct in question has with other constructs. To maintain construct validity, this survey was developed from an extensive literature review. Researchers usually estimate construct validity numerically, based on the notion that responses to various questions measuring a single construct follow a unique pattern of responses that differs from the pattern of responses for another construct (Hensley, 1999).

Exploratory factor analysis is the most often used method to assess whether a set of questions forms a single scale (Spector, 1992; Hair et al., 1995). It may also be used to assess either inter- or intra-scale differences (Hensley, 1999). The construct validity of the present construct was assessed by principle components factors analysis. Factor analysis is a data summarisation tool that aids in the identification of relationships among variables and serves as an aid in looking for common underlying factors among groups of variables. In the exploratory mode, the research allows the tool to determine the optimum number of factors underlying a group of items, or variables, and determine which items load together.
I only perform an exploratory factor analysis on the scales of items for Managerial Practices (including administrative issues and technological issues) and Barriers to Postponement, because they are new and had been developed specifically for this study. Although there are several methods and various rotations for factor analysis, principle components analysis with an orthogonal (Varimax) rotation is well accepted (Spector, 1992). Therefore, this method was selected to analyse the items under consideration.

Analysis of infrastructure factors relating to managerial practices. The respondents were required to report their managerial practices on administrative and technological issues. These were summarised as infrastructure factors relating to managerial practices and composed of twenty-one items. These twenty-one items were subjected to principal components analysis with a Varimax rotation. Two factors with eigenvalues (latent roots) greater than 1 were introduced. Latent Root Criterion is the most commonly used technique to determine the number of factors to be extracted (Hair et al., 1995). All factors with eigenvalues less than 1 were considered insignificant and were disregarded (Hair et al., 1995). The analysis yielded two factors, which have a cumulative eigenvalue of 7.718, explaining 77.63% of the total variance (see table 5.7). According to Hair et al. (1995), when the total variance explained by factors is higher than 50%, it ensures practical significance for the derived factors. Factor loading are the correlation between an original variable and its factors (Hair et al., 1995). As indicated in Table 5.7, the factor loadings range from 0.539 to 0.932 which are larger than 0.4 and considered satisfactory according to Hair et al. (1995).

When the research instrument was developed, the nature of the constructs and the number of items used to measure each construct had been proposed in advance. According to the results of factor analysis, the extracted factors were identical with the two infrastructure factors relating to managerial practices proposed in the survey instrument in terms of the number of items and the nature of the theory. Therefore, this indicated that the two constructs of administrative issues and technological issues are actually measuring what they are supposed to measure. In other words, the two constructs have adequate construct validity.
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Table 5.7 Total Variance Explained by Infrastructure Factors Relating Managerial Practices (Extraction Method: Principal Component Analysis).

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Table 5.8 Factor analysis* of infrastructure factors from managerial practices

*Extraction Method: Principal Component Analysis.
*Rotation Method: Varimax with Kaiser Normalisation
*Rotation converged in 3 iterations.

Factor analysis of barriers to postponement. According to Nunnally (1978) and Black and Porter (1996), if a factor was valid as a construct, its set of items would form a single factor when it was subjected to an individual principle component analysis (unifactorial determination). Barriers to postponement was designed as one construct in the current study. In order to assess its construct validity, the set of items pertaining to barriers to postponement were subjected to an individual principle components analysis. The results in table 5.9 show that the factor
loading of each item ranged from 0.553 to 0.876 which exceeded the generally
recommended minimum value of 0.4 (Hair et al., 1995). This indicated that all
the items load on one factor. The factor solution confirmed that each of the items
measured only one underlying idea and this provided proof of construct validity
with regard to barriers to postponement. The variance explained by this factor is
51.47%. This is adequate according to Hair et al. (1995), who proposed a cut-off
of 50% as an acceptable percentage of total variance explained by a single factor
in order to ensure practical significance.

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Table 5.9 Factor Analysis* of Barriers to Postponement
* A component extracted (Extraction method: principal component analysis)

5.3.2.3 Criterion-related Validity
Criterion-related validity refers to the ability of the construct to at least predict one
or more external variables (Malhotra and Grover, 1998). It is a measure of the
relationship between the scale and surrogate measures of the construct (Hensley,
1999). A scale exhibiting a strong relationship between the scale and the
surrogate measures may be used as an accurate measure of the construct in the real
world to predict future performance (Spector, 1992). The analysis on criterion-
related validity requires identification of external (criterion) variables that have
well documented theoretical relationships with the scale. Malhotra and Grover
(1998) highlight the difficulty in establishing such strong theoretically based
criterion in production and operations research. In the present study, I have
established a theoretical relationship between uncertainty and postponement (see
Section 3.2). In this regard, uncertainty and its infrastructure factors were presumed to be the predictors of postponement applications. Therefore, criterion-related in this study was a measure of how well scales representing uncertainty and its infrastructure factors were related to the measure of postponement applications. Uncertainty and postponement were each designed as constructs in the current study. The correlation between the constructs of uncertainty and postponement applications is 0.179 (significant at the 0.01 level, 2-tailed). That is, they have statistically significant positive correlation. This suggests that the predictor variables in the instrument are significantly related with criterion variables and the strengths of the correlation are justified theoretically. Thus, criterion-related validity was supported for this study.

5.4 FINDINGS

My questionnaire survey mainly tests the hypothesised relationships among the variables, postponement, uncertainty, managerial practices and company performance (as shown in Figure 5.1). I use multiple regression analysis to test Hypotheses H1, H2, and H3, while using simple regression analysis to test Hypotheses H4. Regression analysis seeks to identify and estimate the amount of variance in the dependent variable attributed to one or more independent variables. To facilitate the further discussion, I recall my five hypotheses as follows:

H1. There is a positive relationship between the level of environmental uncertainty and postponement.
H2. There is a positive relationship between postponement and administrative factors in managerial practices.
H3. There is a positive relationship between postponement and technological factors in managerial practices.
H4. There is a positive relationship between postponement and company performance.

H5. Postponement is increasingly used in industry.

Additionally, part of my questionnaire was used to investigate postponement applications (to test H5) and identify various barriers to postponement.

![Research Hypotheses Diagram]

**Figure 5.1 Research Hypotheses**

### 5.4.1 Hypotheses H1-H3

Prior to conducting multiple regression analysis, the multi-collinearity between independent variables was assessed. Multi-collinearity occurs when a single predictor variable is highly correlated with a set of other predictor variables. Relatively high levels of multi-collinearity between independent variables can lead to higher standard errors of the estimated correlation coefficient, which results in difficulties in drawing inferences on the basis of the regression estimate. The Variance Inflation Factor (VIF), which measures the inflation in parameter estimates due to collinearities among the independent variables, is commonly used as a measure of multi-collinearity (Hair *et al.*, 1992). *Hair et al.* (1992) suggested that a common cut-off threshold of VIF is 10, however, other researchers suggested 5 or even less (Asher, 1983). For the model in the current study, VIF was calculated during the multiple regression analysis and the VIF values were shown in table 5.10. It can be noted that all VIFs in the current research were well within the VIF limit of 5, indicating that multi-collinearity did not have an undue influence on the least squares estimates. Thus, all variables in the model were retained for further analysis.
The results of multiple regression analysis (in table 5.10) indicate that postponement is significantly influenced by uncertainty, administrative factors and technological factors (in managerial practices). That is, my data analysis leads to the acceptance of Hypotheses H1, H2 and H3, which states that postponement is positively related to uncertainty, administrative factors and technological factors (in managerial practices). More importantly, the variance of the dependent variable explained by the independent variable \((R^2)\) is 0.768, indicating that uncertainty, administrative factors and technological factors (in managerial practices) accounted for almost 77% of the total variation in postponement.

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Hypotheses</th>
<th>Independent Variables</th>
<th>VIF</th>
<th>Coefficient</th>
<th>Significance</th>
<th>Model Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postponement</td>
<td>H1</td>
<td>Uncertainty</td>
<td>1.293</td>
<td>.85</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H2</td>
<td>Administrative Factors</td>
<td>1.328</td>
<td>.60</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H3</td>
<td>Technological Factors</td>
<td>1.035</td>
<td>.83</td>
<td>0.01</td>
<td>(R^2 = 0.768)</td>
</tr>
</tbody>
</table>

Table 5.10 Results of Multiple Regression Analysis

The support for Hypothesis H1 emphasises the role of postponement in dealing with environmental uncertainty. This extends Van Hoek's (1998a) finding that demand uncertainty is positively related to postponement. Postponement enables a company to keep its options open on how and where to design, produce, or distribute the product, incorporating the flexibility to cope with environmental uncertainty. In this sense, the strength of postponement is its substitutability (Bucklin, 1965), because of the irreversibility of some operations. In line with Towill and McCullen (1999), who state 'the supply chain which best succeeds in reducing uncertainty and variability is likely to be the most successful in improving its competitive position', it may be argued that, when increasingly adopting strategies to improve overall supply chain management, companies should look to wider implementation of postponement (Davis and Sasser, 1995). However, it should be recognised that postponement is just one of many routes which companies have towards dealing with uncertainty. Postponement has its limits in dividing a process into a standard/common and a configuration/
differentiation stage to push uncertainty forward rather than eliminate it, due to characteristics of product design, production solutions and distribution system. For example, if customers demand a relatively high delivering frequency and/or a relatively short delivery, it will not likely be appropriate to employ postponement strategies (Pagh and Cooper, 1998).

The support for Hypotheses H2 and H3 has significant managerial implications for companies looking towards postponement strategies. For example, to pursue the implementation of postponement, one idea might be based on earlier methods such as quality function deployment, which has considerable customer involvement. This is further reflected by my finding in Subsection 5.4.4, where ‘Direct customer interaction’ is one of highly ranking barriers to postponement. Regarding how to help companies adopt and progress the implementation of postponement, H2 and H3 are relevant to another stream of postponement research in the literature, where positive relationships are hypothesised among different postponement strategies. Using a questionnaire survey, Chiou et al. (2002) recently showed that there are positive relationships among manufacturing postponement, assembly postponement, packaging postponement and labelling postponement. Following this, the strategic shift to a specific postponement strategy might require a major shift to other postponement strategies, which is intuitively understandable. For example, unless movement is made to production postponement, logistics postponement usually means that inventories must increase and logistics costs will increase. Similarly, production postponement may not be successful without purchasing postponement (Yang et al., 2004). However, considering the early stages of adopting postponement strategies, this study may be of more value to further progressing postponement applications. The support for H2 and H3 may also mean that companies need to acquire an assessment of their ability before going for postponement strategies. That is, they have to discover the degree of fit between the business opportunity inherent in postponement and their ability to capitalise on this opportunity. In this regard, postponement is not the best strategy for every company. For example, postponement applications may be limited by a company’s administrative heritage and existing operating practices (e.g. Van Hoek et al., 1998; Waller et al., 2000).
5.4.2 Hypothesis H4

With regard to Hypothesis H4, table 5.11 presents the results of simple regression analysis, indicating company performance is significantly related to postponement. This leads to the acceptance of Hypothesis H4. To address the reason for going for postponement, most of the literature is highly conceptual, as I demonstrated earlier in Chapter 2. For example, there is lack of empirical validation on the implications of supply chain management and agility for the adoption of postponement. In terms of showing benefits of postponement, previous empirical research was comprised primarily of case studies (such as HP and Benetton). Thus the survey result here is encouraging, since it generalised the findings in the case studies to a large population of companies and provided empirical evidence that postponement has a positive impact on company performance.

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Hypotheses</th>
<th>Independent Variables</th>
<th>Coefficient B</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>H4</td>
<td>Postponement</td>
<td>.85</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Table 5.11 Results of Simple Regress Analysis

Here, I used a regression approach to investigate the significance of the relationships between the independent and dependent variables, in order to test the hypotheses H1, H2, H3 and H4. Building on these methods, a more powerful statistics data analysis method, structural equation modelling (SEM), could be used to further examine the relationships between postponement, uncertainty, managerial practices and performance. As a second-generation multivariate technique, the SEM approach has a number of advantages (e.g. Fornell, 1982; Hughes et al., 1986; Hair et al., 1992; Chau, 1997): (1). It provides a rigorous validation of instruments for unobserved constructs and test of the research model, and thus it makes the assumptions, constructs, and hypothesised relationship in a researcher's theory explicit; (2). It adds a degree of precision to a researcher's theory, since they require clear definitions of constructs, operationalisations, and the functional relationships between constructs; (3). It permits a more complete representation of complex theories; and (4). It provides a formal framework for constructing and testing both theories and measures, and can be viewed as an integration of those methods like multiple regression, path analysis and factor
analysis. SEM applications are so widespread today that Marcoulides and Schumacker (1996) stated that the use of the term SEM was broadly defined to accommodate models that included latent variables, measurement errors in both dependent and independent latent constructs, multiple indicators, reciprocal causation, simultaneity and interdependence. The commercial software packages that implement SEM include AMOS (Analysis of Moment Structures), EQS (Equation Modelling System), and LISREL (Linear Structural Relations). However, one practical concern that is critical in SEM application is sample size, since it is an important factor in establishing adequate power for the SEM test (Malhotra and Grover, 1998). Malhotra and Grover (1998) suggest that at least 100 responses are desirable. Anderson and Gerbing (1988) and Schumacker and Lomax (1996) recommend the size of at least 100 to 200 for models of moderate complexity. Kelloway (1998) claims that 200 observations would be an appropriate minimum to obtain stable parameter estimates. A general rule proposed by Hair et al. (1995) and accepted by many other researchers is that five or more observations are needed for each parameter to be estimated. For the current study, there are 46 parameters (excluding those about barriers to postponement) to be estimated, which require at least 230 samples. Since there are only 76 usable responses in my survey, the power of the test can be deemed inadequate. Therefore, SEM is considered not to be viable in my data analysis.

5.4.3 Hypothesis H5 (Postponement applications)
This section discusses the results of the survey dealing with postponement applications. The respondents were asked to indicate the extent to which companies engaged in the various postponement applications three years ago, at the present time and after three years respectively. The descriptive statistical results of specific postponed activities are shown in table 5.12.

Table 5.12 reveals that currently the two most widely used postponement applications are postponed manufacturing (mean = 2.38) and logistics postponement (mean = 2.38). Companies stress those two postponed activities overwhelmingly over the other postponed activities: postponed engineering (mean = 1.89), postponed packaging/ labelling (mean = 1.72), postponed final manufacturing/ assembly (mean = 1.55), and postponed purchasing (mean = 1.47).
This is in line with previous empirical studies (e.g. Van Hoek, 1998a), where postponement was found to be mainly exploited in downstream activities in the

<table>
<thead>
<tr>
<th>Mean</th>
<th>Three Years Ago</th>
<th>At present</th>
<th>After Three Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postponed engineering</td>
<td>2.11</td>
<td>1.89</td>
<td>2.04</td>
</tr>
<tr>
<td>Postponed purchasing</td>
<td>1.42</td>
<td>1.47</td>
<td>1.53</td>
</tr>
<tr>
<td>Postponed manufacturing</td>
<td>2.20</td>
<td>2.38</td>
<td>2.09</td>
</tr>
<tr>
<td>Postponed final manufacturing / assembling</td>
<td>1.26</td>
<td>1.55</td>
<td>1.66</td>
</tr>
<tr>
<td>Postponed packaging/labeling</td>
<td>1.55</td>
<td>1.72</td>
<td>1.72</td>
</tr>
<tr>
<td>Logistics postponement</td>
<td>2.47</td>
<td>2.38</td>
<td>2.30</td>
</tr>
<tr>
<td>Sum</td>
<td>11.01</td>
<td>11.39</td>
<td>9.54</td>
</tr>
</tbody>
</table>

Table 5.12 Postponed activities engaged by the companies
Note: Sample size = 76; 1 = up to 20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80% and 5 = 81-100%

supply chain. As can be seen from Table 5.12, the overall applications of postponement (sum of means = 11.39) are slightly higher than three years ago (sum of means = 11.01). However, overall the respondents expected postponement to be less used in three years (sum of means = 9.54) than at the present time (sum of means = 11.39). Therefore, Hypothesis H5 is not supported. This is in contrast with postponement supporters' belief that postponement is expected to be increasingly used (e.g. CLM, 1995; Morehouse and Bowersox, 1995; Van Hoek, 1998a). The reasons some respondents pointed out in my follow-up survey are mainly due to their business customers (e.g. demanding a shortening delivery time) or their products (e.g. shortening product life cycles). As a result, this might raise the measure issue of postponement. The existing measure of postponement does not include the cross-company dimension of postponement. Since postponement requires a supply chain wide perspective, the further improvement in the measure of postponement may possibly focus on a supply chain as a whole, rather than only on one company (as in my current questionnaire survey).

5.4.4 Barriers to Postponement
The questionnaire includes 13 factors that may have hindered postponement, as identified in the literature survey and theoretical study. Table 5.13 summarises the respondents' perceptions. The most significant barrier highlighted by
respondents (mean over 4) was 'Supplier delivery performance'. The other significant barriers (mean between 3.20 and 3.30) are 'Direct customer interaction', 'Culture and organisation change', 'Involvement of suppliers in engineering and operations', 'Product characteristics' and 'Production characteristics'. Overall, three of the top six barriers are related to how the company manages its external networks (suppliers or customer). Obviously, those factors are not under the direct control of a company itself. This linkage is also supported by the postponement literature (e.g. Feitzinger and Lee, 1997). The third highest ranked barrier is about culture and organisation change, which has received little attention in the postponement literature. Attention needs to be directed to how to incorporate the appropriate organisational changes (e.g. in culture and structure) with the postponement process (see Subsection 3.4.1). In product development postponement, for example, many companies might be stuck in postponement because too frequently project management stems from the idea that all requirements must be defined before any design work can begin, and project managers try to meet target dates by starting the design process as soon as they can. This often forces them to specify items for which accurate information is not yet available, and it exposes them to making changes when accurate information becomes available (Thomke and Reinertsen, 2000). Also, following a postponement strategy, some resources (e.g. equipment and human resources) may need to be reserved. However, there is a fundamental belief that projects will get done faster and better if everyone's utilisation is maximised – everyone should be busy (Elliott and Hughes, 2000). On the other hand, few projects managers would let their team members get totally involved in other projects, since they are afraid that they could not get them back when needed, given the scarcity of skilled resources.

Compared to the above barriers, respondents perceived the following barriers less significant: 'operational control', 'market policies', 'incompatible communication/information system with their suppliers and customers', and 'the implementation of postponement would be too costly'. A perhaps surprising result in table 5.13 is that companies ranked issues related to distributors towards the end of the list. Both 'Intricate and direct distribution' and 'The ability to handle product configuration in the distribution channel' are among the bottom four barriers. One
may have expected that these two barriers would be as significant as those related to suppliers. One possible reason for this may be because distributors are becoming skilled at managing postponement manufacturing/distribution activities with short lead times and at an acceptable expense (Pagh and Cooper, 1998; Van Hoek, 1998a; Lowson, 2001). Respondents ranked 'governmental regulation' as the least significant barrier, possibly because of the nature of my sample companies of which more than 74% were small and medium sized companies (see table 5.3).

<table>
<thead>
<tr>
<th>Barriers</th>
<th>N</th>
<th>Mean</th>
<th>Std. Error</th>
<th>Std.</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier delivery performance</td>
<td>76</td>
<td>4.04</td>
<td>.11</td>
<td>.916</td>
<td>.838</td>
</tr>
<tr>
<td>Direct customer interaction</td>
<td>76</td>
<td>3.29</td>
<td>.13</td>
<td>1.14</td>
<td>1.30</td>
</tr>
<tr>
<td>Culture and organisation change</td>
<td>76</td>
<td>3.25</td>
<td>.14</td>
<td>1.19</td>
<td>1.42</td>
</tr>
<tr>
<td>ISEO*</td>
<td>76</td>
<td>3.25</td>
<td>.15</td>
<td>1.29</td>
<td>1.68</td>
</tr>
<tr>
<td>Production characteristics</td>
<td>76</td>
<td>3.25</td>
<td>.13</td>
<td>1.17</td>
<td>1.38</td>
</tr>
<tr>
<td>Operational control</td>
<td>76</td>
<td>3.12</td>
<td>.11</td>
<td>.99</td>
<td>.96</td>
</tr>
<tr>
<td>Market policies</td>
<td>76</td>
<td>3.11</td>
<td>.13</td>
<td>1.17</td>
<td>1.37</td>
</tr>
<tr>
<td>ICISSC**</td>
<td>76</td>
<td>2.95</td>
<td>.15</td>
<td>1.31</td>
<td>1.73</td>
</tr>
<tr>
<td>Intricate and direct distribution</td>
<td>76</td>
<td>2.72</td>
<td>.11</td>
<td>.98</td>
<td>.97</td>
</tr>
<tr>
<td>IPWBTC****</td>
<td>76</td>
<td>2.70</td>
<td>.12</td>
<td>1.06</td>
<td>1.12</td>
</tr>
<tr>
<td>AHPCIDC****</td>
<td>76</td>
<td>2.70</td>
<td>.12</td>
<td>1.03</td>
<td>1.06</td>
</tr>
<tr>
<td>Governmental Regulation</td>
<td>76</td>
<td>2.55</td>
<td>.13</td>
<td>1.17</td>
<td>1.37</td>
</tr>
<tr>
<td>Valid N (listwise)</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.13 Barriers to Postponement

* ISEO = Involvement of suppliers in engineering and operations
** ICISSC = Incompatible communication/information system with my suppliers and customers
*** IPWBTC = The implementation of postponement would be too costly
****AHPCIDC = The ability to handle product configuration in the distribution channel

5.5 SUMMARY

My data analysis is based on the feedback received from 76 British companies across four industry sectors (ranging from electronics to automotive to food and clothing). This chapter tests the sample size and non-response bias as well as
analyses the validation of the instrument in this study. As tested in Section 5.2, the sample size is adequate for the current study and the results of this study would not be affected greatly by non-response bias. To demonstrate that respondents represent the whole population, demographic data for the respondents are provided in this chapter, including the frequencies of companies’ appearance within particular industrial sectors, the size of the companies, the respondents’ position in their company, and the response rates of my survey. Then, the validation of the survey instrument has been primarily assessed by adequate reliability, content validity, construct validity and criterion-related validity. For example, in accordance with the recommendation of Flynn et al., (1990), this study used internal consistency as a measure of reliability which was represented by Cronbach’s alpha. The overall scale demonstrates an acceptable degree of internal consistency with a Cronbach alpha coefficient higher than 0.75. Exploratory factor analysis has also been conducted to those variables which were developed specifically for this study. I found that related items showed up as a single factor in this data sample.

I found that the overall applications of postponement are slightly higher than three years ago. However, the respondents expected postponement to be less used in three years. This is contrary to the existing postponement literature. As identified in my survey, the highest ranked barriers to postponement include ‘supplier delivery performance’, ‘direct customer interaction’, ‘culture and organisation change’ and ‘involvement of suppliers in engineering and operations’. While most of those barriers are related to how the company manages its external networks (suppliers or customer), the barriers related to distributors (‘intricate and direct distribution’, and ‘the ability to handle product configuration in the distribution channel’) were put towards the bottom of the list. Time and resource constraints prevented me from further empirically investigating those contrary issues using a follow up open questionnaire survey or personal interviews. Meanwhile, since research concerning barriers to postponement is in its infancy, my discussion in Subsection 5.4.4 should be treated as a series of concerns, suggestions, or assertions that future researchers might find useful as a guide to the way they frame their research studies. With regard to testing hypotheses H1, H2, H3 and H4, the outcomes of the data analysis in this chapter support that the
relationships among the variables (uncertainty, postponement, managerial practices and company performance) were significant and positive. Further, the interpretation of my survey data could be improved using structural equation modelling. Unfortunately, insufficient responses from this survey make it impossible to look to that method. Nevertheless, the study of this issue would be included in future research (e.g. enlarging the sample size or achieving a far better response rate) together with the other issues mentioned above. Recommendations made to future research will be based on the results of this data analysis, together with my theoretical study, as I will show in Chapter 6.
CHAPTER 6. CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

This chapter is to evaluate the findings of this research in the context of the existing literature and develop recommendations concerning directions for future research. While interpreting the implications of my findings, I should keep in mind the limitations of the present study. However, in the context of this thesis, it is first of all essential to demonstrate the original contributions of this study to the overall body of knowledge in the subject area.

6.1 THE NATURE OF THE CONTRIBUTION

The nature of the contribution made by this particular study to the overall body of knowledge related to this particular subject area can be summarised in the following points:

1. While a number of studies have noted that further development in postponement research should point towards more applied issues, there are pending issues regarding the theoretical aspects of postponement. Over time, postponement has gradually been applied throughout the whole supply chain. However, the existing postponement strategies are mainly concerned with the
narrow scope of manufacturing and logistics. This is in part reflected by the fact that most authors cite the seminal work by Bucklin (1965), while more recent publications are referenced less often. Before this study was undertaken, it may be argued that there were no adequate postponement strategies to match the extending scope of postponement applications such as in product development. More recently, Waller et al. (2000) propose the concepts of production postponement, upstream postponement and downstream postponement. Unfortunately, the term of upstream or downstream postponement is too broad to be followed. As a result, the conceptual development of postponement in Section 3.1 is a first step towards broadening the range of postponement to exploit more opportunities inherent to today’s business environment.

2. As supply chains have evolved from traditional forecast-driven push to demand-driven pull systems, postponement is playing an increasingly important role in a supply chain. However, the existing literature on the role of postponement in the supply chain mainly hinges on the decoupling point, as I demonstrated in such strategies as leagility, mass customisation, speculation-postponement and glocalisation in Chapter 2. While the literature has also identified the factors influencing the location of the decoupling point, little attention has been directed to how these factors can be balanced. My theoretical study in Section 3.2 has extended this work by further proposing how postponement can help locate the decoupling point from both information flow and material flow perspectives. I further investigated postponement implications for the issues around supply chain integration, power and control, and capacity planning.

3. The previous postponement literature lacks any study in depth on formulating methodologies that realign company strategies, capabilities, process and resources towards the implementation of postponement. To address this, my theoretical work also proposed an integrated framework (see figure 3.4), where I am mainly concerned with the development of a set of general ideas upon which future work can be based. The practical difficulties (and some potential solutions) associated with moving towards postponement are also
included in this framework. For example, I suggest that companies may need to incorporate the appropriate organisational structures and cultures with the development of postponement strategies. This may corroborate the idea that postponement is not every company's best strategy, since existing organisation structure and culture of some companies may not fit the business opportunities inherent to postponement.

4. The literature review and theoretical study conducted for this research identified that there are two broad types of factors related to postponement: environmental uncertainty and managerial practices. Previous studies in this area have focused on a limited number of items of these two key constructs. The original contribution of this thesis is that it attempted to examine the role of uncertainty and managerial practices (in postponement) from a systematic approach. Also, very few studies concerned with postponement strategies have been conducted in British companies. My questionnaire survey was carried out with 368 British manufacturing companies.

5. By contrast with the relatively rich literature on postponement enabling practices and technologies, it is much less easy to find information about factors hindering the adoption/implementation of postponement. My empirical investigation represents the first efforts to use a survey methodology to capture the barriers to postponement. Additionally, as demonstrated in Chapter 2, important consideration is being given to mass customisation, agile and e-business strategies in many companies today. The literature has well documented that those strategies should result in more interest in postponement. However, there has been an absence of empirical research supporting this implication. It is still unclear whether companies adopting a higher degree of postponement are likely to be more successful than their competitors adopting a lower degree of postponement. To fill this gap, my empirical study has also attempted to answer the question of whether companies should adopt postponement strategies because this may lead to better performance.
6.2 LIMITATIONS AND FUTURE DIRECTIONS

As companies are unable to rely on finished product inventories to adjust to demand fluctuations, postponement may be viewed as a natural follow up to shifting from product-oriented to demand-oriented system. That is, the key fact that must be strong and supportive of a postponement strategy is the current business environment. In this context, this research was performed with the intent of exploring what factors facilitate or hinder the applications of postponement. It includes two separate research efforts: 1. a theoretical study; and 2. an empirical study by means of a questionnaire survey. Admittedly, my empirical study only tested a small part of the theoretical results in Chapter 3. For example, the postponement implications for the supply chain are highly conceptual and there has been an absence of empirical validation in this thesis. However, this might be justified by the nature of a PhD project in terms of time and cost constraints. After analysing the survey data, some results were established. In Section 6.1, I have presented the main contributions of this thesis. To make the most of postponement, there are certain actions which managers should consider. Managers are recommended to take into consideration many of the findings of the study related to the relationships among environmental uncertainty, postponement, managerial practices and company performance. For example, it is recommended that companies have an assessment of their organisation structure and culture, before embarking on postponement strategies. However, my findings must be considered in the light of some weakness of the study. Just like any other research, there are limitations in this research. Also, further research could be carried out to extend the findings in this thesis.

1. Survey Sample. My present study attempted to maximise the scope of industry sectors. Meanwhile, I took account of the balance between the high level and
the low level of postponement applications. My data analysis was based on the feedback received from 76 companies across four industrial sectors, ranging from electronics to automotive to food and clothing. However, there are some limitations of generalising my conclusions from the four industrial sectors that I surveyed. Considering product characteristics and managerial practices, the degree of postponement applications (such as engineer-to-order, make-to-order, and assemble-to-order) may differ from industry to industry. If this is radically different, then there may be some shortcomings that limit the generalisability of this research. For example, increasing uncertainty is a definitive feature of today’s environment. However, the uncertainty does not impact all different companies in different industrial sectors in the same way. There are product-specific factors that determine the degree to which uncertainty affects the postponement strategies. For this reason, in my data analysis I have chosen to focus on the average level of postponement applications, rather than the detailed level on every single postponement strategy. Similarly, this study has not distinguished the impact of individual items in one construct. That is, limitations are related to the data level in my data analysis. Future research should address a much broader random sample of companies in order to improve the generalisability of this study.

2. Measurements related to postponement survey. As I discussed in Subsection 5.4.2, a future area of research would be the development of a survey on a larger scale. It may then be possible to better test my hypothesised model in figure 5.1 (p. 133), e.g. using structural equation modelling. Also, the model used in this study may need to be expanded on some measurements. For example, in this study, a fist stage in measuring the barriers to postponement has been constructed from which future studies may be made. I have developed a measure for barriers to postponement and tested its reliability and validity. Although quantitative data has been analysed in this study, future studies might include data of in-depth qualitative nature to further develop this measurement. It is recommended that barrier measurement, in addition to the measurement of postponement performance, be added to the model as a principle measurement in future research. In addition, to take advantage of this understanding of a range of barriers that prevented the exploitation of
postponement strategies, it may need to further identify possible approaches to overcoming these barriers. Also, my findings contrast with much of the previous work, which posits that postponement is increasingly used in industry. In Subsection 5.4.3, I suggest developing items that provide a better view of postponement applications. However, this does not necessarily dismiss the measure of postponement here as hopelessly flawed. In other words, one could not conclude that not finding a trend of increasingly using postponement was purely a measurement issue. Further investigation into this would be a subject of future work.

3. **Fit other concepts into postponement research.** There is a need for integrating other related concepts/strategies into postponement, supplementing rather than replacing each other. To accomplish postponement within time and processing cost constraints, some attempts have recently been made in relation to just in time (Waller et al., 2000; Van Hoek, 2001), consolidation in transportation (Bowersox and Closs, 1996; Ballou, 1999; Bhatnagar and Viswanathan, 2000), merge-in-transit (Bowersox et al., 1999a), cross-docking (Yang et al., 2004), lead time reduction and quick response (Aviv and Federgruen, 2001). This is consistent with the increasing calls for a supply chain wide perspective in postponement research (e.g. Zinn and Levy, 1988; Van Hoek, 2001). Following this, further research needs to consider the postponement concept in holistic terms. From a theoretical perspective, it might be helpful to integrate such concepts like trans-shipment, flexibility and just-in-time into postponement research, in order to more completely understand the nature of postponement. Apparently, some of the above concepts have similar characteristics as postponement. For example, trans-shipment can also lead to cost reductions and improved services by enabling the sharing of stock among different locations, thereby reducing the inventory in the supply chain. Further, trans-shipment can be viewed as a form of logistics postponement, because it delays the point of differentiation which transforms a generic item (an item at any location) into a specific item (an item at a specific location) (Herer et al., 2002). In addition, both flexibility and postponement are reactive adaptation behaviours (to deal with the consequences of uncertainty, rather than attacking the sources of uncertainty).
As demonstrated in Section 3.1, postponement may contribute to several types of flexibility such as product development flexibility (through product development postponement) and product mix flexibility (through production postponement). Since the literature has well documented the relationship between flexibility and uncertainty (see Swamidass and Newell, 1987; De Meyer et al., 1989; Gerwin 1993; Upton, 1994) and a dominant feature of the flexibility literature is use of taxonomy to classify different types of flexibility, it may be worth further exploring the relationship between different postponement strategies and different types of flexibility.

4. Modular issues in postponement. As demonstrated previously such as in Subsection 2.2.2 and 3.3.2, modular designs for products and production are crucial for the implementation of postponement. The choice of different postponement strategies also depends on the extent to which it is possible for a company to modularise its products and processes (e.g. Ulrich, 1995; Lee, 1998; Van Hoek, 1997; Chiou et al. 2002; Yang et al., 2004). However, this modularity is necessary but not itself sufficient for postponement applications. For postponement to work, product design may need to further isolate the most variable portion of the functionality from other functions in order to be added last. This becomes obvious when one poses the following question: what is the motivation behind modularity? For modularity in design, product designers are interested in reducing lead times and costs for design and development (e.g. in parallel development of modules by independent design teams). In modularity in production, managers try to increase operation efficiency. Modular production design may enable production of the modules to reduce production cycle time (Lee, 1998). The more recent initiative to introduce production modules is also associated with the manufacturers’ wish to cope with in-line complexity due to ever-increasing product variety. Furthermore, a strong linkage exists between the design of the product, the design of the production processes and the accompanying supply chain of participating organizations. Fine (1998) claims that integral products tend to be developed and built by integral processes and supply chains, whereas modular products tend to be designed and built by modular processes and supply chains. However, pre-existing organisation structures and capabilities
also influence product architecture/design (Gulati and Eppinger, 1996). For example, some highly specialised companies are closely linked to within-
modular innovation (Chesbrough and Kusunoki, 2001). They are unlikely to
promote modular product architecture that provides competitors with
advantages within modules and renders their integrative skills less valuable.
Also, under uncertainty, it is better to err on the side of integrality (e.g.
integrality in organisation architecture and system integration capability) than
on modularity in product architecture to promote innovation (Ethiraj and
Levinthal, 2003), as it requires addressing unpredictable inter-module or inter-

5. Impact of e-business on postponement. As discussed in Section 2.1 and
Section 3.1, e-commerce has significantly affected postponement applications.
In the e-commerce environment, the ease of communication and access to real
time information enables the implementation of postponement. However, its
impacts on postponement are not that straightforward. For example, on the
side of logistics postponement, e-commerce increases the total number of
vehicle movement posing opportunities and challenges to the logistics
channel, which facilitate the adoption of logistics postponement. On the other
hand, the journey costs of delivery may be significantly reduced, since e-
commerce encourages companies to dematerialise a physical product with as
many digital contents as possible, to reduce the costs of handling, warehousing and shipping (Lee and Whang, 2001). Recent years have seen this trend in toys and mobile phones. If products (e.g., book, software, music and business cards) can be downloaded online, delivery can occur almost instantaneously with a negligible cost. This might facilitate the adoption of the higher level of postponement shifting from logistics postponement. Consider the case of MusicMaker. They allow customers anywhere to create CDs of their own by sorting through vast lists of recording. That is, MusicMaker postpone designing, colouring and labelling the CDs until a customer has personalised them, rather than traditionally compiling a collection of music for the average listener and carrying an acceptable inventory. From the above discussion, it may be noted that the impacts of e-commerce on postponement should be further clarified in the long term.
PUBLICATIONS (2001- )

Journal

Conference
REFERENCES


171


APPENDIX A: COVER LETTERS

1. Cover letter (with the original e-mail questionnaire)

Dear Sir/Madam,

2003 survey on the management of uncertainty through postponement

Today's global business environment is more uncertain than ever before. For companies, remaining competitive relies on a true understanding of how to develop strategies that incorporate the uncertain nature as an opportunity and not a problem. To effectively cope with uncertainty, you need to make the most of postponement, which is defined as delaying activities (e.g. as to the form and/or place of goods) until the latest possible time (e.g. when a customer order is placed):

*Why make anything and then push it to the market when you don't know whether customers are willing to buy the product at all?*
- Womack, J. P. and Jones, D. T. (1996), Lean thinking

*HP recently closed the division for other business reasons, but it still considers the division's use of postponement a best practice.*

In 2000, a 3-year research project was commissioned within the Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University, to develop postponement strategies to cope with uncertainty. At this final stage, we would like to listen to your voice, in order for us best to help you to drive your success. This study will be used as a guideline by companies interested in better pursuing more customer-driven activities. The output of this research may also help a company to discover the degree of fit between the business opportunity inherent in postponement and its organisation's ability to capitalise on the opportunity. Also, this questionnaire represents a major part in my doctoral research in postponement. A summary report will be sent to you at the end of this study.

*We would very much appreciate your contribution by answering the questions in the attached 4-page questionnaire and returning it via e-mail*. Most of the questions only require a tick and this should not take more than ten to fifteen minutes of your valuable time. *A hard copy of the questionnaire is available on request (simply by e-mailing us with the word “questionnaire” on the subject line)**. Your responses will be kept confidential and all data would only be reported in an aggregated form.

I look forward to hearing from you soon and I take this opportunity to thank you for your co-operation and assistance in the research.

Yours faithfully,
2. First and Second Round Follow-up Cover Letters

Dear Sir/Madam,

Within the past few weeks a questionnaire was posted (e-mailed) to you about Management of Uncertainty through Postponement. It is very important that your answers be included in our research, if the results are to accurately represent British companies.

If you have already completed and returned it to us, please accept our sincere thanks. If not, please do so now. Most of the questions only require a tick and this should not take more than ten to fifteen minutes of your valuable time. Please find attached the background information and the questionnaire*. A hard copy of the questionnaire is available on request (simply by e-mailing us with the word “questionnaire” on the subject line). Your responses will be kept confidential and all data would only be reported in an aggregated form.

Please complete and return this questionnaire by 15 July, 2003**.

Thank you for your help in this effort!

Yours faithfully,

...
APPENDIX B: QUESTIONNAIRE
2003 Survey on Management of Uncertainty through Postponement

Name of the respondent (optional):

Position of the respondent in the company:

Please choose to answer questions based either on your division, business unit or entire company:

☐ A division  ☐ A business unit  ☐ The entire company

If applicable, please specify your division or business unit:

It may be useful to select a specific product line or family in your main product stream to assist you throughout the survey. When answering questions you may base you answers on this representative product. Please specify this product:

Please tick the appropriate boxes to indicate which of the categories best define your business.

Number of employees

☐ 1-50  ☐ 51-100  ☐ 101-500  ☐ 501-1000  ☐ over 1000

Gross annual sales (£)

☐ < 1 million  ☐ 1-10 million  ☐ 11-50 million

☐ 51-100 million  ☐ over 100 million

Which of the following best describe your business?

☐ Original equipment manufacturer (OEM)  ☐ Contract manufacturer (CM)

☐ Other

Part I Postponement Applications

The objective of the following questions is to understand the extent to which postponement has been used in your company.

Q1. Please tick the percentages of goods related to the following strategies in your company at present, three years ago and in three years.

ETO — Product is designed and produced based on customer order
PTO — Product is made to customer order, but no parts or materials are held in your inventory
MTO — Product is fabricated from inventoried parts or raw materials at the customer’s request
FM/ATO — Base products are first produced and stored and then manufactured/assembled based on customer order
PLTO — Packaging/labelling operations (including final identification) are not performed until a customer order is received
STO — Finished product is not shipped (e.g. to the retail store) until a customer order is received

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Three years ago (%)</th>
<th>At present (%)</th>
<th>In three years (%)</th>
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<tbody>
<tr>
<td>ETO</td>
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<td>PTO</td>
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<td>MTO</td>
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<tr>
<td>FM/ATO</td>
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<td>PLTO</td>
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<td>STO</td>
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</table>
Any comments:

Part II. Managerial Practices

Over time, many managerial practices have become available that may or may not be appropriate to your company's integration plans. Q2. Please tick the box to indicate the extent to which each statement listed below correctly describes your company. 1- strongly disagree, 2- somewhat disagree, 3- neither agree nor disagree, 4- somewhat agree, 5- strongly agree.

Creating a great level of trust among your supply chain members
Sharing strategic planning with your suppliers and customers
Use of cross-functional team to make decisions
Facilitating concurrent operations throughout the company
Distributing the decision-making process through the organisation
Early involvement of suppliers and customers in product/service/marketing plans
Extensive use of Just-In-Time (JIT) production
Extensive use of Just-In-Time (JIT) delivery

Any comments:

Q3. Please tick the appropriate box to indicate the extent to which the following initiatives/systems have been implemented in your company. 1- not pursued, 2- started, 3- partially in place, 4- most in place, 5- fully in place

Information Technology
- Extensible markup language (XML)
- Communication skills/systems (e-mail, internet, intranet and extranet)

Customer Issues
- Quality function deployment (QFD)
- Customer relationship management (CRM)

Production
- Quality management tools using the ISO 9000 standards
- Total quality management (TQM)
- Cellular manufacturing
- Enterprise resource planning (ERP)
- Material requirement planning (MRP) / Manufacturing resource planning (MRPII)

Product Design
- Product configurator
- Design for assembly/manufacturing (DFA/M)
- Modular design
- Parts standardisation

Any comments:
Part III. Performance

The objective of the following questions is to understand the level of your company overall performance compared to your major competitors.

Q4. Please rank the importance of the following goals which your company is now targeting (A is the highest followed by B and so on while goals that are not applicable are ranked as N/A), and assess them on each goal compared to your competitors 1- far worse, 2- worse, 3- about the same, 4- better, 5- far better.

<table>
<thead>
<tr>
<th>Goals</th>
<th>Rank</th>
<th>Performance</th>
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</thead>
<tbody>
<tr>
<td>Improving quality of the product</td>
<td>A</td>
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<tr>
<td>Lowering product costs</td>
<td>B</td>
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<tr>
<td>On-time delivery to customers (reliability)</td>
<td>C</td>
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<tr>
<td>Speedy delivery to customers (responsiveness)</td>
<td>D</td>
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<td>Rapid new product introduction to the marketplace</td>
<td>E</td>
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<tr>
<td>Others (please specify):</td>
<td>N/A</td>
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Any comments:

Part IV Environmental Uncertainty

The objective of the following questions is to understand what degree of environmental uncertainty your company has experienced.

Q5. Please consider the factors below and indicate if they are easy or difficult to predict. Simply tick the box which corresponds to your particular experience. 1- extremely unpredictable, 2- somewhat unpredictable, 3- neither unpredictable nor predictable, 4- somewhat predictable, 5- extremely predictable

<table>
<thead>
<tr>
<th>Competition</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tbody>
<tr>
<td>Changes in the markets served by competitors</td>
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<td>Changes in competitors' strategies</td>
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<td>Entry of new companies to the market</td>
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<tr>
<th>Products, markets and demand</th>
<th>1</th>
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<tr>
<td>Customer preference</td>
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<td>Product demand</td>
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<td>Availability of substitute products</td>
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<td>Availability of complementary products</td>
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<th>Government and policies</th>
<th>1</th>
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<tbody>
<tr>
<td>Legal regulations affecting the business sector</td>
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<tr>
<td>Public political attitude towards industry and its particular product</td>
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<td>International regulations/standards</td>
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<tr>
<th>Technology in your industry</th>
<th>1</th>
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<td>Product changes</td>
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<td>Changes in product quality</td>
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<td>New product introductions</td>
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<td>Changes in production processes</td>
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Any comments:
Part V. Barriers to Postponement

Q6. Please tick the appropriate box to indicate how you rate the following barriers to expanding the use of postponement in your company?  

1- not relevant at all, 2- relevant, 3- neutral, 4- significant, 5 - most significant

<table>
<thead>
<tr>
<th>Market policies</th>
<th>1</th>
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<tr>
<td>Product characteristics</td>
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<td>Production characteristics</td>
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<td>The implementation of postponement would be too costly</td>
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<td>Operational control</td>
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<td>Supplier delivery performance</td>
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<td>Involvement of suppliers in engineering and operations</td>
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<td>Intricate and direct distribution</td>
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<td>The ability to handle product configuration</td>
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<td>in the distribution channel</td>
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<td>Culture and organisation change</td>
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<td>Direct customer interaction</td>
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<td>Incompatible communication/information system with your suppliers and customers</td>
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<td>Governmental regulation</td>
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<td>Others (please specify)</td>
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Any comments:

Thank you for your support of this research effort. We will send you a copy of the study’s findings when they are completed.

☐ If you would like to participate in our further research, please tick the box*.

? If you have any questions or concerns, please contact us at:

Mr. Biao Yang  The Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University, Leicester, LE11 3TU  
Tel: +44(0) 01509 227690  Fax: +44(0) 1509 227648  E-mail: b.yang2@lboro.ac.uk

Note*: In the postal questionnaire, this sentence is replaced by “If you would like to participate in our further research, please attach your business card to the completed questionnaire”.

4-4