Managing the impact of product variety and customisation on business function and supply chain performance: A comparison between the UK and South Korea

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy

by

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June 2013

ABSTRACT

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Degree of Doctor of Philosophy – Ph.D.

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2013

Mass customisation is displacing mass production, and a conspicuous trend is for businesses to extend the variety of their products in order to provide more tailored solutions and choice for customers. Flexibility-enhancing initiatives have been implemented in order to help businesses adopt customer-centric strategies to satisfy their high-variety ambitions. Such strategies can require major changes to the way businesses and key business functions are organised; yet it is imperative that these initiatives are implemented and high-variety solutions are profitably achieved without an overall deterioration of business function performance. In particular, most manufacturers have started to recognise that a trade-off exists between product variety and supply chain performance. In order to manage the impact of product variety, numerous variety-related strategies to improve supply chain performance have been suggested.

However, different levels of customisation require different strategies and approaches and affect business function and supply chain performance differently. This research aimed to assess the potential impact of product variety on business function performance and test a model designed to manage that impact on supply chain performance qualified by the level of product customisation. Further investigation aimed to determine typical differences in focus on variety-related strategies and supply chain performance according to the level of customisation. Lastly, the research findings compared the UK and South Korea. By adopting a quantitative research method, a survey of 364 manufacturing sector companies from the UK and South Korea was conducted. The results provide theory developments that support and contradict exiting views on product variety-related issues. The key findings and contributions of this research are fourfold:

First, the analysis examined the impact of product variety on the performance of five business functions including engineering, manufacturing, purchasing, logistics and marketing according to the type of customisation. The research also investigated the relationships between business function performance, degree of customisation and the level of product variety offered. An increase in product variety was found to influence business functions differently depending on the combination of customisation and variety offered to customers. The findings demonstrate that low customisation types typically had a more significant impact on business function performance than high

customisation types with an increase in product variety. In addition, high variety with low customisation displayed the highest negative impact on business function performance due to a mismatch between the level of variety and customisation offered. The results support organisational decision-making by providing managers working in manufacturing environments with guidance on how to provide more supportive business function design for heterogeneous market requirements and responses. In particular, specific findings have important managerial implications for the adoption of different approaches to variety under different customisation profiles.

Second, the research tested models designed to support the management of product variety increases on supply chain performance, that is, it examined the relationship between variety control strategies including modularity, cellular manufacturing and postponement and supply chain performance including supply chain flexibility, agility, cost efficiency and customer service. Adopting the agility concept as an external competence of supply chain performance, this research also attempted to develop a procedure to manage variety-related impacts according to the level of product customisation. In addition, the relationship between a variety control strategy and supply chain performance was explored further by considering the level of customisation. In this scenario, supply chain flexibility and agility resulting from a variety control strategy in the model had a positive effect on supply chain cost-efficiency and customer service. However, supply chain agility in a low customisation context played a relatively insignificant role compared to a high customisation context. These findings provide guidance for manufacturers by explaining the structural procedure to manage the trade-off between product variety and supply chain performance.

Third, the research is dedicated to addressing differences in variety-related strategies and supply chain performance according to the level of customisation. The results revealed that a high customisation context is associated with a higher level of customer relationships, variety control strategy, differentiation, flexibility and agility than a low customisation context, while a low customisation context is associated with a higher level of cost leadership than a high customisation context. The findings prove the general theory related to characteristics for high and low customisation; however, partnership with suppliers revealed contradictory results and displayed a higher performance in the case of high customisation through joint product development and problem-solving.

Finally, the research compares its findings for the UK and South Korea. As expected, the UK exhibits a higher level of product variety, customisation, customer relationships, customer service and differentiation than South Korea, while South Korea displays higher cost leadership and cost-efficiency than the UK. The comparison reveals the weaknesses and strengths of the two countries. For South Korea, higher manufacturing cost due to increased variety with a relatively low level of customisation is a major issue that needs to be overcome. On the other hand, the UK has relatively lower supply chain agility compared to its level of customisation. These findings can help international companies set up specific variety-related strategies in order to achieve global competitiveness.

Generally, the results from the research support the proposition of variety management and its relationship to customisation in the supply chain. It also contributes to the current literature by arguing that the complex relationship between product variety and supply chain performance varies depending on the level of customisation. Finally, the research reveals that appropriate variety-related strategies for managing variety qualified by the manufacturer's level of customisation are imperative for effective and efficient supply chain performance.

ACKNOWLEDGMENTS

Throughout my Ph.D. programme, I have benefitted from the fruitful guidance and support of faculty, friends, and family. I would like to extend my sincere thanks to those who have kindly helped me develop both academically and personally all the way through my doctoral studies.

First and foremost, I would like to gratefully and sincerely express my deepest gratitude to my first supervisor, Prof. Andrew Lyons, who was abundantly helpful and offered invaluable assistance, support, and guidance through the duration of this study. I was extremely fortunate to have the opportunity to work with Prof. Lyons. Without his guidance, direction, knowledge and immeasurable level of support this dissertation project would not be possible.

My thanks also extend to Dr. Dong Li, my second supervisor, for his diligence, feedback and for the support of this project, in particular, at the beginning of my Ph.D. programme.

I sincerely thanks to Prof. Myong Sop Park for leading my life into the place where I really want to be involved. For his kind guidance for more than 10 years as a mentor, I can satisfy my ambitions.

I would like to give my deepest thanks to my parents and wife, Dr. Jongsoo Um, Soonja Lee and Hojin Kang, for always supporting and encouraging me in my whole life. My sincere appreciation goes to them for always having an open door, sympathetic ears and just the most appropriate advice when I plan to do something. I am extremely indebted to them for their spiritual encouragement and financial support through my doctoral study.

I also wish to thank my father and mother in law, my sister, my brother in law and for their kind support over the last four years.

Finally, I would like to thank all my friends for their continued support which have made my Ph.D. journey enjoyable.

Liverpool, June 2013

June Ho Um

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CHAPTER ONE

INTRODUCTION

1.1. INTRODUCTION

This chapter begins by providing an overview of the research background. It then outlines the research needs, objectives, questions, scope and sample, followed by a description of the expected contribution. The chapter closes by presenting an outline of the thesis.

1.2. RESEARCH BACKGROUND

Sustained success for manufacturing businesses is often predicated on an ability to innovate, generate new ideas and introduce new products. Global competition has created a competitive environment where sales can be rarely increased or even maintained from a fixed range of products or markets. More often, sales growth is dependent on the ability of a manufacturer to stimulate an existing market or penetrate a different one by offering new choices. Consequently, product development has become more rapid (Fisher and Ittner, 1999), manufacturing systems have become more flexible (Fisher and Ittner, 1999; Meyr, 2004; Hu et al., 2011) and product proliferation and variety continue to increase (Hu et al., 2011). Differentiation of products has gone beyond the simple and prosaic categories of age, size and gender to include regional and national tastes, and personal lifestyle. The management of the complexity associated with wide product diversity is core to competitive advantage (Stalk and Hout, 1990).

Decisions relating to product variety can be viewed as focusing on how to engineer and manufacture products with the requisite level of customer choice. However, only by extending this focus to other business functions can the full implications of product variety be revealed (Ramdas, 2003). It has been argued that manufacturing managers prefer minimal process complexity and oppose product proliferation, whilst marketing managers strive to satisfy diverging customer needs and actively support product diversity (Kekre and Srinivasan, 1990). The fundamental question concerns the level of variety offered. Excessive product variety can significantly increase cost and consumer confusion. Ultimately it can cause consumers to withdraw from the purchasing decision (Child et al., 1991; Alford et al., 2000). The solution necessarily concerns the need to assess the benefits in relation to the increased cost and resource burden. Product variety by new product introduction impacts not only on manufacturing but also on engineering, purchasing, logistics and marketing functions (Krishnan and Ulrich, 2001). Therefore, variety impact needs to be examined across a range of business functions.

Many manufacturers have now recognised that a trade-off exists between product variety and supply chain performance (Thonemann and Bradley, 2002). Measuring supply chain performance involves analysis of cost efficiency, customer service level and supply chain flexibility (Beamon, 1999; Sezen, 2008). To mitigate the trade-off between product variety and supply chain performance, manufacturers can manage product variety by limiting it through focused manufacturing and/or increased flexibility (Kekre and Srinivasan, 1990; Yeh and Chu, 1991; Gerwin, 1993; de Groote, 1994; Silveira, 1998). However, when considering long-term profits and competition for market share in a world of increasing demand uncertainty, improving flexibility and agility can offer a more competitive and effective way of responding to customer needs. Therefore, in order to manage increased product variety and customisation, supply chains should be responsive to a constantly changing market (Yang and Burns, 2003). In other words, maintaining supply chain flexibility and agility remains crucial in managing variety-related issues. Adopting a variety control strategy (VCS), measures such as modularity (i.e. product flexibility), cellular manufacturing (i.e. process flexibility) and postponement, have also proven to be essential in achieving supply chain flexibility and agility (Qiang et al., 2001; Nair, 2005; Scavarda et al., 2010; Jacobs et al., 2011b). In addition, supply chain flexibility and agility have a positive influence both on performance of resource efficiency and customer service (Narasimhan and Jayaram, 1998; Hiroshi and David, 1999; Tummala et al., 2006).

Fisher (1997) suggested that performance of a supply chain can be attributed to a match or a mismatch between the type of product and the supply chain design. For example, functional products that use efficient supply chains typically have low levels of customisation that focus on cost efficiency, while innovative products that use responsive supply chain strategies typically have high levels of customisation focused on customer service. In addition, the connection between 'qualifiers'/'winners' and 'lean'/'agile' is essential (Aitken et al., 2002; Agarwal et al., 2006). At its simplest, the lean paradigm that typically employs a low level of customisation, is most powerful when the market winning criterion is cost (i.e. cost leadership); however, when service and customer value enhancement (i.e. differentiation) are prime market winning criterion with a high level of customisation, then flexibility and agility become the critical dimensions (Mason et al., 2000). Stavrulaki and Davis (2010) emphasised the alignment between the key aspects of a product and its supply chain processes according to four supply chain strategic focus (e.g. from build-to-stock to design-to-order) and highlighted the links between supply chain processes (e.g. production and logistics) and the supply chain strategy (e.g. lean, leagile and agile).

Therefore, variety-related issues necessarily require the concept of customer involvement (i.e. customisation) to be considered. Products may be differentiated according to the stage in the value chain where the customisation occurs, that is, at the point at which the customer input is injected (Lampel and Mintzberg, 1996). Postponing customisation by employing different de-coupling points allows a supply chain to be more reactive to changes in customer demand (Mason and Towill, 1999). Therefore, the strategic focus in business functions and supply chains differs according to the levels of customisation (Agarwal et al., 2006; Stavrulaki and Davis, 2010).

1.3. RESEARCH NEEDS

A trend towards an increase in product variety has been observed across many industry sectors (Fisher et al., 1994). However, simply increasing product variety is able to worsen competitiveness. Rather, how the firm's business functions and its supply chain are managed to implement variety are key issues (Ramdas, 2003). In advance of determining the appropriate approaches and strategies for management of product variety in supply chain, firms need to identity the potential impact of product variety on business function performance, which may differ depending on the level of customisation. Previous researchers have identified, in a piecemeal fashion, the impact of product variety on different business functions (MacDuffie et al., 1996; Fisher and Ittner, 1999; Randall and Ulrich, 2001; Thonemann and Bradley, 2002; Benjaafar et al., 2004; Hu et al., 2008). These researchers have primarily focused on the impact of product variety on a single functional area, or on a single industry. This thesis concerns the relative impact of product variety on overall business function performance according to the level of customisation.

In addition, this thesis proposes the development of a conceptual approach that can manage the trade-off between product variety and supply chain performance. Studies reported in the operations and supply chain literature have focused on providing theoretical frameworks for the management of product variety in the supply chain (Ulrich et al, 1998;

Thonemann and Bradley, 2002; Ramdas, 2003; Blecker and Abdelkafi, 2006) or investigating the impact of a specific strategy to manage product variety on supply chain performance (Nair, 2005; Davila and Wouters, 2007; Ramdas and Randall, 2008; Yadav et al., 2011) and business performance (Jacobs, 2011b). However, these studies have not identified a clear procedure to mitigate trade-off between product variety and supply chain performance through fundamental variety control strategies. In other words, the impact of variety control strategy on supply chain performance, particularly with the concept of supply chain flexibility and agility, has rarely been studied empirically.

Furthermore, varying levels of customisation (i.e., customer involvement) require varying strategies (e.g. cost leadership, differentiation and partnerships) to handle variety issues, which may differently impact supply chain performance. However, it is still questionable whether such a strategy would influence on supply chain performance (e.g. flexibility, agility, efficiency and customer service) and whether strategies and performance would differ according to levels of customisation in real industry fields. Therefore, it will be valuable to address the gap between theory and practice by conducting empirical research.

1.4. RESEARCH AIMS

Against this background, the aims of this research address three main challenges. First, insights from the literature analysed in the next chapter suggest that product variety makes an impact on various aspects of business function and supply chain performance. However, an increase in variety may impact differently on the performance of each business function. This phenomenon closely related to required or desired level of product customisation (Yeh and Chu, 1991; Agarwal et al., 2006; Stavrulaki and Davis, 2010). Therefore, based on a resource-based view (RBV) of a firm, this study explores the impact of product variety on business function performance from the perspective of a general manufacturing firm. The key aims are as follows:

- to explore and compare the impact of product variety on business function performance;
- to examine these impacts according to the levels of customisation and product variety offered.

The second challenge specifically concerns supply chain and how the impact of product variety on the supply chain can be managed. The research proposes and tests a model that supports the management of the trade-off between product variety and supply chain performance, demonstrating the relative effects that a variety control strategy (VCS) has on performance of the supply chain. The research then examines how a VCS can affect the performance of the supply chain according to differing levels of product customisation. Though studies investigating the management of increased variety in supply chain have demonstrated the effectiveness of VCSs, empirical attempts to examine the relationship between a VCS, supply chain performance and level of customisation have rarely been studied. The key aims of this second challenge concern:

- to explore the relationship between a variety control strategy and supply chain performance;
- to examine these relationships according to the level of customisation.

In order to identify the gap by looking at the general theories that describe the characteristics of customisation levels (see Table 3-3), the research investigates the differences in variety-related strategies and supply chain performance, according to different levels of customisation. The key aims of this third challenge concern:

- to investigate and examine differences in variety-related strategies and supply chain performance according to the level of customisation;

Finally, the findings from this research are then employed to compare the situation in the UK with that in South Korea[1], in terms of economic background, variety-related strategies, and business function and supply chain performance. A comparison study between the UK and Korea is conducted in order to confirm the findings of the thesis and provide suggestions to the countries. In particular, the differences in economic structure lead to this aim. For example, the Korean economy focused on manufacturing (39.2% of GDP) more than the UK did, while the UK economy focused on the service sector (77.7% of GDP). In addition, exports dependability accounted for a higher percentage of the GDP in Korea (48%) as compared to the UK (20%). The aims associated with this challenge are as follows:

- to prove the findings by comparing differences between the UK and Korea.
- to provide suggestions by comparing differences between the UK and Korea.

1.5. RESEARCH QUESTIONS

To fulfil the identified research needs and objectives, the following research questions were formulated after an extensive review of the literature:

Q1.1. How does an increase in product variety affect business function performance?

Q1.2. Does an increase in product variety impact on business function performance differently according to differences in the level of product customisation offered?

Q2.1. What is the association between a variety control strategy and supply chain performance?

[1] 'South Korea' and 'Korea' are used interchangeably when there is no likehood of confusion.

Q2.2. Is the relationship between a variety control strategy and supply chain performance affected by differences in the level of product customisation?

Q3. What are the differences in variety-related strategy and supply chain performance according to differences in the level of product customisation?

Q4.1. What are the differences in variety, customisation, variety-related strategies and supply chain performance that exist between the UK and Korea?

Q4.2. Which factors are responsible for creating the differences in the level of product variety? and what are the appropriate policies for each country?

1.6. RESEARCH SCOPE AND SAMPLE

This research explores the relationships between variety, customisation, and business function and supply chain performance, and proposes a model that supports the management of the impact of variety through the use of a variety control strategy. The level of product variety and customisation may vary according to external influences such as the economic and market environment of the country concerned. As a result, this research applies a comparative analysis to the case of the UK and Korea. However, the relative associations between a product variety strategy, customisation and supply chain performance are supported clearly by general theories.

A sample of 1,950 manufacturing units was selected from 15 industry sectors. Survey questionnaires were distributed to directors and managers of each manufacturer. The final sample comprised 212 manufacturers in the UK and 152 manufacturers in Korea. The responses show that participating firms are widely dispersed across the manufacturing sector industries. As a result of this the researcher can generalise the findings (Gatignon and Xuereb, 1997).

1.7. RESEARCH CONTRIBUTIONS

This thesis makes two contributions to the body of knowledge:

For academics, it offers a significant contribution to the operations and supply chain literature. The findings reported in this research provide a better understanding of the impact of product variety on overall business function performance. In terms of the supply chain model proposed here to support the management of increases in variety, the findings from the model suggest a structural procedure to manage the trade-off between product variety and supply chain performance through the adoption of variety control strategies, supply chain flexibility, and agility. With regard to the characteristics of the level of customisation in terms of variety-related strategies and supply chain performance, the findings are able to provide the basis of a more general theory.

For manufacturing industry, the research provides a basis that allows understanding of the relationships between product variety, customisation and supply chain performance. This can be used as a guide by manufacturers seeking an effective/efficient variety-related strategy to manage the impact of variety on supply chain performance based on their required or desired level of product customisation. In short, the findings have important managerial implications for the adoption of different approaches to product variety under different customisation profiles. In addition, the findings of the research should encourage manufacturers to manage the impact of variety increases on supply chains through the adoption of variety control, supply chain flexibility and agility strategies. Finally, the comparison between the U.K. and

South Korea has confirmed research findings and led to suggestions for appropriate policies and strategies in terms of variety issues for both countries.

1.8. STRUCTURE OF THE THESIS

Figure 1-1 illustrates that this thesis is organised into eight chapters. Chapter One presents a background to the research. It identifies the limitations and gaps in the relevant literature, defines the research objectives and research questions and provides a brief description of the contribution this research is expected to make to knowledge. Chapter Two provides an in-depth review of relevant literature relating to the impact of product variety and customisation, as well as strategies for managing the trade-offs between product variety and supply chain performance.

Chapter Three is dedicated to the conceptual framework of the research. It also develops the related hypotheses considering the relationships between product variety, customisation, business function performance, variety control strategies, supply chain flexibility and agility, cost efficiency, customer service, competitive capability (e.g. cost leadership, differentiation), partnership with suppliers and customer relationships factors.

Chapter Four explains the design of the research, the research strategy, including information on the source of the data, construct measurements, and the procedure for developing the questionnaire. This chapter also focuses on the process of data collection, and considers both sampling and the procedures used. The chapter concludes with a brief explanation of strategies for measuring and analysing data statistically.

Chapter Five is devoted to analysing the data, beginning with an explanation of general descriptive statistics, including demographic statistics and response rates. This chapter then describes the preliminary concerns regarding the survey research, such as normality, missing data and issues of bias. With respect to specific analyses, the research first looks at results showing the impact of product variety on business function performance, according to the type of customisation and product variety offered through analysis of variance (ANOVA) and cluster analysis. Then, it tests the relative effect of a variety control strategy on supply chain performance through confirmatory factor analysis (CFA) and structural equation modelling (SEM). Following this, differences in variety-related strategies and performance are analysed, according to levels of customisation through exploratory factor analysis (EFA) and T-test. Finally, the chapter provides a detailed discussion of the results of the hypothesis testing. Chapter six presents the results of the comparison between the U.K. and Korea, taking into consideration differences in their economics and supply chain backgrounds with the research findings.

Chapter Seven provides a comprehensive discussion of the empirical results in this research. The thesis is concluded in Chapter Eight, which provides an overview of the research findings and theoretical contributions of the study. The implications for management, limitations of the research and directions for future research are also discussed.

1.9. CHAPTER SUMMARY

This chapter has presented an overview of the research background, with the aim of highlighting current literature and body of knowledge. It also explains the research objectives and questions that need to be answered based on the gaps identified in the pertinent literature; and briefly discusses the contribution this research will make. The chapter concludes by presenting the structure of the thesis.

Figure 1-1 Outline of thesis

Chapter 1
Introduction

- Research Background
- Research Needs and Aims
- Research Questions
- Research Contribution
- Structure of the Thesis

Chapter 2
Literature Review

- Product Variety Management
- Customisation Management
- The Impact of Product Variety on Business Function Performance
- Supply Chain Performance
- Strategies to Manage Product Variety

Chapter 3
Conceptual Framework and Hypothesis Development

- Conceptual Research Framework
- Hypothesis Development

Chapter 4
Research Methodology

- Research Design
- Research Strategies: Sources of Data and Questionnaire Design
- Data Collection Strategies
- Data analysis Strategies

Chapter 5
Survey Application and Results

- General Descriptive Statistics
- Data Screening
- The Impact of Product Variety and Customisation on Business Function Performance
- Supply Chain Design to Support the Management of Product Variety Increases
- Strategy and Performance Difference according to the Level of Customisation
- Hypothesis Testing

Chapter 6
Comparison

- Economics and Supply Chain Background for the UK and Korea
- Comparison between the UK and Korea

Chapter 7
Discussion of Results

- The Impact of Product Variety on Business Function Performance
- Supply Chain Design to Support the Management of Product Variety Increases: the relative relationship between a variety control strategy and supply chain performance
- Strategy and Performance Differences according to the Level of Customisation
- Comparison between the UK and Korea

Chapter 8
Conclusions

- Research Findings
- Contributions and Implications of the Study
- Limitations and Future Research Directions

CHAPTER TWO

LITERATURE REVIEW

2.1. INTRODUCTION

The aim of this chapter is to provide a background to the research carried out. Thus, the chapter is largely devoted to a review and analysis of an extensive body of literature on product variety, customisation, supply chain performance and variety management strategies. The chapter begins, in sections 2.2 and 2.3, by examining product variety and customisation management. Section 2.4 reviews the impact of product variety on business function performance. Then in section 2.5, supply chain performance factors that are affected by product variety are introduced. These include supply chain flexibility, supply chain agility, cost efficiency, customer service and business performance factors. Finally, section 2.6 illustrates variety-related strategies that mitigate the trade-off between product variety and supply chain performance. The remainder of this chapter is used to identify potential gaps and limitations in the existing literature.

2.2. PRODUCT VARIETY MANAGEMENT

2.2.1. Product variety

Intense global competition, rapid new product development, and flexible and adaptive manufacturing systems have resulted in an enormous number and variety of products being offered in today's markets. Companies are obliged to consider very carefully the levels of their products' variety in order to realise opportunities that gain market share and increase profits. So far, the trend has been to extend product ranges and provide increasing levels of customisation. By responding rapidly to changing preferences in design, function, colour, size, packaging and accessories, it has been possible for businesses to increase customer satisfaction. This has resulted in enhanced competitive advantage (Stalk and Hout, 1990). For example, in large supermarkets, the number of products available for purchase increased dramatically from 1000 in the 1950s to 30,000 (Thonemann and Bradley, 2002). It is argued that manufacturers prefer minimal process complexity and low levels of product proliferation for lower unit production costs. However, the perceived marketing philosophy for success aims to satisfy diverging customer needs and provide increased market share and growth by way of broader product lines (Kekre and Srinivasan, 1990). In order to maximise long-term profit, firms should strive to balance the revenue gains from variety against its cost impact (Ramdas, 2003). Furthermore, as customer needs change rapidly, firms can no longer make profits by producing large volumes of a standardised products (MacDuffie et al., 1996).

2.2.2. Product variety dimensions and management

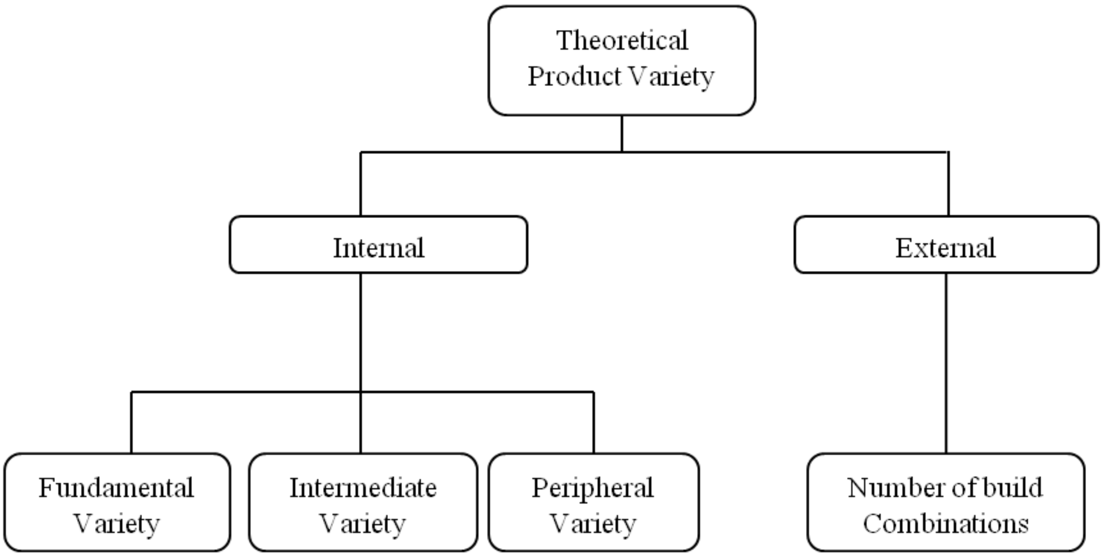
The term "product variety" is ambiguous as it is used with a number of different conceptual meanings (Stablein et al., 2011). There are various classifications for product variety. MacDuffie et al. (1996), in investigating the US automotive industry, argued that to achieve economies of scale many manufacturers adopted a strategy of minimising the variation in fundamentally different models. This they defined as fundamental variety. By offering a large number of options (i.e. end items) for the basic designs, high variety could be offered to the consumer. This they defined as peripheral variety. In between these extremes is intermediate variety that is driven by consumer choice.

Peripheral variety is a type of general variation in which manufacturers are able to add variety at a late stage (e.g. distribution and sales stages). Intermediate variety increases the part complexity during the assembly stage of production, which affects the sequencing of the product, and the flow of parts and materials, while fundamental variety is shown at the fabrication and design stages (MacDuffie et al., 1996). In examining product variety, MacDuffie et al. (1996) examined five measures that captured product complexity in the automotive industry:

- Model mix complexity measures fundamental variety and is based on the number of different platforms, body styles and models, scaled by the number of different body shops and assembly lines in each plant.
- Parts complexity results from an intermediate level of product variety that is partially driven by consumer choice (e.g. exterior colour, the combinations of the engines and transmissions). However, parts complexity also reflects the impact of higher variety on product design (e.g. the number of main wire harnesses, and the commonality of parts across models) and the supply system (e.g. the number of assembly area part numbers, and the number of suppliers to the assembly area).
- Option content and option variability are measures of peripheral variety since they are independent of the core design. Option content is calculated from the percentage of vehicles built with various options aggregated across all models in a plant; whilst, option variability captures the variance in option content within each model and across models manufactured in the plant.

Such a description is a reference to internal variety. Internal variety is commonly viewed as variation involved in creating the product within a firm or supply chain, while external variety is the amount of different and distinguishable products offered in the marketplace (Stablein et al., 2011). In simplistic terms, internal variety is what the factory has to deal with, and external variety is what the customer sees. Stablein et al. (2011) considered a potential restriction involving "option bundling" where some options are not able to be freely chosen other than as a part of package. There are also technical incompatibilities forced on customers by the manufacturer. For example, it is not possible to order a sunroof for a convertible. Figure 2-1 shows the internal and external variety from Stablein et al. (2011).

Figure 2-1 Theoretical product variety



Source: Stablein et al. (2011)

According to Fisher et al. (1999), product variety can be defined by two attributes: the breadth of the products that a firm offers at any given time and the rate at which the firm replaces existing products with new products. Randall and Ulrich (2001) defined product variety as the number of different versions of a product presented by a firm at any single point in time. They defined two types of variety to investigate costs resulting from product variety. Variety is production-dominant if increases in production costs by increased variety outweigh the increase in market mediation costs. Conversely, variety is mediation-dominant if the increase in mediation costs associated with increased variety outweighs the growth in production costs.

Martin and Ishii (2002) classified variety into spatial variety and generational variety. Spatial variety indicates the variety that a company offers the marketplace at any given point in time, whilst generational variety concerns product breadth across different generations of products. Martin and Ishii (2002) described a step-by-step method that aids companies in developing product platform architectures using two indices to provide a ‘‘scheme by which the function of a product is allocated to physical components’’. The first index is the generational variety index (GVI), a measure of the amount of redesign effort required for future designs of the product. The GVI is an indicator of which component are likely to change over time. The second index is the coupling index (CI). The CI indicates the strength of coupling between the components in a product. The stronger the coupling between components, the more likely a change in one will require a change in the other (Martin and Ishii, 2002).

Randall et al. (2003) classified product variety in the market using five different measures: the number of models, the number of brands, the number of frame materials per product line, the number of component groups per frame and the number of different frame geometries in the product line. The five measures were used to investigate the relationships between responsive supply chains, higher product variety, industry growth rate, higher contribution margin, and higher demand uncertainty.

In addition, Holweg and Pil (2004) identified the differences between static and dynamic variety. Static variety represents a single snapshot of the variety handled by the manufacturing firm whereas dynamic variety reflects the whole picture as variety evolves. In short, dynamic variety is the product mix that a company creates over time in order to serve the marketplace better (Fogliatto and Silveira, 2011). There is strong support for the increase of such dynamic variety in some industries such as automotive as the average life cycle of the products has been decreasing constantly (Holweg and Pil, 2004). Clearly, the variety a manufacturer faces also changes over time primarily as a result of changes in market requirements. Typically there are two measures related to such change (Holweg and Pil, 2004). The first concerns the product life cycle, or the marketing life cycle, which determines the time frame in which the product is available for sale. The second is the model range which may also change over time, typically increasing to stimulate demand.

Stablein et al. (2011) investigated product variety and measured not just how much variety theoretically could be produced, but how much was actually demanded by the customer. To this effect the authors proposed a variety measure based on dynamic and market-based variety measures. In a second step, they extend their analysis by applying these measures and empirically testing the impact of variety mitigation strategies such as postponement and options bundling. However the analysis was developed within a single firm and a single industry - automotive.

2.3. CUSTOMISATION MANAGEMENT

2.3.1. Customisation

Variety and customisation are related but distinct concepts. Duray et al. (2000) articulated the difference as follows: “variety provides choice for customers but not the ability to specify the product”. A high variety offering may act as a proxy for customisation but true customisation requires customer involvement in the product specification. However, the consideration of variety across different business functions necessarily requires the notions of customer involvement and customisation to be considered. Products may be differentiated according to the stage in the value chain where the customisation occurs, that is, at the point at which the customer input is injected (Lampel and Mintzberg, 1996). Identifying the point of initial customer involvement is critical in determining the degree of customisation (Duray et al., 2000). The earlier the involvement of the customer in the production and supply lifecycle of a product the deeper the level of customisation, and so degree of customer involvement is pivotal in determining the degree of customisation (Duray et al., 2000).

2.3.2. Customisation dimensions and management

Early research by Lampel and Mintzberg (1996) saw the development of a customisation framework composed of five strategies: pure standardisation, segmented standardisation, customised standardisation, tailored customisation and pure customisation. Lampel and Mintzberg (1996) applied this framework to various industries and found that the most striking trend had not been towards pure customisation but towards a middle ground, they labelled "customised standardisation". They defined the level of customisation as follows:

- Pure standardisation: This strategy is based on a "dominant design" targeted at the broadest possible group of customers, with products produced on as large a scale as possible, and then distributed commonly to all. The customer has to make a choice or else switch to another product and has no direct influence over design, production, or even distribution decisions.
- Segmented standardisation: The products offered are standardised within a narrow range of features. A basic design is modified to cover various product dimensions but not at the request of individual customers. At most, there may be a somewhat greater tendency to customise the distribution process. This occurs, for example, in the delivery schedule of major appliances. This "distribution customisation" is investigated in more detail by Squire et al. (2004).
- Customised standardisation (modularisation): Products are made to order from standardised components and the assembly is customised. The basic design is not

customised, and the components are all mass produced for the aggregate market. Each buyer receives their own configuration. However, the configurations available are constrained by the range of available components (e.g. automobile body with standardised material).

- Tailored customisation: The company presents a product prototype to a potential buyer and then adapts or tailors it to the buyer's wishes or needs. Here customisation works backward to the fabrication stage but not to the design stage (e.g. tailored suit).
- Pure customisation: Individualisation reaches its logical conclusion when customer needs penetrate deeply into the design process itself, and the product is designed to order. All stages including design, fabrication, assembly, and distribution are largely customised. The traditional polarisation between buyers and sellers is transformed into a genuine partnership in which both sides become deeply involved in each other's decision making (e.g. large-scale production machinery, industrial instrumentation and jewellery).

According to Gilmore and Pine (1997), mass customisation can be defined by four discrete approaches: collaborative, adaptive, cosmetic and transparent. Collaborative customisers conduct a dialogue with individual customers to help them articulate their needs, to identify the precise offering that satisfies those needs, and to supply the customised product. Adaptive customisers offer one standard but customisable product that is designed so that buyers can alter it themselves. Cosmetic customisers present a standard product differently to different customers. Lastly, transparent customisers provide individual customers with unique goods or services, without letting customers know explicitly that those products and services have been customised. The implementation of mass customisation not only solves the problem of flexibility in the supply network but also strengthens global efficiency and customer responsiveness (Remko et al., 2001).

Amaro et al. (1999) analysed and highlighted four degrees of product customisation: pure customisation, tailored customisation, standardised customisation and non-customisation. Pure customisation provides a new design for individual customers. Tailored customisation is the modification of an existing design. Standardised customisation allows selection from a given set of design options. Lastly, non-customisation takes an existing design as is. The first three categories are those used by Lampel and Mintzberg (1996), and Mintzberg (1988), while the fourth covers non-custom-made or standard products.

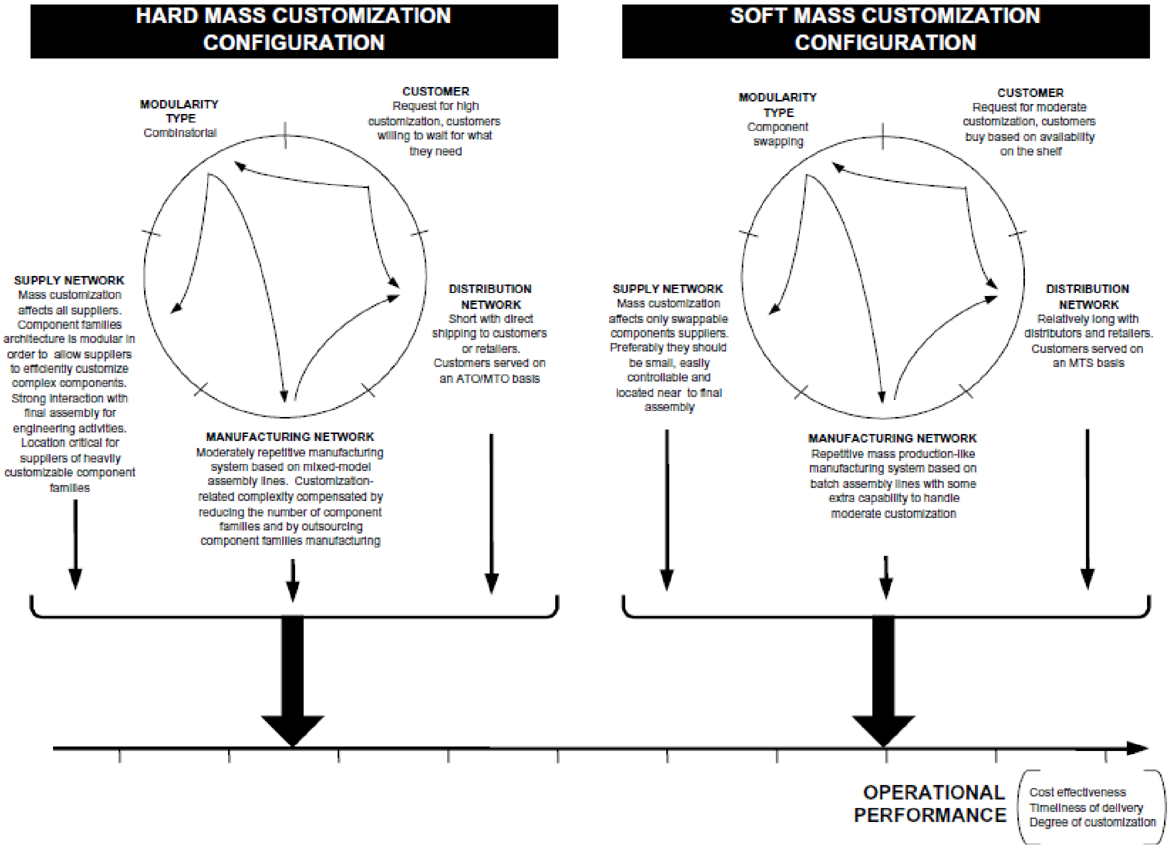
Duray et al. (2000) juxtaposed the level of customer involvement in the design process with the type of modularity employed by the producer to develop a classification matrix of four categories: fabricators, involvers, modularisers and assemblers. These were then validated through an empirical analysis of mass customisers. Fabricators resemble pure customisers employing a modular approach at the customised component level. Involvers incorporate customer involvement in product design and use a modular approach during assembly and delivery stages. Modularisers incorporate customer requirements during assembly and delivery, and a modular approach at the design and fabrication stages Assemblers involve the customer and employ a modular approach in the assembly and use (i.e. sales) stages.

Da Silveira et al. (2001) combined a range of different mass customisation frameworks to produce a continuum of eight generic levels ranging from pure customisation to pure standardisation: 1. standardisation, 2. usage, 3. package and distribution, 4. additional service, 5. additional custom work, 6. assembly, 7. fabrication and 8. design. Design is the top level and represents a collaborative design, manufacturing and delivery of products according to individual customer preferences. Level 7 refers to manufacturing of tailored products following basic, pre-defined designs. Level 6 deals with the arranging of modular components into different configurations according to customer orders. In levels 5 and 4, customisation is achieved by simply adding custom work or services to standard products. In level 3, customisation is provided by distributing or packaging similar products in different ways, while customisation occurs only after delivery through products that can be adapted to different functions or situations in level 2. Lastly, level 1 refers to Lampel and Mintzberg's (1996) pure standardisation.

Squire et al. (2004) associated the different forms of customisation with four manufacturing functions: distribution, assembly, fabrication and design customisation. In the case of distribution customisation, customers may customise product packaging, the delivery schedule, and the delivery location while the actual product is standardised. In the case of assembly customisation, customers are offered a number of pre-defined options. Products are made to order using standardised components. In fabrication customisation, customers are offered a number of pre-defined designs and the products are manufactured to order. Lastly, customer input stretches all the way from the start of the design/production process in design customisation.

Salvador et al. (2004) suggested two types of special configuration: ‘soft’ and ‘hard’ mass customisation. Soft mass customisation concerns long distribution networks and employs a make-to-stock (MTS) system that can handle requests for moderate levels of customisation. In contrast, customers expect to wait and pay more for hard mass customisation products; they are provided by short distribution networks on the basis of assemble-to-order (ATO) and make-to-order (MTO) systems that can handle requests for high customisation. In addition, manufacturing and supply networks normally utilise component swapping modularity in soft mass customisation, while hard mass customisation employs combinatorial modularity types in mixed model assembly processes. The researchers argued that the key mechanism in reducing the trade-off between customisation and operation performance is the appropriate alignment of market requirements, product architectures and supply-chain configurations. Figure 2-2 displays a comparison between soft and hard mass customsiation.

Figure 2-2 Comparison of 'soft' and 'hard' mass customisation



Source: Salvador et al. (2004)

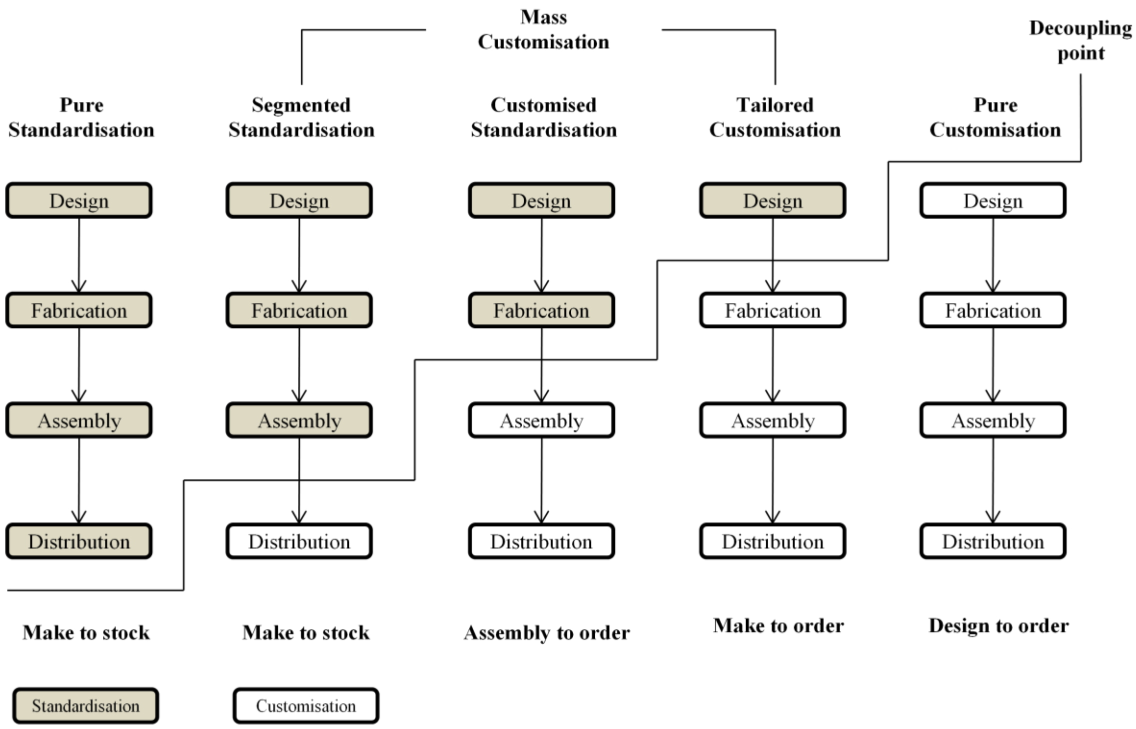
Poulin et al. (2006) extended a previous framework by Montreuil and Poulin (2005) in order to provide a comprehensive view of the degrees of customisation offered to end customers. According to this concept, the framework is sub-divided into eight categories: popularising, varietising, accessorising, parametering, tailoring, adjusting, monitoring and collaborating. Popularising offers a limited number of products to reach a wide variety of customer needs and is for customers who want off-the-shelf products. Varietising mixes products to satisfy almost all customer needs. Hence, the retailers pick products that they want to offer off-the-shelf and rely on quick delivery through their distribution networks. Accessorising has a limited set of core products matched with a wide array of accessories. Final assembly of accessorised products perform to order either by the user or the retailer. With regard to parametering, a customer defines the desired product through the setting of parameters and the selection of options. With tailoring, the product is engineered to meet the customer's needs. Therefore, the customer is closely involved in the product realisation process. In the case of adjusting, the product is adjusted to the customer's needs after usage. With regard to monitoring, through interactive customer feedback, a product is replaced by a more adequate product as the customer's needs evolve, continually ensuring a best-fit product for the individual's preferences. Lastly, the collaboration option views the customer as a collaborator, using open dialogue. Expert field systems interact with customers, seeking to continually optimise the customer's return. Table 2-1 provides a summary of the general level of customisation offered by a range of different approaches and contributions. Figure 2-3 displays the relationship between customisation, de-coupling point and order fulfilment strategy. Lyons et al. (2013) compared framework of Poulin et al. (2006) with the other most-widely cited variety management and customisation classification system.

Table 2-1 General level of customisation

Lampel and Mintzberg (1996)	Gilmore and Pine (MC) (1997)	Amaro et al. (1999)	Da Silveira et al.(MC) (2001)	Squire et al. (2004)	Salvador et al. (MC)(2004)	Poulin et al. (2006)
Pure standardisation		Non customisation	Standardisation /Usage			Popularising
Segmented standardisation	Adaptive/ Cosmetic customiser	Standard customisation	Package and distribution	Distribution customisation	Soft mass customisation	Varietising
Customised standardisation			Additional service, custom work/Assembly	Assembly customisation		Accessorising
Tailored customisation	Transparent customiser / Collaborative customiser	Tailored customisation	Fabrication	Fabrication customisation	Hard mass customisation	Parametering Tailoring
Pure customisation		Pure customisation	Design	Design customisation		Adjusting Collaborating

Source: Adapted from comparison between literature reviews

Figure 2-3 Type of customisation with de-coupling point and order fulfilment strategy



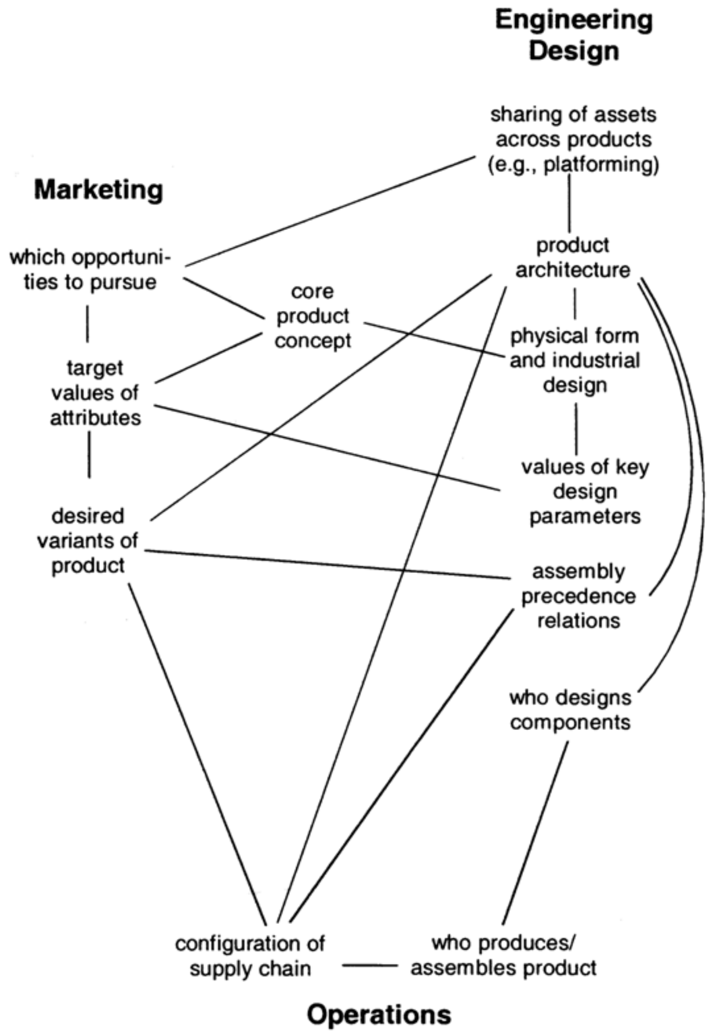
Source: Adapted from Lampel and Mintzberg (1996)

The term 'mass customisation' was first coined by Davis (1987) in his book 'Future Perfect', in which he described a trend where companies sought to micro-segment markets and offer unique products and services to customers. It is Pine et al.'s Harvard Business Review paper (Pine et al., 1993) that popularised the concept of mass customisation and ignited a wave of academic research and industrial experimentation. Mass customisation is a system that employs information technology, flexible processes, and organisational structures to deliver a wide range of products and services that meet specific needs of individual customers at a cost near that of mass-produced items (Tseng et al., 1996; Da Silveira et al., 2001). One essential feature that differentiates mass customisation from mass production is that customers are actively involved in the value creation process in mass customisation (Duray, 2002). Each customer has his or her individual identity and provides inputs in designing, producing, and delivering the product or service based on his or her individual preferences (Chen et al., 2009). The point of customer involvement (i.e. de-coupling point) is a key element in defining the configuration of processes that should be used to produce mass customised products. Hart (1995) pointed key decision factors of mass customisation include customer sensitivity (e.g. firms' ability to produce customer specifications within a reasonable time and cost, and customers' sacrifice for cost, time and service), process amenability (e.g. manufacturing and information technology) competitive environment (e.g. high market turbulence) and organisational readiness (e.g. knowledge sharing through networks of suppliers, manufacturers and retailers). Broekhuizen and Alsem (2002) also suggested key factors that influence the success of mass customisation include customer factors (e.g. customer involvement and willingness to pay a premium price), product factors (e.g. product visibility and adaptability), market factors (e.g. market variety due to the nature of the competitive environment), industrial factors (e.g. information and production technology growth), and organisational factors (e.g. manufacturing/distribution flexibility and readiness to change).

2.4. THE IMPACT OF PRODUCT VARIETY ON BUSINESS FUNCTION PERFORMANCE

Krishnan and Ulrich (2001) stressed three common functions that require to be considered in product development research: marketing, engineering, and operations (e.g. purchasing, manufacturing and logistics). Typically, the marketing function is responsible for many of the product planning decisions and the operations function for the supply-chain design decisions. Engineering design is entrusted with the task of making the bulk of the concept and detailed design decisions (Krishnan and Ulrich, 2001). Supply chain functions such as purchasing, manufacturing and logistics are also part of an integrated system and synchronises a series of inter-related business functions (Min and Zhou, 2002). Figure 2-4 presents functional categories for product variety decisions. Therefore, Engineering, Manufacturing, Purchasing, Logistics and Marketing are the business functions deemed suitable for consideration in this research.

Figure 2-4 Functional categories for product development decisions



Source: Krishnan and Ulrich (2001)

2.4.1. Engineering

Increasing the level of product variety offered by a manufacturer creates a number of challenges for its Engineering function. According to Yeh and Chu (1991) and Fisher et al. (1995), research and development (R&D) and engineering change costs increase with increasing product variety. Milgate (2001) and Jiao et al. (2000) have also lent support to the notion that product variety introduces complexity by forcing manufacturers to change engineering and production processes. Investments in new products include the costs of product development and production, and each new component has to be designed and tested, and requires investment in changing tooling (Fisher et al., 1999). The unit cost of product also increases with increasing product variety mainly because of the increase in overheads (Hayes and Wheelwright, 1984; Anderson, 1995; Krishnan and Gupta, 2001; Ramdas, 2003). There is also an increase in design workload due to design complexity related to the development of numerous new product variants (Milgate, 2001; Forza and Salvador, 2002; Barnes, 2008).

Modular product family architectures, and platform and component sharing provide conspicuous opportunities for manufacturers to reduce the negative impact of product variety on Engineering performance (Krishnan and Gupta, 2001; Salvador et al., 2002; Ramdas, 2003). Component sharing is an approach adopted by many assembled-product manufacturers to achieve high final product variety with both lower component variety and cost (Ramdas et al., 2003). That is, firms can offer high variety in the market by component sharing while retaining low variety in their operations. When designing for variety, introducing modular architectures increase flexibility in design and manufacturing through the separation of subparts of products (Fujita, 2002). Economics of scope without modularity and component sharing increases the unit cost of the product since product volume is proved to be a major factor that influences the unit product cost (Anderson, 1995). As a result of the relatively higher volumes of the generic modularity and shared components, the unit cost of the products decreases (Krishnan and Gupta, 2001).

In addition, anticipating manufacturing requirements through the adoption of design for manufacture (DFM) principles has been regarded as critical for achieving cost-effective product variety (Yeh and Chu, 1991). This principle stresses the use of simple designs, modular assemblies, multifunctional parts, self-locating features, parts standardisation, and elimination of adjustments. When applied early in the development of new products, DFM principles can reduce overall part variety by up to 40 per cent while significantly reducing assembly time (Kumpe and Bolwijn, 1988). DFM principles require that engineers and designers work together to achieve mutual long-term goals (Yeh and Chu, 1991).

To minimise the complexity of product variety, manufacturers in many industries may consider platform-based product development. Product platforms, which are component and subsystem assets shared among product-families, allow firms to better leverage investments in product design and development (Krishnan and Gupta, 2001). In addition, the benefits of using platform-based product development are reduction in the fixed cost of developing individual product variants, a greater degree of reuse, improved architectures, lower unit variable cost, quicker development of product variants and an increase in the optimal quality level of the product (Krishnan and Gupta, 2001). Although the product platforms are not appropriate for all product and market conditions, the platform-based development approach is more profitable than the independent development of products (Krishnan and Gupta, 2001). In particular, they reported that platforms are not appropriate for extreme levels of market diversity. In addition, cellular manufacturing (CM) where processing requirements are grouped into a family of similar design parts, can enhance flexible process design (McCutcheon and Raturi, 1994, Abdi and Labib, 2004).

2.4.2. Manufacturing

High product variety causes an escalation in costs and increases the complexity of manufacturing processes (Alford et al., 2000). Furthermore, the introduction of a new product incurs significant expenses associated with the production and launch (Bayus et al., 2003). A corollary to this is that as product variety increases, the expectation is that the performance of internal operations decreases, as a result of higher direct labour and material cost, manufacturing overhead cost (e.g. materials handling, quality control, information systems and facility utilisation), delivery times, and inventory levels (Hayes and Wheelwright, 1984; Abegglen and Stalk, 1985; Foster and Gupta, 1990; Forza and Salvador, 2001; Salvador et al., 2002). Manufacturing complexity often leads to a requirement for additional tooling, process areas and floor space owing to the diversity in the number of parts (Fisher and Ittner, 1999). Fisher et al. (1995) have also supported the idea that higher product variety increases supply chain costs such as material handling and parts or raw material purchasing costs. A consequence of an increase in parts variety is that process variety also increases. Process variety is the diversity and complexity in the processes due to process alternatives for each product variant (Zhang et al., 2005). Manufacturing flexibility initiatives can mitigate the negative impact of product variety. For example, cellular manufacturing allows a large variety of products to be produced with mass production efficiency by grouping products or parts with similar manufacturing and/or design characteristics into families and setting aside clusters of processes or "cells" for their manufacture. In this way the impact of product variety can be reduced when modern technology and sophisticated operations management are employed (Tang and Yam, 1996).

Banker et al. (1990) regarded product complexity as having a significant impact on the cost of supervision, quality control, and tool maintenance in automotive component manufacturing. Quality and rework problems may increase with an increase in product variety and engineering changes due to product variety lead to more complex task assignment and scheduling increases, which requires more supervisory effort (Fisher et al., 1995; MacDuffie et al., 1996). Sutton (2001) has also addressed trade-offs between product quality and variety in differentiated product industries.

MacDuffie et al. (1996) noted that as the complexity of parts and the number of product lines increase, direct labour cost and quality may suffer since production personnel are confronted with an increasingly diverse array of different parts to work with. If there is no increase in machine capacity, lot sizes must be reduced and process changeovers increased in order to meet the greater variety of customer needs (Yeh and Chu, 1991). The study of MacDuffie et al. (1996) revealed that mean optional content per vehicle (i.e. peripheral variety) and parts complexity (i.e. intermediate variety) have a significant impact on labour productivity. However, differences in the model mix (i.e. fundamental variety) had no significant association with labour productivity or quality since plants had an appropriate level of tooling in the body shop for any level of model mix due to a flexible production system. In addition, product variety increases product flexibility (Yeh and Chu, 1991), and manufacturing flexibility through the introduction of advanced technology such as computer aided design (CAD), computer aided manufacturing (CAM) and numerically controlled (NC) machines (Silveira, 1998).

Martin and Ishii (1996) developed the concept of Design for Variety (DFV). They attempted to capture actual costs due to product variety through the measurement of three indices: commonality, differentiation point, and set-up cost. The commonality index (CI) accounts for the utilisation of standardised parts; whilst the differentiation index (DI) implies the placement of a differentiation point that can reduce inventory and lead time; and the setup cost Index (SI) measures the percentage cost contribution of setup to total costs. Keeping the system as common as possible through standardisation or commonality and postponing the commitment to variety requirements have been proven effective for mitigating the negative cost impact of product variety (Martin and Ishii, 1997). In particular, mass customisation calls for postponement principles and delays some value-adding activities until a customer order arrives (Blecker and Abdelkafi, 2006). In addition, Martin and Ishii (2002) have described a structured methodology that allows DFV to aid the development of product platform architectures that incorporate the standardisation and the modularisation features needed to reduce future design cost and effort.

Fisher and Ittner (1999) examined the impact of product variety on automobile assembly plant performance. Their research investigated which dimensions of product variety affect measures of manufacturing performance including labour productivity, rework and inventory. The empirical study conducted concluded that variability in option content increases overhead hours, rework and inventory while bundling options with a few packages can reduce the amount of buffer capacity required. In addition, manufacturing diversity and parts variety increases scheduling complexity through the need to determine when to hold inventory and when to reschedule orders of parts (Flynn and Flynn, 1999).

Randall and Ulrich (2001) argued that variety imposes two types of costs on a supply chain: production costs and market mediation costs. Production costs include incremental fixed investments associated with providing additional product variants. These include direct materials, labour, manufacturing overhead and process technology investment. Market mediation costs arise because of uncertainties in product demand created by variety including inventory holding costs and product markdown costs that occur when supply exceeds demand and the costs of lost sales when demand exceeds supply (Fisher, 1997). Based on this notion, variety can be divided into two types: production-dominant and market mediation-dominant variety. Production-dominant variety arises when production costs outweigh the market mediation cost while market-mediation dominant variety occurs when market mediation cost outweighs production cost. In order to achieve economies of scale in production cost, a firm might attempt to aggregate production volumes for different geographic markets into one facility. However, aggregating production often creates longer replenishment times and demand forecasting difficulties, which increase demand uncertainty and market mediation cost. Therefore, to minimise market mediation costs, a firm has an incentive to build plants locally at a cost of reduced scale (Randall and Ulrich, 2001). They also found that production-dominant variety is positively associated with scale-efficient and distant production, while market mediation-dominant variety is positively related with scale-inefficient and local production (Randall and Ulrich, 2001).

According to Thonemann and Bradley (2002), as waiting time in the batch buffer, and manufacturing time in the process queue increase, expected manufacturing lead time increases with product variety. Therefore, manufacturers need to consider the full supply chain process, since even a small reduction in set-up time can affect final retailer efficiency. They also found that the expected replenishment lead time and cost at retailers were concave increasing with product variety and that the expected lead time can be reduced by reductions in unit manufacturing time. Table 2-2 summarises the findings of the effect of parameter-value changes on supply chain performance.

Table 2-2 Effect of parameter-value changes on supply chain performance

Parameters	Expected lead time	Retailers' cost
Product variety	Concave increasing	Concave increasing
Setup time	Linear increasing	Concave increasing
Unit manufacturing time	Convex increasing	Convex increasing
Number of retailers	Nor affected	Concave increasing
Demand rate	Convex increasing	Increasing

Source: Thonemann and Bradley (2002)

As variety increases, the assembly and supply processes can become very complex. In assembly systems, this complexity may cause human errors to increase. This in turn impacts on system performance (Hu et al., 2008). Complexity also impacts on supply chain configuration and inventory control policy. Based on this idea, Hu et al. (2008) proposed a unified measure of complexity using an entropy concept of product variety. Models are developed to describe the complexity propagation in multi-stage assembly systems and multi-echelon supply chains for complexity mitigation. Hu et al. (2011) also investigated assembly system design, planning and operations within the context of product variety. This allowed discussion of complexity and the role of human operators in assembly systems. Assembly is an important part of the manufacturing process, and critical for effective product variety. In addition, manufacturing complexity has a negative impact on manufacturing plant performance (Bozarth et al., 2009) and unstable production schedules additionally drive dynamic complexity in the manufacturing environment (Vollmann et al., 2005).

Research by Corrocher and Guerzoni (2009), using evidence from the ski manufacturing industry, found that prices were positively affected by product quality and variety in service characteristics. This revealed that a high degree of product variety allows firms to charge a premium price to consumers. This results from the fact that customers are able to find the product that best meets their needs and are willing to pay a higher price. In contrast, variety in technical characteristics negatively impacts prices (Corrocher and Guerzoni, 2009). In industries where a dominant design has emerged, and new varieties are not radically different from each other, the gains in economies of scale and scope outweigh the costs of the increased flexibility in the equipment required to produce variety. From this it can be observed that the variety in technical characteristics is related with relatively low prices (Corrocher and Guerzoni, 2009).

On the other hand, Foster and Gupta (1990) observed that there is only a limited correlation between overhead costs and complexity based cost drivers such as total number of parts, number of suppliers and breadth of product line. Anderson (1995) also found very low correlation between manufacturing overhead cost and complexity. This research also investigated the relationship between manufacturing overhead cost (MOHC) and product mix heterogeneity and found that MOHC increased with severity of set-ups. Hence, a plant that has the greatest experience producing a heterogeneous mix of products mitigate cost of product mix heterogeneity by reducing the cost of set-ups (Anderson, 1995).

2.4.3. Purchasing

Increases in product variety also increase purchasing costs (Fisher et al., 1995; Randall and Ulrich, 2001). Paradoxically, this is mainly caused by a reduction in volumes of purchased parts and components (Fisher et al., 1999), which precludes the use of quantity discounts. In other words, product variety exacerbates production costs when volume is split among multiple products so that quantity discounts in purchasing are unattainable. Consequently, suppliers may experience diseconomies owing to component variety, with potential negative impacts on component prices, delivery times, and component inventory levels (McCutcheon and Raturi, 1994; Krishnan and Gupta, 2001). At a broader level, MacDuffie et al. (1996) have also argued that increased product variety has a significant adverse impact on supply chain performance particularly in quality, productivity, and material supply. They argued that long term contracts with a small number of suppliers reduce coordination costs in dealing with the higher number of parts typically associated with high product variety.

Forza and Salvador (2002) noted that the order acquisition and fulfilment process can become a serious bottleneck, as the multiplication of the product features induces a growth in the volume of information that has to be exchanged between the manufacturer's sales organisation and its customer base. They found that the proliferation of products generates two problems at the order cycle level. First, it becomes more difficult for a customer to choose the product characteristics that are best suited to his/her needs. Second, it becomes more difficult for the company to collect, store and process the larger amount of information relating to customer orders. Product documentation originating from the customer contains information that is vital for materials management, as well as manufacturing and assembly activities (Forza and Salvador, 2002). This in turn negatively impacts on the purchasing order process between supplier and manufacturer. Zhang et al. (2007) also reported that order processing time is independent of manufacturing time and more model variations may significantly increase order processing time under a build-to-order (BTO) scenario. Furthermore, unreliable supplier lead times can force manufacturers to adopt planning and materials management processes characterised by longer planning horizons and greater levels of detail (Vollmann et al., 2005).

Salvador et al. (2002) investigated how manufacturing characteristics affect the type of modularity that is embedded into the product family architecture, and how modularity interacts with component sourcing. They derived three empirical generalisations about modularity type and component sourcing which emerged from their empirical study. First, when the product variety level is low and production volume is high, the appropriate type of modularity is component swapping modularity, whereas when product variety level is high and production volume is low, then the appropriate type of modularity is combinatorial modularity. Second, firms that select component swapping modularity can mitigate the trade-off between product variety and operational performance by relying on component family suppliers located near their final assembly facilities. These suppliers tend to be smaller or directly controlled by the final assembler. Lastly, firms that choose combinatorial modularity limit the negative impacts of product variety on operational performance by reducing the total number of component families, by working with suppliers to modularise the respectively allocated component families, and by setting up mutual relationships with suppliers of component families.

In addition, as product variety increases, manufacturers might find alternative suppliers who can provide the new components and material. Carr and Pearson (2002) revealed that supplier involvement has a positive impact on strategic purchasing and financial performance. In their research, purchasing/supplier involvement refers to the act of integrating a firm's key suppliers into its decision-making process with respect to sourcing decisions. An important area for a manufacturer and its suppliers to be integrated in is the firm's product development process. The act of participating in cross-functional teams and providing proactive support in the product development process is an indication of purchasing and supplier involvement in the firm (Carr and Pearson, 2002).

2.4.4. Logistics

According to Martin and Ishii (1996), increasing product variety can incur many indirect costs including raw material costs, work in process, finished goods, post sales service inventories and logistics costs. These costs are difficult to capture and are frequently neglected when making decisions about extending variety. One conspicuous cost that relates to variety is inventory cost since the introduction of new products increases the level of stock keeping units (SKUs), and purchased and semi-finished parts inventory (Forza and Salvador, 2002).

Fisher et al. (1995) found, using a field study of automotive plants, that greater parts variety implies lower volume per part. Part variety not only increases production costs, but also increases the coefficient of variation in demand of a particular part. This entails holding greater safety stocks to reduce risks of stock outs. Benjaafar et al. (2004) also examined the effect of increased product variety on inventory costs, and showed that total cost increases linearly with the number of products.

Increasing product variety has a different impact on average flow time and average inventory level (Er and MacCarthry, 2003). Increasing product variety always leads to longer average lead times since manufacturers have to manage more types of materials. However, it is argued that increasing variety alone does not have a significant impact on the average total inventory cost; rather, it is strongly affected by uncertainty in supply delivery time. Their research also showed that the negative impact of variety-driven material variation can be reduced through standardisation of materials. Standardisation of modules (modularity) restricts component variety and permits the use of a batch or repetitive manufacturing methodology which provides low cost and consistent quality without sacrificing end-item variety (Duray et al., 2000).

Furthermore, market mediation costs increase because of uncertainty in product demand created by variety (Randall and Ulrich, 2001). Market mediation costs include the inventory holding costs and product markdown costs that occur when supply exceeds demand and the costs of lost sales when demand exceeds supply. To mitigate the trade-off between production cost and market mediation cost, outsourcing of production to a scale-efficient plant is needed in each regional market (Randall and Ulrich, 2001). It was also found that firms with scale-efficient production (i.e., high-volume firms) offer types of variety associated with high production costs, and firms with local production offer types of variety associated with high market mediation costs.

Transportation is a significant contributory factor to costs incurred by most global supply chains (Chopra and Meindl, 2007). Shipping products with unpredictable demand directly to store can result in less-than-truck-load (LTL) shipments. In such cases, with small batches, the transportation is no longer cost-effective (Lee, 2002). Chopra (2003) argued that higher transportation costs arise because of long distances and disaggregated shipping and particularly, loss in aggregation in outbound transportation further increases cost. In addition, there is a significant positive correlation between order-to-delivery lead time and the product variety (McCutcheon and Raturi, 1994; Zhang et al., 2007). Even if customers are willing to wait for a customised product, firms need to embrace the growing pressure for agile response (McCutcheon and Raturi, 1994). One initiative that allows firms to reduce logistics costs and concentrate on their core competencies is the outsourcing of the logistics function to partners, known as third-party logistics (3PL) providers (Lieb and Bentz, 2005).

2.4.5. Marketing

Consumers are the ultimate source of demand. Increasing product variety increases a company's competitive marketing power (Yeh and Chu, 1991). In order to improve profitability, firms should make competitive moves and new product introductions (NPI) are one of the competitive moves that have the potential to positively influence market share and returns (Otero-Neira et al., 2010). The development of new products with a global market focus is also positively related to the financial performance of the NPI programme (Ozer and Cebeci, 2010). As a result, many manufacturers expand their brands by introducing more products to compete for market share (Bayus et al., 2003; Kim, 2005). Besides, the development of customised products enhances consumer satisfaction (Lifang, 2007). Bayus et al. (2003) also investigated the effect of new product introductions on three key drivers of firm value: profit rate, profit rate persistence and firm size as reflected in asset growth. The results indicated that new product introductions influence profit rate and size positively, but have no effect on profit rate persistence. They also argued that product line expansion can also increase a firm's profitability by reducing selling, general and administrative expenses, and other marketing and advertising costs.

Kekre and Srinivasan (1990) investigated the market benefits and cost disadvantages of broader product lines using the profit impact of marketing strategies (PIMS) database. They found that significant market benefits could accrue from broader product lines. From a large sample of over 1,400 business units, they concluded that product variety increases market share and a firm's profitability. Higher product variety also increases the complexity of demand forecasting (Whang and Lee, 1998; Randall and Ulrich, 2001; Er and MacCarthry, 2003).

Fisher et al. (1994) assessed the potential impact of greater levels of product variety on the predictability of demand using data from a clothing company. They argued that as product variety increases, demand is divided over a growing number of stock-keeping units (SKU). Although manufacturers and retailers can forecast aggregate demand with some certainty, it is still difficult to measure exactly and predict how aggregate demand will be distributed across all the SKUs. Companies must, therefore, assess the level of variety that the customer will find attractive, and the level of complexity that will keep costs low to achieve competitive advantage, because differentiation in product variety has assumed ever-increasing importance as a marketing instrument (Jiao and Tseng, 1999).

According to Rajagopalan and Swaminathan (2001), total demand increases proportionally with an increase in variety. However, in the case of mature firms, increased variety does not increase total demand. Firms increase variety to retain market share. Paradoxically, when faced with higher variety customers enjoy the decision-making process more, but also become frustrated with the choices available and as a result are less likely to make a purchase (Iyengar, 2000). In short, an extensive array of options can at first seem highly appealing to consumers, yet can reduce their motivation to purchase the product.

Thonemann and Bradley (2002) provided insights on the impact of product variety on manufacturing lead time for a single manufacturer and multiple retailers. They argued that the effect of changeovers on the supply chain via increased product variety is due mainly to set-up time rather than set-up cost. This eventually results in increased cost to the retailer, since longer average lead-time requires retailers to hold more inventories. Thonemann and Bradley (2002) argued that in such case retailers' cost can be reduced by consolidation of retailers.

2.4.6. The impact of product variety on cost

As much as 70 % of the final costs of a product are determined by its design and complexity (Barnes, 2008). Child et al. (1991) also insisted that the complexity costs of product variety ranges from 10% to 40% of total costs, depending on the number of items (materials, parts, packaging), tasks (making design changes, preparing the production schedules), flows (production site and distribution channel), and inventory (raw material, work in process and finished goods). Stalk (1988) has suggested that scale-related costs decrease as volume increases, usually falling by 15% to 25% per unit each time volume doubles. Variety-related costs include the costs of complexity in manufacturing, such as set-up, materials handling, inventory and many of the overhead costs. In most cases, as variety increases, costs increase, usually at a rate of 20% to 35% per unit in which variety doubles. On the other hand, reducing product variety by half can improve productivity by 30% and decrease costs by 17% (Stalk, 1988). Furthermore, in flexible manufacturing systems, variety-related costs start lower and increase more slowly as variety grows (Stalk, 1988).

As mentioned in Chapter 1, studies have typically investigated the impact of product variety on specific business function performance and focused on the negative impacts such as cost and complexity. In addition, the impact of product variety has rarely been studied with the concept of level of customisation. Table 2-3 lists aspects of key business function performance, including cost, non-cost negative and non-cost positive performance in five business functions - Engineering, Manufacturing, Purchasing, Logistics and Marketing - with related literature.

Table 2-3 Business function performance and related literature

Business function performance		Related literature
Engineering	Design complexity	(Milgate, 2001; Forza and Salvador, 2002; Barnes, 2008)
	R&D cost	(Yeh and Chu, 1991; Fujita, 2002)
	Unit cost of product	(Hayes and Wheelwright, 1984; Anderson, 1995; Krishnan and Gupta, 2001; Ramdas, 2003)
	Engineering/model change cost	(Yeh and Chu, 1991; Fisher et al., 1995; Jiao et al., 2000; Milgate, 2001)
Manufacturing	Total quality (problem/control)	(Banker et al., 1990; Fisher et al., 1995; MacDuffie et al., 1996; Tang and Yam, 1996; Fisher and Ittner, 1999; Sutton, 2001)
	Manufacturing cost	(Yeh and Chu, 1991; Anderson, 1995; Fisher and Ittner, 1999; Flynn and Flynn, 1999; Alford et al., 2000; Forza and Salvador, 2002; Thonemann and Bradley, 2002; Bayus et al., 2003)
	Utilisation of standardised parts (Commonality)	(Anderson, 1995; Martin and Ishii, 1997; Martin and Ishii, 2002)
	Utilisation of postponement (Differentiation postponement)	(Martin and Ishii, 1997; Van Hoek et al., 1999; Blecker and Abdelkafi, 2006)
	Set up cost	(Yeh and Chu, 1991; Fisher and Ittner, 1999; Thonemann and Bradley, 2002)
	Product/manufacturing flexibility	(Yeh and Chu, 1991; Silveira, 1998; Corrocher and Guerzoni, 2009)
	Direct labour cost	(Abegglen and Stalk, 1985; Banker et al., 1990; MacDuffie et al., 1996; Randall and Ulrich, 2001)
	Process variety	(Yeh and Chu, 1991; Zhang et al., 2005)
	Part variety	(Yeh and Chu, 1991; Fisher et al., 1999; Anderson, 2004)
	Manufacturing complexity	(Yeh and Chu, 1991; Fisher and Ittner, 1999; Alford et al., 2000; ElMaraghy et al., 2005; Hu et al., 2008; Hu et al., 2011)
	Supervision effort	(Yeh and Chu, 1991; Fisher et al., 1995; MacDuffie et al., 1996)
	Scheduling complexity	(Yeh and Chu, 1991; MacDuffie et al., 1996; Flynn and Flynn, 1999; Vollmann et al., 2005; Bozarth et al., 2009)
	Material cost	(Fisher et al., 1995; Tang and Yam, 1996; Randall and Ulrich, 2001; Er and MacCarthry, 2003)
	Overhead cost	(Hayes and Wheelwright, 1984; Anderson, 1995; Fisher and Ittner, 1999; Randall and Ulrich, 2001; Forza and Salvador, 2002)
	Manufacturing lead time	(Thonemann and Bradley, 2002; Er and MacCarthry, 2003)
	Process technology investment cost	(Randall and Ulrich, 2001)

Purchasing	Purchasing cost	(Fisher et al., 1995; Randall and Ulrich, 2001)
	Order processing (complexity)	(Carr and Pearson, 2002; Forza and Salvador, 2002; Vollmann et al., 2005; Zhang et al., 2007; Bozarth et al., 2009)
	Purchased component / part variety	(Fisher et al., 1999; Forza and Salvador, 2002)
Logistics	Work in-process inventory	(Yeh and Chu, 1991; Martin and Ishii, 1996; Srinivasan and Viswanathan, 2010)
	Finished goods inventory	(Yeh and Chu, 1991; Randall and Ulrich, 2001; Forza and Salvador, 2002; Benjaafar et al., 2004)
	Total inventory cost (Inventory level)	(Martin and Ishii, 1996; Fisher and Ittner, 1999; Thonemann and Bradley, 2002; Er and MacCarthry, 2003; Benjaafar et al., 2004)
	Purchased parts inventory	(Forza and Salvador, 2001)
	Delivery time	(Anderson, 1995; Kotteaku et al., 1995; Fisher and Ittner, 1999; Flynn and Flynn, 1999; Forza and Salvador, 2002; Zhang et al., 2007)
	Material inventory/handling cost	(Abegglen and Stalk, 1985; Yeh and Chu, 1991; Fisher et al., 1995; Benjaafar et al., 2004)
	Market mediation cost	(Fisher, 1997; Randall and Ulrich, 2001)
	Outsourcing	(Randall and Ulrich, 2001; Chopra, 2003; Lieb and Bentz, 2005)
	Transportation cost	(Lee, 2002; Chopra, 2003; Chopra and Meindl, 2007)
Marketing	Demand forecasting uncertainty	(Fisher et al., 1995; Whang and Lee, 1998; Randall and Ulrich, 2001; Er and MacCarthry, 2003)
	Customer satisfaction	(Kekre and Srinivasan, 1990; Yeh and Chu, 1991; Vollmann et al., 2005; Lifang, 2007)
	Market share	(Kekre and Srinivasan, 1990; Tang and Yam, 1996; Rajagopalan and Swaminathan, 2001; Bayus et al., 2003; Otero-Neira et al., 2010)
	Competitive advantage	(Yeh and Chu, 1991; Tang and Yam, 1996; Jiao and Tseng, 1999; Otero-Neira et al., 2010)
	Retailers' cost (Product cost at retailer)	(Thonemann and Bradley, 2002)

Source: Martin and Ishii (2002), Thonemann and Bradley (2002), Kim (2005), Lieb and Bentz (2005), Blecker and Abdelkafi (2006), Zhang et al. (2007), Chopra and Meindl (2007), Lifang (2007), Bames (2008), Corrocher and Guerzoni (2009), Bozarth et al. (2009), Srinivasan and Viswanathan (2010), Otero-Neira et al.(2010) and Hu et al. (2011)

2.5. SUPPLY CHAIN PERFORMANCE

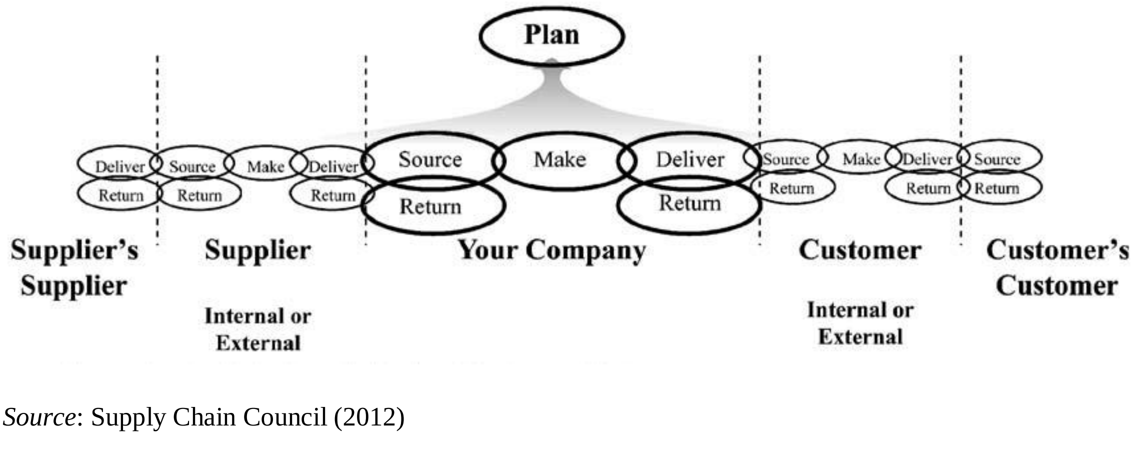
2.5.1. Definition of supply chain management

The term supply chain management was introduced in the early 1980s. Since then supply chain management (SCM) has been widely discussed and employed. Houlihan (1987) defines supply chain management as "*the integration of the various functional areas within an organization to enhance the flow of goods from immediate strategic suppliers through manufacturing and distribution chain to end user*". A supply chain is also defined as "*the integration of key business processes from end users through original suppliers that provides products, services, and information that adds value for customers and other stakeholders*" (Lambert et al., 1998). In addition, some authors have considered supply chain management as the integration of business activities (Larson and Rogers, 1998; Heizer and Render, 2011); whilst others have characterised it as the integration of business functions across the supply chain (Mentzer et al., 2001; Min and Zhou, 2002). Mentzer et al (2001) investigated categories of supply chain management in the global environment and defined SCM as "*the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole*". More recently, Stock and Boyer (2009) have developed a more encompassing definition of SCM by analysing 173 different difinitions in major journals over the period 1994 to 2008. From it they propose the following definition of SCM:

"*The management of a network of relationships within a firm and between interdependent organizations and business units consisting of material suppliers, purchasing, production facilities, logistics, marketing, and related systems that facilitate the forward and reverse flow of materials, services, finances and information from the original producer to final* *customer with the benefits of adding value, maximizing profitability through efficiencies, and achieving customer satisfaction.*"

To help in further justifying and establishing supply chain concept, it is valuable to identify the supply chain operations reference (SCOR) model (see Figure 2-5) endorsed by the Supply Chain Council (2012). This framework defines a supply chain as integrated processes of "plan," "source," "make" and "deliver," that cover the value chain from the supplier's supplier upstream to the customer's customer downstream. In short, the SCOR model demonstrates the linkage of value-adding processes that exist in supply chain networks within a firm's departments (intra organisational), and between firms (inter-organisational) (Robinson and Malhotra, 2005). This model supports the idea that each linkage and node in the chain must perform without causing any disruption to the satisfaction of final customers, and that only a single weak link in the supply chain is needed to result in detrimental performance such as late deliveries, incomplete order fulfillment, and poor product quality (Robinson and Malhotra, 2005).

Figure 2-5 The SCOR model



Source: Supply Chain Council (2012)

2.5.2. Supply chain flexibility

Supply chain flexibility has emerged from the manufacturing flexibility literature (Stevenson and Spring, 2007). Slack (1987) defined two aspects of flexibility: range and response. Range flexibility is related to capability and range of the production system (i.e. how much the system change), while response flexibility is related to response of the system and affects cost and time (i.e. how fast the system changes). At the total manufacturing system level, Slack (1987) also identified four main types of flexibility: product, mix, volume and delivery flexibility. Slack and Correa (1992) also compared the flexibility between a pull/push system in terms of coping with product variety and uncertainty and argued that pull systems had far great response flexibility than push systems. Furthermore, Gerwin (1993) has stressed the importance of manufacturing flexibility and suggested several flexibility dimensions including mix, changeover, modification, volume, rerouting and material flexibility. Manufacturing flexibility enables the manufacturing system to respond to changes in demand, product design, process technology, and material supply (Slack, 1983, 1987; Sethi and Sethi, 1990; Upton, 1995; Duclos et al., 2003; Sánchez and Pérez, 2005).

Da Silveira (1998) investigated the gaps between the strategic importance of product variety and companies' capabilities, and suggested the implementation of an adaptive and flexibility strategy to close the gaps. Five strategic flexibilities (e.g. product, mix, production, volume and expansion flexibility) and six operational flexibilities (e.g. delivery, process, programming, routing, machine and labour flexibility) were proposed.

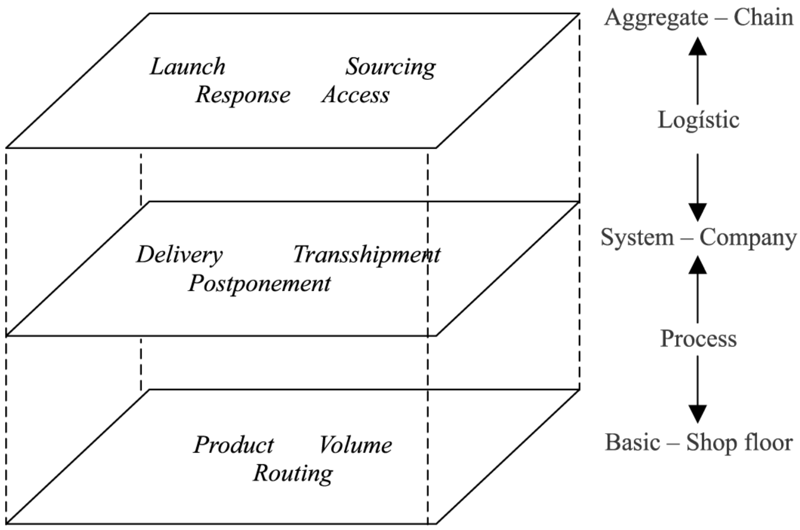
Vickery et al. (1999) identified five dimensions of supply chain flexibility: product flexibility; volume flexibility, new product flexibility, distribution flexibility, and responsiveness flexibility. The findings of their research indicate that volume flexibility and launch flexibility are key responses to marketing uncertainty and product uncertainty.

Volume flexibility is also positively related to all measures of overall firm performance and highly related to market share and market share growth (Vickery et al., 1999). On the other hand, Narasimhan and Das (1999) highlighted procurement flexibility in the supply chain and noted that strategic sourcing representing the firm's ability to utilise supplier capabilities can impact on the firm's manufacturing capabilities.

Duclos et al. (2003) added the requirement of supply chain flexibility within and between all partners in the chain including departments within an organisation and external partners including suppliers, carriers, third-party companies, and information systems providers. They proposed six dimensions of flexibility: operation system flexibility, market flexibility, logistical flexibility, supply flexibility, organisational flexibility, and information flexibility. Lummus et al. (2005) also suggested flexibility characteristics for supply chain management and used an Internet-based Delphi study involving a group of expert practitioners to enumerate the characteristics and the importance of those characteristics in making a supply chain flexible. They investigated six Delphi characteristics aligned with the conceptual model: customer / marketing focus, internal process/operation focus, information and system support focus, wide organisational focus, supply focus and logistics focus.

Sánchez and Pérez (2005), based on the bottom-up classification of flexibility including basic, system and aggregate flexibility, suggested different types of supply chain flexibility dimensions (see Figure 2-6). The dimension of product, volume and routing flexibility represent shop-floor capabilities that impact on the supply chain (basic flexibility); the delivery, transshipment and postponement flexibility are hierarchically located at the company level (system flexibility); and launch, sourcing, response and access flexibility link to supplier-customer relationships (aggregate flexibility).

Figure 2-6 Supply chain flexibility dimensions



Source: Adapted by Sánchez and Pérez (2005)

Gosain et al. (2004) argued that there are two types of supply chain flexibility: offering flexibility and partnering flexibility. Offering flexibility refers to the ability of an existing supply chain linkage to support changes in product or service offerings in response to changes in the business environment (i.e. the robust network view). On the other hand, partnering flexibility implies the ease of changing supply chain partners in response to changes in the business environment (i.e. supply flexibility).

Swafford et al (2006) posited that flexibility in a firm's supply chain process is derived from the coalignment of its range and adaptability dimensions. Furthermore, they divided supply chain flexibility attributes into three critical processes; procurement/sourcing, manufacturing and distribution/logistics flexibility. They also found that a firm's supply chain agility is impacted by the synergy among the flexibilities of these three processes. In short, supply chain process flexibility is regarded as an important antecedent of supply chain agility.

Stevenson and Spring (2007) reviewed the supply chain flexibility literature and sub-divided it into four categories: linking firm's flexibility to the supply chain, flexibility in the supply chain relation, flexibility in design of the supply chain and flexibility of the inter-organisational information system. Stevenson and Spring (2009) also investigated a wide range of supply chain flexibility practices: collaboration, product design, supplier training, information sharing, sourcing policy, shared resources, inventory policy, tactical outsourcing, leasing / hiring, standardisation and codification. The authors termed the ability to change counterparts "configuration flexibility" and the ability to change the timing, volume and design of supply "planning and control flexibility" in terms of inter-organisational aspects of flexibility. Thus the research suggested that firms make complex trade-offs between these elements in the interest of achieving overall supply chain flexibility.

2.5.3. Supply chain agility

It is crucial to clearly distinguish between the concepts of flexibility and agility. A firm attains agility by tapping into the various synergies among different forms of flexibility within a firm (Agarwal et al., 2006). Supply chain flexibility is concerned with internally focused capability and adaptability of a firm's internal supply chain functions of purchasing, engineering, manufacturing and distribution, while agility represents an externally focused competence focusing more on speed at the organisational level such as market responsiveness, delivery reliability and frequency of product introduction (Swafford et al., 2008). From their theoretical review, Bernardes and Hanna (2009) clarified the conceptual differences between flexibility, agility and responsiveness – terms that are used inconsistently and ambiguously in operations management. They defined flexibility as "*the ability to change status within an existing configuration of pre-established parameters*" while they considered agility "*the ability to rapidly reconfigure with a new parameter set in business level*". Finally, they defined responsiveness as "*propensity for purposeful and timely behaviour change in the* *presence of modulating stimuli*" Thus, supply chain flexibility can be regarded as an antecedent capability required for supply chain agility (Bernardes and Hanna, 2009).

According to Goldman et al. (1995), flexible and rapid response represents an element of organisational agility where agility was defined as the capability of an organisation to adapt to or react to marketplace changes or exploit market opportunities. Thus, an agile manufacturing system has the capacity to operate profitably in a competitive environment of continually and unpredictably changing customer opportunities. Sharifi and Zhang (1999) have also defined agility as "*The ability to cope with unexpected challenges, to survive unprecedented threats of the business environment, and to take advantage of changes as opportunities.*" Further, Sharifi and Zhang (1999) viewed agility as comprising two main factors: responding to changes in proper ways and due time and exploiting changes as opportunities.

In addition, Van Hoek et al. (2001) considered agility in relation to responsiveness to customer need and mastering market turbulence. They also investigated what might represent the dimensions of agility in the supply chain and suggested five dimensions including customer sensitivity, virtual integration, process integration, network integration and measurement. According to their notion, customer sensitivity includes market understanding and customer "enrichment", but also includes initiatives such as customisation, postponement and rapid response. Virtual integration relates to leveraging information (e.g. immediate conversion of demand information into new products) while process integration relates to mastering change across organisations (e.g. workforce management). Network integration relates to cooperating to compete (e.g. partnerships). Lastly, measurement is added as a separate element, given the focus on measuring agility in the supply chain.

Agarwal et al. (2006) affirmed the necessity for a much higher level of agility given volatile customer demand and high customer need for variety. Agarwal et al. (2006) also analysed the effect of market winning criteria and market qualifying criteria in three types of supply chains: lean, agile and leagile. Furthermore, the paper explored the relationship among lead-time, cost, quality, and service level and the leanness and agility of a case supply chain in a fast moving consumer goods business.

According to Hallgren and Olhager (2009), three factors distinguish an agile from a lean manufacturing system: high customisation capability, efficient variety handling and new product agility. In addition, the choice of a cost-leadership strategy fully mediates the impact of the competitive intensity of industry as a driver of lean manufacturing, while agile manufacturing is directly affected by both internal and external drivers (i.e. differentiation strategy as well as the competitive intensity of industry) (Hallgren and Olhager, 2009). Agile manufacturing is found to be negatively associated with a cost-leadership strategy, emphasising the difference between lean and agile manufacturing. Table 2-4 presents a comparison of characteristics of lean, agile and leagile supply chains.

Table 2-4 Characteristics of lean, agile, and leagile supply chains

Distinguishing attributes	Lean supply chain	Agile supply chain	Leagile supply chain
Market demand	Predictable	Volatile	Volatile and unpredictable
Product variety	Low	High	Medium
Customisation	Low	High	Medium
Product life cycle	Long	Short	Short
New product agility	Low	High	Medium
Customer drivers	Cost	Lead-time and availability	Service level
Profit margin	Low	High	Moderate
Dominant costs	Physical costs	Marketability costs	Both
Stock out penalties	Long term contractual	Immediate and volatile	No place for stock out
Purchasing policy	Buy goods	Assign capacity	Vendor managed inventory
Information enrichment	Highly desirable	Obligatory	Essential
Forecast mechanism	Algorithmic	Consultative	Both/either
Typical products	Commodities	Fashion goods	Product as per customer demand
Lead time compression	Essential	Essential	Desirable
Eliminate muda	Essential	Desirable	Arbitrary
Rapid reconfiguration	Desirable	Essential	Essential
Robustness	Arbitrary	Essential	Desirable
Quality	Market qualifier	Market qualifier	Market qualifier
Cost	Market winner	Market qualifier	Market winner
Lead-time	Market qualifier	Market qualifier	Market qualifier
Service level	Market qualifier	Market winner	Market winner
Competitive strategy	Cost leadership	Differentiation	Cost leadership & Differentiation

Source: Adapted from Agarwal et al. (2006), Hallgren and Olhager (2009)

2.5.4. Cost efficiency and customer service performance

Earlier studies of supply chain modelling employed several different performance measures, including cost, customer responsiveness, and activity time (Lee and Billington, 1993; Pyke and Cohen, 1993; Arntzen et al., 1995). Beamon (1998) undertook a literature survey of quantitative performance measures used in supply chain environments and found a predominance of two types of performance measures: cost and customer responsiveness. Costs are related with inventory and operating costs such as cost minimisation, sales maximisation, profit maximisation, inventory investment minimisation and return on investment maximisation. Customer responsiveness measures include lead time, delivery, stock-out probability and fill rate. From this, Beamon (1999) was able to develop a framework through the mixture of performance measures for supply chain systems. Three types of performance measures were identified as crucial components of a supply chain performance measurement system: resource, output and flexibility. The resource measures provide a goal for a high level of efficiency (e.g. the total costs of resources, inventory, manufacturing, distribution in the supply chain). Output measures provide goals for a high level of customer service. These are related to customer satisfaction, customer response times, on-time deliveries, order fill rate, customer complaints, backorder/stock-out, manufacturing lead time, and shipping errors. The final measure – flexibility - is the ability to respond to the changing environment. It includes the ability to respond to and accommodate demand variations, periods of poor manufacturing performance, periods of poor supplier performance, periods of poor delivery performance, and new products, new markets, or new competitors (Beamon, 1999).

Ramdas and Spekman (2000) defined six variables that reflect different approaches to measuring supply chain performance. These include inventory, time, order-fulfilment, quality, customer focus and customer satisfaction. Inventory indicates the extent to which a supply chain partner affects inventory levels, inventory turns and inventory cost. Time refers to product development time, time to market and time to break even. Order fulfilment denotes order processing time and shipment accuracy. Quality represents the percentage of defects and the extent to which a supply partner contributes to continuing improvement. Customer focus identifies the contribution margin, value added and customer value. Lastly, customer satisfaction refers to end user customer satisfaction and account penetration (Ramdas and Spekman, 2000).

Thonemann and Bradley (2002) considered the role of the set-up time, manufacturing lead time and the retailers' cost while investigating the effect of product variety on supply chain performance. Kleijnen and Smits (2003) conducted a critical analysis of various performance metrics for SCM. Five logistical performance metrics of a SCM system were considered: fill rate, confirmed fill rate, response delay, stock and delay. Fill rate is defined as the percentage of orders delivered 'on time' while confirmed fill rate is defined as the percentage of orders delivered 'as negotiated'. Response delay is the difference between the requested delivery day and the negotiated day, and stock refers to total work in process (WIP). Lastly, delay is defined as actual delivery day minus confirmed delivery day (Kleijnen and Smits, 2003).

Vickery et al. (2003) examined the performance implications of an integrated supply chain strategy, with performance of customer service and business (i.e. financial performance). In their research, customer service is treated as an intermediate performance outcome while financial performance is viewed as the final performance outcome. The customer service items considered included pre-sale customer service, post-sale customer service, responsiveness to customers, delivery dependability, and delivery speed. Otto and Kotzab (2003) also explored suitable metrics to measure the effectiveness of SCM. The outcome of their research is a set of six unique perspectives that allow measurement of SC performance. It includes system dynamics (e.g. inventory level and stock out), operations research (e.g. service level and time to deliver), logistics (e.g. lead time and order cycle time), marketing (e.g. customer satisfaction and market share), organisation (e.g. flexibility and relationship) and strategy (e.g. time to market and ROI).

According to Jeong and Hong (2007), customer oriented supply chain performance outcomes refer to the extent of an organisation's defence of its competitive advantage through the implementation of customer oriented supply chain practices. Supply chain performance outcomes have three dimensions: informational outcomes, operational outcomes and customer outcomes. Informational outcomes are related to problem solving through the use of information technology throughout the supply chain while operational outcomes are related to competitive advantage in terms of operational effectiveness, including cost, quality, delivery, flexibility, and time. Customer outcome refers to the extent of customer responsiveness that results in sustaining a loyal customer base and/or expanding a new customer base. (Narasimhan and Soo Wook, 2002; Chan and Qi, 2003; Otto and Kotzab, 2003; Treville et al., 2004).

Based on the performance structure of Beamon (1999), Khan et al. (2009) also argues that supply-chain driven organisational performance can be separated into three categories: resource performance that reflects value added in the form of achieving efficiency; output performance refers to value added in terms of a firm's ability to provide high levels of customer service; and flexibility performance reflects value added in terms of a firm's ability to respond (Khan et al., 2009).

2.5.5. Business performance

Business performance should be measured by accounting data that shows the firm's performance and market valuation of a firm's activities is paramount in this (Vickery et al., 2003). Vickery et al. (2003) measures financial performance by employing a set of traditional performance measures including pre-tax return on assets (ROA), return on investment (ROI) and return on sales (ROS). However, a firm's financial leverage can affect its ROI to such a degree that it renders comparisons between firms meaningless. ROI also ignores opportunity costs and the time value of investment (Tan et al., 1999). As a result, Tan et al. (1999) suggested nine different measures of performance that determine senior management's perceptions of a firm's performance. They involve market share, return on assets (ROA), and overall competitive position (e.g. market share growth, sales growth, ROA growth, production cost, customer service levels, product quality and competitive position). Vickery et al. (1999) also used ROI, ROS, market share and each performance's growth (e.g. market share growth) for business performance to investigate the relationship between supply chain flexibility and business performance.

Rosenzweig et al (2003) used four measures of business performance: ROA, sales growth, customer satisfaction and % revenue from new products to investigate the hypothesis that supply chain integration intensity leads directly to improved business performance. Droge et al. (2004) also investigated the effects of integration practices on time based performance and on overall firm performance. They utilised time based performance with three outcomes including time to market (e.g. product development and launch speed), time to product (e.g. the overall product delivery speed and lead times) and customer responsiveness (e.g. customer service and product support). On the other hand, they defined overall firm performance by: market share performance (e.g. market share and share growth) and financial performance (e.g. ROA, ROI and ROS).

Sánchez and Pérez (2005) explored the relationship between supply chain flexibility and firm performance using six measures: ROI, ROS, market share, ROI growth, ROS growth and market share growth. Kim (2006a) utilised market (e.g. sales growth), financial performance (e.g. ROI) and customer satisfaction to assess a firm's performance in attempting to examine the causal linkages among supply chain management (SCM) practice, competition capability, the level of supply chain (SC) integration, and firm performance.

Market performance was measured using sales growth and market share growth. Financial performance was measured using total cost reduction, return on investment (ROI), return on assets (ROA), financial liquidity and net profit. Customer satisfaction relates to the reduction of response time in design change, volume change and product returns, accuracy of order processing, reduction degree of product return ratio and speed of order handling. In addition, Panayides (2007) argued that a composite measure of performance would reflect more accurately firm improvements as opposed to a single quantitative or accounting-related performance measure and related the business performance to profitability, market share, sales growth, sale volume, ROI and overall assessment.

2.6 STRATEGIES TO MANAGE VARIETY

Ulrich et al. (1998) provided several reasons for managing product variety that apply to most industries. Strategic decisions involve creating an effective variety delivery system and include: 1) the dimensions of variety offered, 2) the nature of the customer interface and distribution channel, 3) the degree of vertical integration, 4) the process technology, 5) the location of the decoupling point, and 6) the product architecture. They also reported that variety strategies are dynamic. No single variety strategy dominates since every firm possesses different sets of capabilities, unique context, and distinct competitive position.

Ramdas (2003) also provided a framework for management decisions concerning product variety. He argued that the success of a firm’s product variety strategy is determined by two main determinants: how firms create variety and how the firms implement variety. Key aspects in variety-creation include: 1) dimensions of variety, 2) product architecture, 3) degree of customisation, and 4) timing. Key aspects in variety-implementation are: 1) process capability, 2) point of variegation, and 3) day-to-day decisions.

Scavarda et al. (2010) investigated the trade-off between product variety and supply chain performance in emerging markets. There is a strong link between variety and supply chain cost. Attempts to investigate this so that a more cost efficient provision of product variety is achieved can be broadly grouped into three categories. First, there are changes in product architecture, in particular the use of modular and platform strategies and component standardisation, which can reduce the complexity and associated cost in product development, sourcing and manufacturing (Forza and Salvador, 2002; Holweg and Pil, 2004). Second is flexibility in manufacturing operations, such as quick machine changeovers and multi-skilling of the workforce (Child et al., 1991; Berry and Cooper, 1999). Finally, there is the postponement of product configuration decisions beyond the final assembly of products into the distribution system (i.e. late configuration).

There are three fundamental strategies to reduce the negative impacts of product variety. These include process-based strategies (i.e. flexibility), product-based strategies (i.e. modularisation), and postponement. In addition this research also investigates all possible and related strategies from a thorough literature review including external strategy such as partnership with suppliers and close customer relationships, matching strategy with product type and uncertainty, competitive strategy (e.g. cost leadership or differentiation) and other strategies to support the management of product variety.

2.6.1. Process-based strategies

Fisher et al. (1999) classified approaches to cope with increased product variety as process- or product-based strategies. Process-based strategies aim to provide production and distribution with sufficient flexibility to enable the accommodation of a high level of variety at a reasonable cost. Grouping components into families is a variety management strategy that has frequently been discussed in connection with cellular manufacturing in order to achieve flexible manufacturing (Blecker and Abdelkafi, 2006). According to McCutcheon and Raturi (1994), manufacturers can achieve flexible process design through flexible technology with plant configurations based on the principles of cellular manufacturing. As a result, even a plant with a large variety of products and a small production volume for each can take advantage of mass production while maintaining the flexibility of job-shop production (Yeh and Chu, 1991). In addition, cellular manufacturing is able to reduce material inventory and labour in process inventory (Yeh and Chu, 1991). Furthermore, according to Qiang et al. (2001), cellular manufacturing enables a manufacturer to reduce setup time, increase equipment utilisation, and streamline management. Bhandwale (2008) also stated that adoption of CM reduces setup times, in-process inventory, tooling, and enhances product quality. Using group technology principles in cellular manufacturing, parts with similar design characteristics and processing requirements are grouped into a family of parts, which lead to manufacturing flexibility (Abdi and Labib, 2004). This greatly reduces materials handling time/cost, reduces work-in-process inventory, and shortens throughput time (Hyer and Wemmerlöv, 1984). Ko and Egbelu (2003) proposed the Virtual Cellular Manufacturing System (VCMS) which is suitable for production environments subject to frequent product mix changes. In VCMS, the shop floor configuration is changed over time in response to changes in the product mix.

Flexibility in production and distribution has been studied by many researchers (Stalk, 1988; Yeh and Chu, 1991; Silveira, 1998; Krishnan and Gupta, 2001; Graves and Brian, 2003; Yadav et al., 2011). Stalk (1988) compared manufacturing costs relating to volume and variety between a traditional and a flexible factory system and concluded that a flexible factory offers more variety with lower total costs when compared to a traditional factory. Yeh and Chu (1991) suggested possible solutions to mitigate the impact of product variety. They included small lot production, setup reduction and focused production. Small lot production is a key strategy for gaining product flexibility while keeping inventory down due to reduced inventory levels and production lead times. As a result, the operation will become flexible enough to respond to changing market demand. Production planning, standardisation, and cellular manufacturing / group technology, can reduce the number of set-ups. Third, focused production can concentrate on a narrow production mix for a particular market niche. As a result, its costs, and especially its overheads are likely to be lower than those of a traditional plant. Fisher et al. (1995) stressed the investment in flexible manufacturing capability such as technology, organisational system and human skills. They argued that combining these flexible capabilities not only offers the ability to make multiple products simultaneously, but also benefits from reduced changeover costs across product generations. In addition, Silveira (1998) also suggested three major types of flexibility strategies from a case study; the first was the development of capabilities relating to flexibility such as machine set-ups, product development, production planning and inventory management. The second was the development of resources relating to flexibility, including technologies such as CAD, numerically controlled (NC) machines and automated guided vehicles (AGVs) and methodologies such as design for manufacturability. The third was improving the range and responsiveness of labour skills in the organisation.

In an attempt to manage the complexity of offering greater product variety, firms in many industries may consider platform-based product development. According to Krishnan and Gupta (2001) product platforms are component and subsystem assets shared across a product family that enable a firm to better leverage investments in product design and development. Although, platform-based product development provide the advantage of low unit variable cost, it often results in larger product differentiation and an optimal profit (Krishnan and Gupta, 2001). Yadav et al. (2011) also reported that products can be designed in accordance with existing customer diversity using a platform approach that reduces product development costs and enhances the responsiveness of firms.

Graves and Tomlin (2003) found that supply chains with higher levels of process flexibility enhance the overall scale efficiency of the plants and help to imitate a high production dominant strategy. They also reported that process flexibility allows multiple products to be manufactured using a cost-effective flexibility configuration that is able to meet uncertain demand. Recently Jacobs (2011b) has investigated the relationship between product and process modularity and the effects of each on firm growth performance. They reported that product modularity (e.g. modularity and standardisation) facilitates process modularity (e.g. cellular manufacturing, flexible manufacturing group technology), engenders manufacturing agility, and improves growth performance in terms of ROI, ROS and market share.

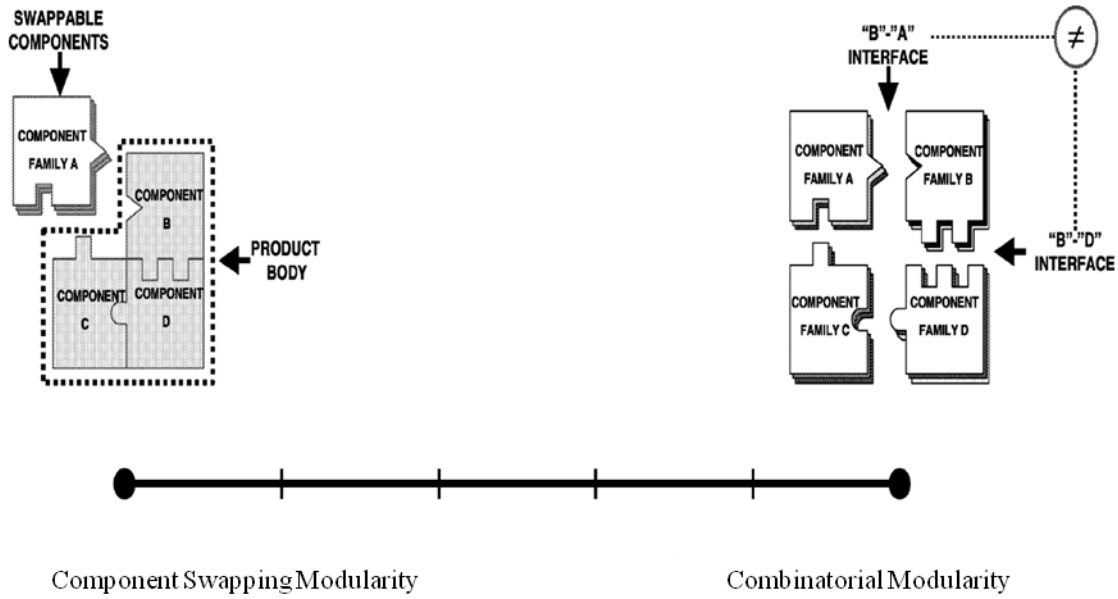
2.6.2. Product-based strategies

Product-based strategies enable product designs that allow a high level of variety while maintaining a relatively low level of component variety and assembly complexity in production and distribution (Fisher et al., 1999). McCutcheon and Raturi (1994) argued that companies can best achieve product variety and speed through a modular production configuration. Modularisation also enables the standardisation of materials and component sharing (Feitzinger and Lee, 1997), which in turn reduces product development costs as well as that of procurement and part inventory. Ulrich et al. (1998) noted that while non-modular products require changes to every component to accommodate changes in any functional element, modular product enable changes to each corresponding element independently. Therefore, the major advantage of modularity involves the fact that companies can make changes or improvements in modularity without affecting other parts of the system (Galvin and Morkel, 2001).

With regard to standardisation of materials and components, Child et al. (1991) suggested that to reduce the number of seperate elements in product and process design, firms need to standardise product components, and parts within these components. Though designing common components and standardising parts may incur additional direct costs, the benefits from reduced parts variety and lower overheads may even be higher (Anderson, 2004). In addition, Blecker and Abdelkafi (2006) considered variety management strategies for both product level (e.g. component commonality and product modularity) and process level (e.g. component families, process modularity and delayed differentiation). They also stressed that component commonality and product modularity improves delayed differentiation to help manage product variety.

Ulrich and Tung's (1991) work is probably the most explicit in listing the benefits of modular products including: (1) component economies of scale due to the use of components across product families, (2) ease of product updating due to utilisation of functional modules, (3) increased product variety from a smaller set of components, (4) decreased order lead-time due to fewer components, (5) ease of design and testing due to the de-coupling of product functions, and (6) ease of service due to differential consumption. Ulrich and Tung (1991) also articulated a typology of product modularity that distinguishes among component swapping, component sharing, fabricate-to-fit, bus and sectional modularity. Component-swapping modularity occurs when different product variants within the same product family can be obtained by pairing different components with the same basic product while component-sharing modularity refers to the presence of common components across different product families. Fabricate-to-fit modularity occurs when a product includes a component with some continually varying feature. Bus modularity occurs when a product component has two or more interfaces that can be matched with any selection of components from a set of component types. Finally, sectional modularity allows a connection of components chosen from a set of component types to be configured in an arbitrary way, as long as the components are connected at their interfaces (Ulrich and Tung, 1991). In addition, Salvador et al. (2002) investigated the relationship between type of modularity, product variety and component sourcing decisions. They concluded that component-swapping modularity is appropriate when the level of product variety is low and production volume is high. However, if the level of product variety is high, combinatorial modularity is appropriate in mass customisation. Figure 2-7 shows the graphical representation of the component swapping and combinatorial modularity spectrum.

Figure 2-7 Component swapping and combinatorial modularity spectrums



Source: Adapted by Salvador et al. (2002)

Product modularity eases the outsourcing of production activities to a manufacturer's suppliers, so that internal manufacturing operations may be simplified (Langlois and

Robertson, 1992; Kim and Chhajed, 2000; Kaski and Heikkila, 2002). It also allows for economies of scope since the same manufacturing process can be used to accommodate multiple product variants (Garud and Kumaraswamy, 1995); and can allow postponement of some product customisation activities downstream in the distribution network (Salvador et al., 2004). As a result, the time lag between decisions as to what exact product variants have to be built and customer buying decisions can be cut, so that the impact of uncertain demand forecasts can be reduced (Feitzinger and Lee, 1997; Van Hoek et al., 1999). Furthermore, the use of modularity not only shortens product development time by removing complexity but also reduces manufacturing complexity, thereby reducing manufacturing lead time (Novak and Eppinger, 2001). Therefore, modularity in product design has been employed to speed up new product development (NPD), to reduce NPD cost, and to enhance customisation possibilities for consumers (Jacobs et al., 2011b).

Despite the well known advantages of component sharing, conflicts exist between component sharing and product quality. For example, Fisher et al. (1999) examined component sharing in automobile front brakes and found it had only a weak influence on product quality. However, Ramdas and Randall (2008) investigated the impact of component sharing on reliability in the automotive industry and concluded that component sharing can, in some cases, damage product quality.

2.6.3. Postponement

Managing product variety is challenging given the complexities of today's supply chains (Ramdas, 2003). Another solution for managing product variety is to postpone the configuration of a product to customers' specifications as late as possible in the supply chain. Postponement of the point of product differentiation reduces complexity of the supply chain and this approach has recently received considerable attention as one of the most beneficial concepts for reducing the costs and risks of product variety and improving the performance of supply chains (Davila and Wouters, 2007). In their book "Logistical management: The integrated supply chain process", Bowersox and Closs (1996) suggest that there are three types of postponement: form, time and place.

- Form postponement entails delaying the process that transforms the form and function of products until customer orders have been received
- Time postponement refers to delaying the movement of goods until customer orders have been received
- Place postponement implies positioning the inventories in centralised manufacturing or distribution operations (especially international supply chain)

Delayed product differentiation calls for the redesign of products and processes in order to delay the point at which product variations assume their unique identities (Blecker and Abdelkafi, 2006). Therefore Feitzinger and Lee (1997) stressed that form postponement requires modular product architectures and the modularity enables standardisation of materials. In addition, these postponement strategies can cause repositioning of the inventory, final manufacturing and procurement activities in the supply chain (Bowersox and Closs, 1996). Van Hoek (1999) also argued that implementation of postponement may require extensive reconfiguration of the supply chain involving outsourcing and geographical reconfiguration. Postponing manufacturing activities opens up opportunities for outsourcing these activities to a third party.

Postponement of the point of product differentiation is a potentially powerful strategy to improve supply chain management under high product variety. Using postponement improves not only flexibility but also forecast accuracy for final product demand in the long term (Whang and Lee, 1998). The benefits of postponement are reduced inventory, increased responsiveness from shortening the final customising cycle time and reduced complexity in operations (Van Hoek et al., 2001). Nair (2005) investigated the perceived benefits of postponement using survey data and found postponement to be associated with better asset productivity, delivery performance, and value chain flexibility. In addition, based on a cross-case analysis, Lee et al. (2005) proposed that postponement could be used as part of a strategy to reduce uncertainty in response to short-term dynamics in the supply chain. Davila and Wouters (2007) also found a positive relationship between postponement and improved inventory turns, customer service quality, as well as lower operational costs.

2.6.4. Matching supply chain strategies with product characteristics and uncertainty

As described previously, Randall and Ulrich (2001) argued that firms with matching types of product variety and supply chain structure will be able to mitigate costs incurred from product variety. That is, some types of variety incur high production costs and other types of variety incur high market mediation costs. Therefore, the firms producing product variety that incur high production costs attempt to concentrate production on scale efficient plants while firms producing variety associated with demand uncertainly might be better off producing close to the market (Randall and Ulrich, 2001).

Thonemann and Bradley (2002) analysed the effect of product variety on supply-chain performance, measured in terms of expected lead time and expected retailers' cost. They found that the expected replenishment lead time and retailers' costs are concave increasing in terms of product variety. This suggests that changes in supply chain structure might improve the performance of the supply chain when variety increases. Therefore, they argued that if demand is allocated across fewer retailers, demand variability decreases relative to the mean demand over the lead-time, which implies that cost can be reduced by consolidating retailers.

Fisher (1997) suggests that based on demand patterns, products can be classified into two classes: functional or innovative. According to this notion, products are classified as functional if products satisfy basic needs that do not change much over a period. These types of product have stable, predictable demand with long product life cycles and lower profit margins. Innovative products have high innovation or fashion content and have a higher profit margin and short life cycle that results in highly unpredictable demand. Lee (2002) extends Fisher's framework to include supply uncertainties and suggested that functional products usually have less product variety with low demand uncertainty when compared to innovative products. From this a framework was proposed that aligns supply strategies with the different levels of demand and supply uncertainty. Four different strategies emerged, and Figure 2-8 provides a view of matched supply chain strategies.

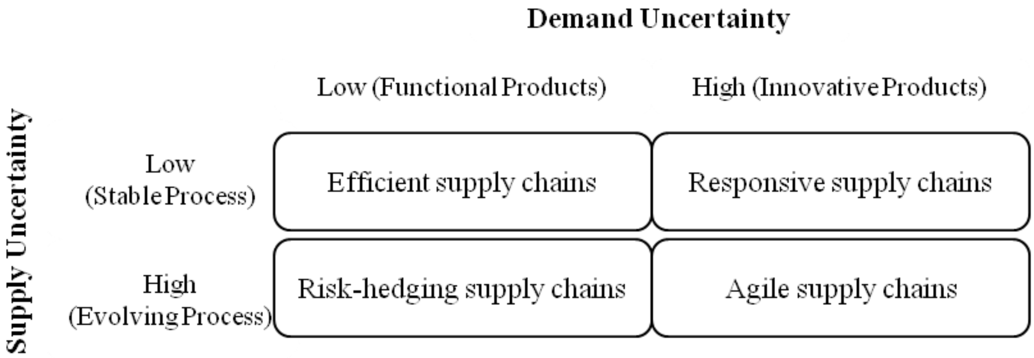
- Efficient supply chains: when companies have predictable demand patterns with a stable supply process, they should aim at improving supply chain efficiency to provide the lowest possible costs for their customers.

- Risk-hedging supply chains: when the supply processes are still evolving under low demand uncertainty and causing uncertainties in the yield, process reliability, supply source and lead time, companies should attempt to prevent such uncertainties from ultimately affecting demand fulfilment. Companies should establish "risk hedging" strategies aimed at pooling and sharing resources in a supply chain so that the risks of supply disruption can also be shared.

- Responsive supply chains: when demand is highly unpredictable with stable supply, companies should develop a "responsive" strategy. This strategy is aimed at being responsive and flexible to the changes and diversity of customer needs.

- Agile supply chains: companies with innovative products and unstable supply processes should establish "agile" supply chains. These supply chains utilise the combination of "responsive" and "risk-hedging" strategies. These are aimed at being responsive and flexible to customer needs, while attempting to hedge the risks of supply shortages or disruption by pooling inventory and other capacity resources.

Figure 2-8 Matched strategies



Source: Lee (2002)

The ‘long tail’ phenomenon in the distribution of product sales was first observed through the comparison between off-line and on-line sales (Anderson, 2006; Brynjolfsson et al., 2006). Anderson (2006) first coined the term ‘long tail’ (see Figure 2-9), which envisages that “more niche products exclusively offered in online stores better satisfy consumers’ diversified preferences and thus have the potential to outgrow the demand for those popular products”. He defined the long tail effect as “the change in the consumption pattern when more niche products are being selected and the demand is shifting from the hits to the niches over time” in pure on-line channels.

The long tail phenomenon can be identified from the two perspectives (Zhou and Duan, 2012). First, the widely agreed-on feature of the long tail effect is that the longer tail should be emerging (i.e. more niche products are being consumed over time). Second, a long tail consumption pattern is also expected to have a relatively fatter tail when demand is shifting away from a focus on a relatively small number of hits at the head of the demand curve and towards a huge number of niches in the tail (Zhou and Duan, 2012). Product variety on the internet resulting from virtually unlimited 'shelf space', make-to-order production and digital distribution can significantly reduce the costs for the manufacturers and retailers (Brynjolfsson et al., 2010). In addition, online product feedback and recommendations can reduce consumer search costs in the pursuit of niche product (Brynjolfsson et al., 2006).

In contrast to the long tail effect, the 'superstar effect' has been defined as the consumption pattern in which a small number of popular products account for the majority of sales (Zhou and Duan, 2012). Although the long tail indicates the shift of demand from the hits to the niches, the very popular products can still dominate market demand at the same time.

Figure 2-9 Long tail distribution curve

Source: Zhou and Duan (2012)

2.6.5. Relationship with suppliers and customer

There have been an increasing number of organisations attempting to develop partnerships with their suppliers and customers (Slack and Chambers, 2007). Therefore, extensive supply chain integration is required to efficiently handle the increased amounts of complexity and uncertainty (Fisher, 1997; Mendelson and Pillai, 1999; Heikkilä, 2002). According to Vickery et al. (2003), two major practices that accomplish integration across a supply chain are supplier partnering and closer customer relationships. The partnership relationship required to ensure high product quality and low cost might entail earlier supplier involvement in product design or acquiring access to superior supplier technological capabilities (Narasimhan and Das, 1999). Close customer relationships enable firms to proactively seek information on customer preferences and needs, and then become more responsive. Insights gained as a result of establishing strong relationships with customers can also be used to enhance operational effectiveness and cost efficiency (Vickery et al., 2003). Therefore, integration of the supply chain from product design through manufacturing to distribution through supplier partnerships and closer customer relationships can be crucial factors in managing product variety and new product development (NPD).

2.6.5.1. Partnership with suppliers

Supplier partnerships are positively related to new product development success (Groves and Valsamakis, 1998; Tan and Kannan, 1998). Tan et al. (1998) found that a supplier’s knowledge and skills are significant when seeking to reduce production costs. In addition, the review of relevant literature shows that forming early and close relationship with suppliers is critical for a company in the product innovation/development process (Carr and Kaynak, 2007; Cousins et al., 2011). In particular, supplier involvement shows a positive impact on turnover (Faems et al., 2005) and product innovativeness (Nieto and Santamaria, 2007), moreover, other key performance criteria such as product costs and quality, and faster time to market (Clark and Fujimoto, 1991; Ragatz et al., 1997). In addition, Suarez et al. (1996) examined the impact of relationships between suppliers and contractors on manufacturing flexibility and found that close relationships have a positive effect on mix, volume and new product flexibility.

Sharing sensitive financial, design or research information may strengthen trust in a partnership and enable quick response to customer needs, thus, through the integration of a cross-functional team with suppliers, manufacturers can enhance not only communication flow but also effective product development (Tummala et al., 2006). Joint problem solving and performance evaluation with suppliers is critical in product development (Tummala et al., 2006). A full partnership requires the sharing of risks and benefits and a supply chain's long-term focus should not be concerned solely with price. Close communication with suppliers is also critical to financial performance (Tan and Kannan, 1998).

2.6.5.2. Close customer relationships

Product variety is determined by many different factors including increasing customer requirements, market competition and customisation (Silveira, 1998). Thus it is vital that each supply chain participant adds value from the perspective of the end customer in the supply chain (Jeong and Hong, 2007). Fisher et al. (1995) argued that companies need a market strategy to minimise product variety that customers do not want and suggested two market strategies: 1) close interaction with customers to ensure that the new product truly reflects customer needs and performance and 2) eliminating products that are no longer beneficial. Child et al. (1991) also suggested that a company must assess the level of variety that customers will find attractive, avoid confusion and result in withdrawal from the purchase decision. Thus the company needs to understand exact customer needs without confusing its customers (e.g. information overload) by building stronger customer relationships. For example, gathering customer feedback from a supply chain can assist in the analysis of changing customer specifications (Tummala et al., 2006). In addition, following up customer's feedback and evaluation of customer complaints is a crucial part of effective customer relationship practice (Tan et al., 1999).

Customer relationship management refers to "demand management practices through long-term customer relationships, satisfaction improvement, and complaint management" (Tan and Kannan, 1998). Jeong and Hong (2007) also defined customer relationships as customer-oriented supply chain practices. In addition, Trevile et al. (2004) argued that increased access to demand information throughout the supply chain permits rapid and efficient delivery, coordinated planning, and improved logistics communication. Heikkilä (2002) also pointed out the need to shift the emphasis from the supply side to the demand side of supply chain management. Compared to supplier management, customer management is highly demand-focused and it is an increasingly important component for enhancing the effectiveness of supply chain practices (Tracey and Tan, 2001).

In the concept of customisation, value is viewed as something that can be built into a product or service during the production process while in the notion of co-creation (or service dominant logic) that has become a popular concept in recent years, value can only be determined by the user during the consumption and usage process (Lusch et al., 2007; Michel et al., 2008). Therefore, according to Kristensson et al. (2004), it has been suggested that involving users as co-creators during NPD process produces ideas that are more creative, more highly valued by customers, and more easily implemented. In particular, user involvement is reported to be useful for capturing the latent needs of consumers that are so important to successful NPD (Kristensson et al., 2008). Therefore, co-creation by customer involvement in increasing product variety can be one of the most effective concepts in managing product variety; and close customer relationship management (CRM) can achieve this aim. CRM is the management of technology, processes, information, and people in order to maximise customer contact (Galbreath and Rogers, 1999). Effective customer relationship management (CRM) can result in high customer satisfaction, which is achieved through customisation, personal relationships, and after-sales support (Galbreath and Rogers, 1999).

2.5.6. Competitive capability

Competitive strategy refers to how an organisation competes in a particular market. It is concerned with how a company can gain competitive advantage relative to its competitors. Its aim is to establish a profitable and sustainable position for the company (Hallgren and Olhager, 2009). Furthermore, Miles and Snow (1978) showed that enhanced corporate competitive status acquired from a superior competition strategy has significant consequences for firm performance. Based on Miles and Snow's (Miles and Snow, 1978) theory, cost leadership priority can be related to highly centralised organisational activities of the supply chain, while a differentiation priority can be linked to highly specialised technological activities for the development of new products and pioneering new market opportunities.

One of the first researchers to propose a theoretical framework for understanding a firm's competitive strategy was Porter (1980). Porter (1980) proposed a framework for analysing industries and competitors. There are three generic strategies that lead to attainment of competitive advantage. They are cost leadership, differentiation and focus:

- Cost leadership is where the firm sets out to become the lowest cost producer in its industry. It requires efficient-scale facilities, pursuit of cost reductions, and cost minimisation in all areas of the firm. This will provide more profit.

- Differentiation occurs when a firm seeks to attain a unique status in its industry along some dimensions that are widely valued by buyers. It includes diverse design and brand image, customer service, and distribution network. Product or service differentiation will help increase customer loyalty and ensure repurchase.
- Focus on markets, buyers, or product lines can also maximise profits.

Cost leadership might emphasise cost reduction and firms strive to become the low-cost producer. Thus, efforts are focused on cost control in order that above-average returns may be forthcoming even at low prices (Porter, 1980; Kotha and Orne, 1989). The second competitive priority is differentiation where the rationale is to avoid direct competition by differentiating the products and services offered in order to deliver higher customer value. This makes it possible for the company to charge a premium price (Porter, 1980). This form of differentiation can encompass style or quality. The objective is to create products or services that are unique to customers (Kotha and Orne, 1989). The third priority is a focused strategy. It occurs when a firm sets out to be the best in a segment within the company’s markets. Within a focus strategy, the firm can choose either a cost leadership or a differentiation approach (Porter, 1980; Kotha and Orne, 1989; Peter and Rebecca, 2000; Santos, 2000).

Rosenzweig et al. (2003) examined the mediating role of manufacturing-based competitive capabilities in supply chain management and found that capabilities such as quality, delivery, flexibility, and cost contribute positively to business performance, either acting alone or in concert with other capabilities. In addition, Kim (2006a) divided the competition capability into four types: cost leadership, customer service, innovative marketing technology and differentiation. According to Kim (2006a), cost leadership is related to cost reduction. Customer service is related to quality with volume flexibility and on time delivery while marketing technology is related to sales and distribution. Lastly, product differentiation is related to new product development with design flexibility.

Hallgren and Olhager (2009) argued that the three strategies of Poter (2004) can fundamentally be reduced to two, since the company must choose between cost leadership and differentiation strategies even with a focus strategy. In addition, these two competitive strategies are able to relate well to leanness and agility, respectively (Hallgren and Olhager, 2009). Cost leadership involves two items including low price and low manufacturing unit cost while differentiation involves the ability to change over products at short notice and the ability to vary volumes of products produced at short notice.

2.6.7. Supply chain factors to support the management of variety

Derocher and Kilpatrick (2000) identified five factors needed for successful supply chain management in a competitive market: information systems, an integrated organisation, partnerships, system chain strategies, and performance measurement. Power et al. (2001) also identified the seven critical factors needed for agile SCs to become more responsive to the needs of customers: a participative management style, computer-based technology (e.g. computer aid design (CAD), electronic data interchange (EDI) and computer integrated manufacturing (CIM)), resource management, continuous improvement enablers (e.g. total quality management (TQM), flexible manufacturing cells (FMC) and value adding management (VAM)), supplier relations, just-in-time (JIT) methodology and technology utilisation. In particular, JIT, TQM and customer relations are principles to enhance global competitiveness (Tan et al., 1999). Managing long-term relationships with partners using cross-functional teams is becoming a common practice in supply chains (Chen and Paulraj, 2004). Chen and Paulraj (2004) argued that expertise is required from various functions within and outside a firm in order to address a wide range of product and process related problems (e.g. cross functional teams, supplier involvement and customer focus).

The information and communication technologies provide the means by which supply chain partners can distribute and share the real time information needed for effective decision making (Tummala et al., 2006). Ranganathan et al. (2004) identified eight factors needed for successful supply chain management in terms of web technology: supplier interdependence, competitive intensity, IT activity intensity, managerial IT knowledge, centralization of the IT unit structure, formalisation of the IT unit structure, assimilation, and diffusion. In addition, Ngai et al. (2004) have demonstrated that communication (e.g. trustful relationship with partners, collaboration and information sharing), commitment of top management, data security, training and education and hard/software reliability are critical factors needed to manage the supply chain network efficiently. Tummala et al. (2006) also identified building customer-supplier relationships, implementing information and communications technology (e.g. enterprise resource planning(ERP), manufacturing resource planning (MRP), distribution resource planning (DRP), electronic funds transfer (EFT) and worldwide web (www)), re-engineering material flows, creating a corporate culture, and identifying performance measurements as five important strategic success factors that need to be focused on in developing and implementing supply chain management (SCM) strategies.

2.7. CHAPTER SUMMARY

The main focus of this chapter was to provide a review of the literature on the concepts of product variety and customisation and to demonstrate how variety has been shown to impact on business function performance. Based on the literature review, supply chain performance factors including supply chain flexibility, supply chain agility, cost efficiency, customer service and business performance factors are identified as key factors which may be affected either directly or indirectly by product management strategies to mitigate the negative impact of product variety. The chapter also reviewed strategies and contributions to manage product variety. First, process-based, product-based and postponement strategies were reviewed. Then matching strategies, partnerships with suppliers, close customer relationships, competitive capabilities and supply chain success factors to support the management of product variety were reviewed. Each of these key factors was reviewed with the aim of identifying gaps and limitations in the literature.

Previous studies have investigated, in a single functional area or industry, the impact of product variety on different business functions (MacDuffie et al., 1996; Fisher and Ittner, 1999; Randall and Ulrich, 2001; Thonemann and Bradley, 2002; Benjaafar et al., 2004; Hu et al., 2008). These studies do not cover the overall and relative impact of product variety on business function performance. In particular, non-cost positive impacts such as the utilisation of standardised parts, postponement, outsourcing, customer satisfaction, market share and competitive advantages have not been investigated in comparison with negative impact, such as cost and complexity, that resulted from variety increases. In addition, studies reported in the operations and supply chain literature have suggested theoretical frameworks to support the management of product variety in supply chains (Ulrich et al, 1998; Thonemann and Bradley, 2002; Ramdas, 2003; Blecker and Abdelkafi, 2006) and focus on a single strategy to manage product variety (Nair, 2005; Davila and Wouters, 2007; Ramdas and Randall, 2008; Yadav et al., 2011). Empirical studies to address relations between the level of customisation and performance related to variety issues, have also rarely been conducted.

Threfore, relevant variety-related issues are to be addressed by presenting research hypotheses in the next chapter (Chapter 3). These are expressed in terms of the degree of impact of product variety on business function performance, supply chain design to mange variety impact on supply chain performance, and differences in variety-related strategies / supply chain performance according to the level of customisation.

CHAPTER THREE

CONCEPTUAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

3.1. INTRODUCTION

This chapter begins by describing the development of the study's conceptual framework against a theoretical background and proposed research model. The conceptual framework of the study is comprised of four parts: 1) the business function performance impact associated with an increase in product variety, 2) the supply chain design to support the management of product variety increases (i.e. the relative relationship between a variety control strategy and supply chain performance), 3) variety-related strategy and supply chain performance differences that depend on the level of customisation and 4) a comparison between the UK and Korea.

"*A hypothesis is a logically conjectured relationship between two or more variables expressed in the form of a testable statement*" (Forza, 2002). Hypotheses should be developed to answer research questions and support the achievement of research objectives. In this research, twenty three hypotheses are proposed concerning the impact of product variety, and the appropriateness of strategy to manage the impact of product variety on the supply chain performance according to the level of product customisation offered. The theoretical rationale of the hypotheses is explained in this chapter.

3.2. THE CONCEPTUAL RESEARCH FRAMEWORK AND STRUCTURE

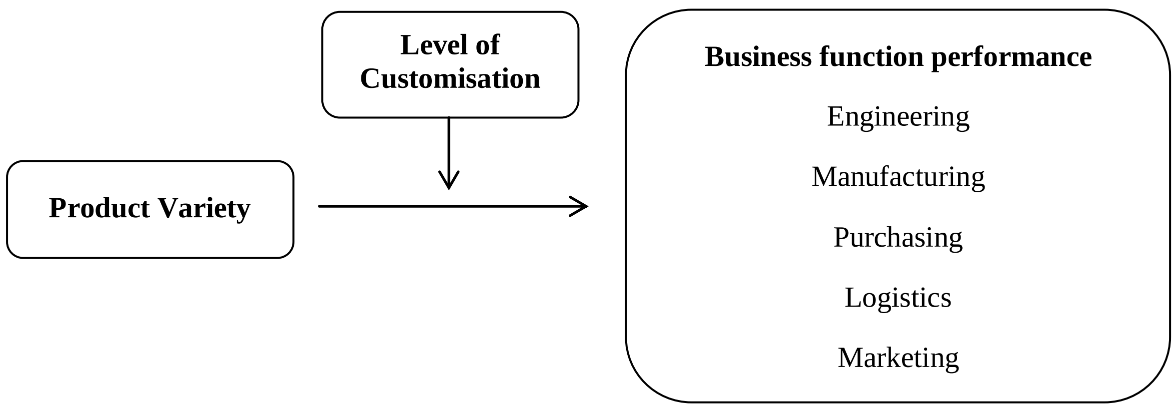
3.2.1. The impact of product variety on business function performance

High product variety may lead to an increase in sales, but it does not necessarily guarantee an increase in a firm's profits or competitiveness. Moreover, product variety can have a positive effect on both sales and market share, but can also have negative consequences for business performance (Yeh and Chu, 1991). For example, higher product variety may increase manufacturing costs through an increase in the complexity of the production process. It can also cause higher complexity of the demand forecasting process and render the alignment of supply with demand in the supply chain obdurate (Whang and Lee, 1998; Randall and Ulrich, 2001). Those increasing their product variety should also, therefore, consider the impact of product variety on the performance and cost profile of their business functions.

Based on the extensive literature concerning product variety impact reviewed in the previous chapter, Engineering, Manufacturing, Purchasing, Logistics and Marketing were the business functions deemed suitable for analysis in this research. These business functions are key to the overall process of dealing with product variety from the manufacturer's perspective (Krishnan and Ulrich, 2001; Randall and Ulrich, 2001). In addition, the research considered the de-coupling point position of each customisation type with regard to each business function. Engineering activity occurs at the design stage, resulting in a de-coupling point position that corresponds to pure customisation (PC). Purchasing and manufacturing activity occur at the fabrication and assembly stages, resulting in de-coupling point positions that correspond to tailored customisation (TC) and customised standardisation (CS) respectively. Logistics activity takes place at the distribution stage with a de-coupling point position that corresponds to segmented standardisation (SS). Finally, marketing activity occurs at the sales stage with a de-coupling point position that corresponds to pure standardisation (PS). Typically, a make-to-stock (MTS) policy is used upstream of the de-coupling point, while a make-to-order (MTO) policy is used downstream (Ramdas, 2003). In addition, the Lampel and Mintzberg (1996) framework was chosen as the model for customisation management in this research. The principal reasons for this concern its relative simplicity and its wide citation by researchers who have provided expositions and critiques of the framework elements (see Table 2-1).

Therefore, the research firstly aims to investigate the possible impact of product variety on business function performance depending on the type of customisation and variety offered, as related to research questions *Q1.1* and *Q1.2*. Figure 3-1 depicts the research framework 1.

Figure 3-1 Research framework 1



3.2.2. Supply chain design to support the management of product variety increases: the relative relationship between a variety control strategy and supply chain performance

The ultimate aim of SCM is to improve both efficiency (i.e. cost reduction) and effectiveness (i.e., customer service) in a strategic framework to obtain a competitive advantage and profitability (Mentzer et al., 2001). However, trade-off exists between product variety and supply chain performance. A variety control strategy, including tactical elements such as modularity, cellular manufacturing (i.e. process flexibility) and postponement, reduces the negative impact of product variety on supply chain performance (Scavarda et al., 2010). Each variety control tactic enhances supply chain flexibility and agility, both of which are key factors in managing product variety in the supply chain (Christopher, 2000; Nair, 2005; Blecker and Abdelkafi, 2006; Davila and Wouters, 2007; Jacobs et al., 2011a). In addition, supply chain flexibility and agility have a positive influence on resource efficiency and customer focus outcomes (Narasimhan and Jayaram, 1998; Hiroshi and David, 1999; Tummala et al., 2006). Variety control strategy can have a direct positive impact on cost efficiency (see Graves and Tomlin, 2003; Anderson, 2004) and customer service (see Davila and Wouters, 2007). However, supply chain flexibility is one of the essential capabilities needed to mitigate the trade-off between product variety and supply chain performance (Scavarda et al., 2010). Simultaneously, flexibility is one of the essential aspect of supply chain performance (Beamon, 1999). Thus, in order to achieve the twin aims of cost efficiency and customer service, flexibility and agility are fostered as an internal function capability and an external response competence respectively.

Supporting variety control is of strategic importance for manufacturers. Thus, this research looked at three general aspects of the structure of strategies utilised to mitigate the impact of product variety on supply chain performance: modular production in the product-based strategy, cellular manufacturing in the process-based strategy and postponement in the structure-based strategy. These strategies are based on the most fundamental variety control strategies suggested by a number of different researches, as explained in the previous chapter (Yeh and Chu, 1991; McCutcheon and Raturi, 1994; Fisher et al., 1999; Galvin and Morkel, 2001; Salvador et al., 2002; Hu et al., 2008; Scavarda et al., 2010).

Supply chain flexibility represents an internally focused capability and is associated with the adaptability of the firm's internal supply chain functions of purchasing, engineering, manufacturing and distribution, whereas agility refers to externally-focused competences focusing more on speed at the organisational level, such as market responsiveness, delivery reliability and frequency of product introduction (Swafford et al., 2008). Bernardes and Hanna (2009) also clarified conceptual differences between the terms in flexibility, agility and responsiveness that are often used interchangeably in operations management. Thus, building on previous research, this research also proposes supply chain flexibility as a distinct but advanced and required capability and antecedent for supply chain agility. Accordingly, the structure of the flexibility concept considers the dimensions of manufacturing, procurement and distribution. Thus, supply chain flexibility involves: 1) production volume, production mix and engineering change flexibility in manufacturing, 2) material order change (quantity and time) flexibility in procurement and 3) delivery flexibility in distribution (Silveira, 1998; Swafford et al., 2006; Swafford et al., 2008). On the other hand, agility relates mainly to the speed of manufacturing and distribution activities in the supply chain. Improving supply chain agility requires: 1) reducing the product development cycle and manufacturing and delivery lead time, 2) increasing the level of product customisation in manufacturing and 3) improving customer service, delivery reliability and responsiveness to market needs (Zhang and Sharifi, 2000; Van Hoek et al., 2001; Swafford et al., 2006; Swafford et al., 2008).

Beamon (1999) developed a framework for the mix of performance measures pertinent to supply chain systems, including three types of measures regarded as crucial components of a supply chain performance measurement system: resource, output and flexibility. Resource performance reflects value in the form of achieving efficiency while output performance refers to value added in terms of a firm's ability to provide high levels of customer service. Lastly, flexibility performance reflects value added in terms of a firm's ability to respond to changes such as demand uncertainty, new product introduction and supplier shortages (Beamon, 1999; Khan et al., 2009). Accordingly, this research considers cost efficiency in terms of resource performance and customer service in terms of overall output performance in the supply chain. Cost efficiency involves minimising the total cost of four items: 1) resources, 2) distribution, 3) manufacturing and 4) inventory (Beamon, 1999; Sezen, 2008). Customer service relates to customer responsiveness, satisfaction and customer value (Lee and Billington, 1993; Beamon, 1998; Treville et al., 2004). Thus, the following eight items were defined as composing the customer service structure: 1) fill rate, 2) on-time delivery, 3) customer response time, 4) quality, 5) manufacturing lead time, 6) customer complaint reduction, 7) customer satisfaction and 8) stock-out reduction (Beamon, 1999; Ramdas and Spekman, 2000; Sezen, 2008; Khan et al., 2009).

As a result, considering the trade-off between product variety and supply chain performance, the proposed model is designed to investigate the relative effect of a variety control strategy on supply chain performance (related to *Q2.1*) depending on the level of customisation (related to *Q2.2*). Figure 3.2 illustrates the conceptual framework used to improve supply chain performance. Table 3-1 illustrates the details of the research constructs, items, code and related references.

Figure 3-2 Research framework 2

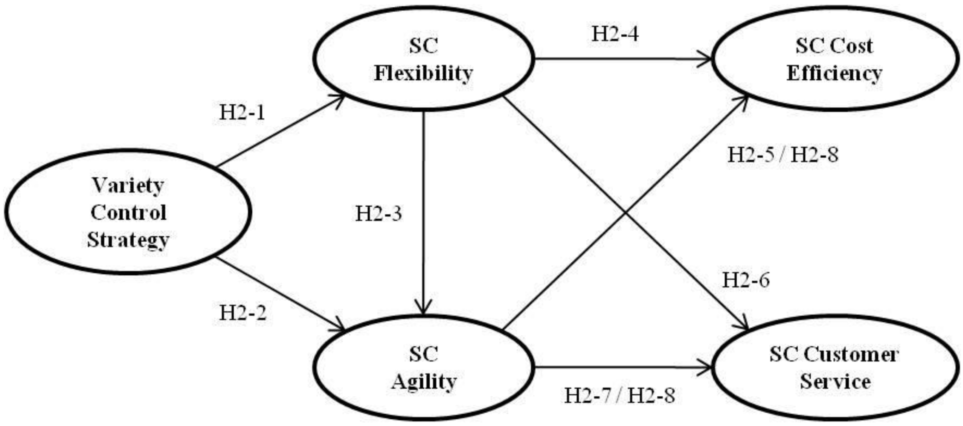


Table 3-1 Research constructs, items and related references

Structure	Variable	Related literature
Variety control strategy (VCS 1-3)	Modular production	(Ulrich and Tung, 1991; Salvador et al., 2002; Blecker and Abdelkafi, 2006; Scavarda et al., 2010; Jacobs et al., 2011b).
	Postponement	(Whang and Lee, 1998; Van Hoek et al., 2001; Nair, 2005; Scavarda et al., 2010)
	Cellular manufacturing	(Yeh and Chu, 1991; Ko and Egbelu, 2003; Abdi and Labib, 2004; Blecker and Abdelkafi, 2006; Scavarda et al., 2010)
Supply chain flexibility (FL1-6)	Change quantity of suppliers' orders	(Narasimhan and Das, 1999; Swafford et al., 2008)
	Change delivery times of orders placed with suppliers	(Narasimhan and Das, 1999; Swafford et al., 2008)
	Change production volume	(Gerwin, 1987; Sethi and Sethi, 1990; Swafford et al., 2008)
	Changes in production mix	(Sethi and Sethi, 1990; Duclos et al., 2003; Swafford et al., 2008)
	Implement engineering change orders in production	(Gerwin, 1993; Swafford et al., 2008)
	Alter delivery schedules to meet changing customer requirements	(Slack, 1983; Duclos et al., 2003; Swafford et al., 2008)
Supply chain agility	Rapidly reduce product development cycle time	(Goldman et al., 1995; Agarwal et al., 2006; Swafford et al., 2008; Hallgren and Olhager, 2009)
	Rapidly reduce manufacturing lead time	(Sharifi and Zhang, 1999; Agarwal et al., 2006;

(AG1-7)		Swafford et al., 2008)
	Rapidly increase the level of product customisation	(Van Hoek et al., 2001; Swafford et al., 2008; Hallgren and Olhager, 2009)
	Rapidly improve level of customer service	(Goldman et al., 1995; Sharifi and Zhang, 1999; Swafford et al., 2008)
	Rapidly improve delivery reliability	(Sharifi and Zhang, 1999; Swafford et al., 2008)
	Rapidly improve responsiveness to changing market needs	(Goldman et al., 1995; Swafford et al., 2008)
	Rapidly reduce delivery lead time	(Goldman et al., 1995; Swafford et al., 2008)
Cost efficiency (CE1-4)	Minimise total cost of resources used	(Beamon, 1999; Sezen, 2008)
	Minimise total cost of distribution (including transportation and handling costs)	(Beamon, 1999; Sezen, 2008)
	Minimise total cost of manufacturing (including labour, maintenance, and re-work costs)	(Beamon, 1999; Sezen, 2008; Zelbst et al., 2009)
	Minimise total cost related with held inventory	(Beamon, 1999; Ramdas and Spekman, 2000; Sezen, 2008)
Customer service (CUS1-8)	Order fill rate	(Beamon, 1999; Sezen, 2008)
	On-time delivery	(Beamon, 1999; Kim, 2006b; Sezen, 2008)
	Customer response time	(Beamon, 1999; Vickery et al., 2003; Sezen, 2008)
	Quality	(Beamon, 1999; Sezen, 2008)
	Manufacturing lead time	(Beamon, 1999; Sezen, 2008)
	Customer complaints reduction	(Beamon, 1999; Ramdas and Spekman, 2000; Kim, 2006b; Sezen, 2008)
	Customer satisfaction	(Beamon, 1999; Ramdas and Spekman, 2000)
	Stock-out reduction	(Beamon, 1999)

3.2.3. Strategy and performance differences according to the level of customisation

The study also compares differences in strategies and performance according to the level of product customisation offered since the degree of customisation may affect a firm's strategies and different strategies affect performance differently. Variety-related strategies in the thesis include the partnership with suppliers, the close customer relationships, variety control strategy, competitive capability (e.g. cost leadership and differentiation), while supply chain performance includes supply chain flexibility, supply chain agility, cost efficiency, customer service, and business performance. In this section, the partnership with suppliers, the customer relationships, cost leadership, differentiation and business performance are illustrated.

According to Vickery et al. (2003), two major practices that accomplish integration across the supply chain are supplier partnering and closer customer relationships for the manufacturer. The partnership with suppliers and close customer relationships are also critical success factors in supply chain management (Derocher and Kilpatrick, 2000; Power et al., 2001; Ngai et al., 2004; Tummala et al., 2006). Those two factors can be key factors in decisions to increase product variety since both factors can mitigate the impact of product variety through supply chain integration. The partnership with suppliers to enhance operational effectiveness and cost efficiency might entail early supplier involvement in product design or acquiring access to superior supplier technological capabilities (Narasimhan and Das, 1999). On the other hand, close customer relationships enable firms to proactively seek information on customer preferences and needs, and then become more responsive. Compared to supplier management, it is an increasingly vital factor for enhancing the effectiveness of supply chain practices from a demand focus perspective (Tracey and Tan, 2001). For example, user involvement is crucial for successful new product development (Kristensson et al., 2008). As a result, a key element of successful supply chain management from product design through manufacturing to distribution involves the downstream integration of customers as well as the management of upstream suppliers (Flynn and Flynn, 1999; Hayes, 2002; Parker and Anderson, 2002).

The partnership with suppliers is composed of four variables: a trustworthy relationship, a relationship in product development, joint problem solving and performance evaluation, and sharing sensitive information (Derocher and Kilpatrick, 2000; Ramdas and Spekman, 2000; Power et al., 2001; Chen and Paulraj, 2004; Ngai et al., 2004; Tummala et al., 2006). The customer relationships has four measurement variables: the response to a customer's evolving needs, the evaluation of customer complaints, monitoring the customer service level and following up with customers for quality and service feedback (Tan et al., 1999; Ramdas and Spekman, 2000; Chen and Paulraj, 2004; Ranganathan et al., 2004; Tummala et al., 2006).

Competitive capability was divided into two factors. One is cost leaderships that includes the capability to reduce manufacturing unit cost and supply low product price (Hallgren and Olhager, 2009). Mainly based on Porter's, and Miles and Snow's theory (Miles and Snow, 1978) differentiation is composed of three items that are related to customer service (i.e. product), technology and marketing differentiation respectively. Customer service differentiation implies the capability to deliver a high quality product with volume flexibility and agility while technology differentiation implies the capability to develop a new product quickly with design flexibility depending on demand (Kim, 2006b, 2006a; Hallgren and Olhager, 2009). Marketing differentiation, which was related to Porter's focus strategy (Porter, 2004), implies the capability to control the sales and distribution network with a distinctive brand image.

Overall, firm performance can include return on investment (ROI), return on sales (ROS), return on assets (ROA), market share, sales growth and market share growth (Vickery et al., 1999; Droge et al., 2004; Sánchez and Pérez, 2005; Panayides, 2007). A composite measure of performance would more accurately reflect firm improvements as opposed to a single quantitative or accounting-related performance measure (Panayides, 2007). ROA, ROS, market share and share growth is used to evaluate business performance in this research.

Accordingly, based on the characteristics of customisation, this research also investigated the differences in strategies and performance that contain supply chain external relationships (i.e. partnership with suppliers and close customer relationships), variety control strategy, supply chain flexibility, supply chain agility, supply chain cost efficiency, customer service, competitive capability (i.e. cost leadership and differentiation) and business performance, which differ depending on the level of customisation, as related to research question *Q3*. Table 3-2 illustrates the details of the research constructs, items and related references.

Table 3-2 Research constructs, items and related references

Structure	Variable	Related literature
Cost leadership (CL1-2)	Reduce manufacturing unit cost	(Rosenzweig et al., 2003; Kim, 2006b; Hallgren and Olhager, 2009)
	Supply low product price	(Rosenzweig et al., 2003; Kim, 2006b; Hallgren and Olhager, 2009)
Differentiation (D1-3)	Customer service differentiation (deliver a high quality product with volume flexibility and agility)	(Kim, 2006b; Hallgren and Olhager, 2009)
	Technology differentiation (develop a new product quickly with design flexibility depending on demand)	(Kim, 2006b; Hallgren and Olhager, 2009)
	Marketing differentiation (control the sales and distribution network with a distinctive brand image)	(Kim, 2006b; Hallgren and Olhager, 2009)
Business performance (BP1-4)	Return on sales	(Vickery et al., 1999; Sánchez and Pérez, 2005; Panayides, 2007)
	Return on assets	(Rosenzweig et al., 2003; Kim, 2006b)
	Market share growth	(Vickery et al., 1999; Sánchez and Pérez, 2005; Panayides, 2007)
	Sales growth	(Rosenzweig et al., 2003; Panayides, 2007)
Partnership with suppliers (PAS1-4)	Trustworthy relationships with suppliers	(Ramdas and Spekman, 2000; Ngai et al., 2004; Tummala et al., 2006)
	Close relationships in product development with suppliers	(Derocher and Kilpatrick, 2000; Power et al., 2001; Ngai et al., 2004)
	Joint problem solving and performance evaluation with suppliers	(Chen and Paulraj, 2004; Tummala et al., 2006)
	Sharing sensitive information with suppliers	(Ngai et al., 2004)
Customer relationships (CR1-4)	Anticipate and respond to customers' evolving needs	(Tan and Kannan, 1998; Ramdas and Spekman, 2000; Chen and Paulraj, 2004)
	Emphasise the evaluation of formal and informal customer complaints	(Chen and Paulraj, 2004; Ranganathan et al., 2004; Tummala et al., 2006)
	Monitor and measure customer service levels	(Tan and Kannan, 1998; Power et al., 2001)
	Follow up with customers for quality/service feedback	(Tan and Kannan, 1998; Chen and Paulraj, 2004)

3.2.4. Comparison between the UK and South Korea

Kim et al. (2012) investigated the adoption of ubiquitous computing technology (UCT) in supply chain management by comparing the UK and Korea and emphasized the difference in the characteristics of the structure of firms and the national economy in the two countries. The UK and Korea have different economic backgrounds, including different economic growth rates, GDPs, GDP sector compositions, trade volume, inflation rates, investment and income distribution. Logistics' capability, transportation infrastructure and demographic characteristics also vary between the two countries. Furthermore, the growth and development of SCM is not driven only by internal motives, but by a number of external factors, such as increasing globalisation, reduced barriers to international trade, improvements in information availability, environmental concerns and government regulations and actions such as the creation of a single European market, and the guidelines of GATT and WTO (Gunasekaran et al., 2004).

The data used for this research was collected from the UK and Korea with the intention of conducting a cross-examination to determine whether the relevant strategies and performance related to variety issues differ in accordance with the structures of a national economy. In other words, the degree of impact of product variety, variety control strategy, supply chain performance, competitive capability and business performance may differ between the UK and Korea. For example, different levels of customisation and product variety due to different economical backgrounds can be related to different strategies, such as the level of focus on either cost leadership or differentiation. Therefore, the study first validates the survey results and then, suggests a strategy by comparing the UK and Korea. Those issues are related to question *Q4.1*.

In addition, a higher level of competition and product customisation (Silveira, 1998) can be external factors which affect product variety. As a result, such external factors can be closely related with variety increases and supply chain performance, which are related to Q4.2.

3.3 HYPOTHESIS DEVELOPMENT

Based on the research framework, hypotheses were developed that encompassed four main dimensions: 1) business function impact associated with variety increase depending on the type of customisation and level of variety offered, 2) the supply chain design to support the management of the product variety increase (i.e. the relative relationship between a variety control strategy and supply chain performance), 3) the strategy and performance difference depending on the level of customisation, and 4) a comparison of product variety, customisation, variety-related strategies (e.g. variety control strategy, partnership with suppliers, customer relationships and competitive capability) and supply chain performance (e.g. flexibility, agility, cost efficiency, customer service and business performance) between the UK and South Korea.

3.3.1. The impact of product variety on business function performance according to the level of customisation offered

Agile supply chain that has high customisation capability has high product variety than lean supply chain (Agarwal et al., 2006; Hallgren and Olhager, 2009). According to Silveira (1998), the three most significant factors that motivate an increase in product variety are the ability to customise the product, the demands made by customers and the level of competition. Thus, with regard to customisation, the first of these factors, a high level of customisation (e.g. PC and/or TC) is expected to have a corresponding higher level of product variety (e.g.

fundamental, intermediate and peripheral) than a low level of customisation (e.g. PS and/or SS). This observation led to hypothesis 1-1:

Hypothesis 1-1*: A high level of customisation has more product variety than a low level of customisation.*

The degree of product variety impact is typically high in continuous-process type followed by flow-shop type and project type manufacturing environments in terms of cost, quality, delivery and flexibility (Yeh and Chu, 1991). Therefore, the impact of increased product variety may decrease across the PS to PC continuum. This is attributable to an increase of the business function flexibility and agility in the highly-customised types that utilise modularisation and an upstream de-coupling point. For example, Hewlett Packard redesigned its supply chain to overcome the problem of variability in demand by pursuing the technique of applying agility downstream from the de-coupling point (Davis, 1993; Lee and Billington, 1993). The company achieved this by postponing the de-coupling point until as late as possible and ensuring that product differentiation also occurred at that de-coupling point. Through postponement, on the downstream side of the de-coupling point is a highly variable demand with a large variety of products, and upstream from the de-coupling the demand is smoothed with the variety reduced (Naylor et al., 1999). This approach has recently received considerable attention as one of the most beneficial concepts for reducing the costs and risks of product variety and improving the performance of supply chains (Davila and Wouters, 2007). As a result, a high level of customisation using an upstream de-coupling point imposes less impact on business function performance than low customisation. This finding led to the following hypothesis:

Hypothesis 1-2*: An increase in product variety impacts business function performance differently depending on the degree of customisation.*

Excessive product variety can significantly increase cost and consumer confusion which can result in a negative customer experience and a withdrawal from the purchase decision (Child et al., 1991; Alford et al., 2000). In addition, some firms (e.g. Unilever and P&G) are manufacturing too many products for certain brands, and by reducing the number of product varieties for a given brand could reduce total costs and increase firm-level profits (Thomas, 2011). In addition, the degree of modularity and manufacturing flexibility can provide capacity to mitigate variety-related negative impacts (Randall and Ulrich, 2001). Therefore, it would be expected that excessive variety compared with the level of customisation has a significant influence on business function performance. For example, the company with high variety and low customisation may create the highest negative impact on business performance through a variety increase. Hence, the following hypothesis was formulated:

Hypothesis 1-3*: An increase in product variety impacts business function performance differently depending on the combination of the degree of customisation and the product variety offered.*

3.3.2. Supply chain design to support the management of product variety increases; the relative relationship between a variety control strategy and supply chain performance

According to McCutcheon and Raturi (1994), companies can best achieve product variety and speed through a modular production configuration. The major advantage of modularity is the fact that companies can make changes or improvements in modularity without affecting other parts of the system (Galvin and Morkel, 2001). Therefore, product modularity (e.g. modularity and standardisation) facilitates process modularity (e.g. cellular manufacturing, flexible manufacturing technology) and engenders agility (Jacobs et al., 2011b). In addition, according to Salvador et al. (2004), the implications of product modularity stretch beyond the boundaries of the firm's value chain, as it can enable the firm to reconfigure its supply, manufacturing and distribution networks (or supply chain). As a result, a flexible and agile supply chain can be achieved through a modular product configuration.

The origin of supply chain flexibility and agility as key business concepts can be traced back to flexible manufacturing systems where automation and cellular manufacturing were exploited to promote rapid and cost effective changeovers (Christopher, 2000; Aitken et al., 2002). As mentioned in the literature review on group technology principles in cellular manufacturing, components with similar design characteristics and processing requirements are grouped into a family of parts which lead to manufacturing flexibility (Abdi and Labib, 2004; Blecker and Abdelkafi, 2006). Thus, cellular manufacturing enables firms to cut setup times and work in process inventory, to improve equipment utilisation and product quality, and streamline management, which helps facilitate mass customisation and enhanced value to the customer (Qiang et al., 2001; Bhandwale and Kesavadas, 2008). Accordingly, the reduction of material inventory, setup time, manufacturing complexity and lead time by cellular manufacturing leads to supply chain flexibility and agility and mitigate the trade-off between product variety and supply chain performance (Yeh and Chu, 1991).

Using postponement increases flexibility and also improves forecast accuracy for final product demand in the long term (Whang and Lee, 1998). Van Hoek (1999) also noted an obvious relationship between the configuration of the supply chain and postponement. He reported that postponement strategies (e.g. form, time and place postponement) can entail relocation of inventories to a central location, repositioning of final manufacturing and procurement activities, and reconfiguration of supply chain structure, which lead to flexible and agile supply chain structures. Therefore, a postponement strategy also enables manufacturers to improve inventory turns, asset productivity and value chain flexibility and facilitate fast delivery as well as customer service performance (Nair, 2005; Davila and Wouters, 2007). Furthermore, postponement is closely related to modularisation and standardisation since form postponement requires modular product architectures and modularity enables the standardisation of materials (Feitzinger and Lee, 1997). Building on the aforementioned arguments, the following hypotheses were developed:

Hypothesis 2-1*: A variety control strategy improves supply chain flexibility.*

Hypothesis 2-2*: A variety control strategy improves supply chain agility.*

Swafford et al (2006) divided supply chain flexibility attributes into three critical processes concerning procurement/sourcing, manufacturing and distribution/logistics flexibility based on key SCOR elements. The results also support the fact that a firm's supply chain agility is impacted by the synergy among the three process flexibilities in the internal supply chain, and the organisation's supply chain process flexibilities are an important precursor for supply chain agility. From a resource-based perspective, agility is a core competence that relies on various capabilities, that is, various forms of flexibility (Swafford et al., 2008). Therefore, flexibility boosts the level of supply chain agility (Agarwal et al., 2006). This research background led to Hypothesis 2-3:

Hypothesis 2-3*: Increased supply chain flexibility improves supply chain agility.*

All activities within a supply chain should be focused on satisfying consumer needs and service. Thus, supply chain flexibility should be examined from an integrative, customer-oriented perspective (Vickery et al., 1999). In other words, companies should view any supply chain flexibility taxonomy from the perspective of the entire value-adding system. From this point of view, Vinod et al. (2006) defined and considered five types of flexibility including product, sourcing, delivery, new product and responsive flexibility. Therefore, firms should enhance their customer service by aiming for customer-focused supply chain flexibility. Further, the attainment of supply chain flexibility leads to cost efficiency and productivity improvements due to reduced inventory, rework costs and external failure costs, which, in turn, lead to superior levels of customer satisfaction, resulting in better sales and profits (Narasimhan and Jayaram, 1998). Supply chain flexibility also can provide a variety of innovative, low-cost, high-quality products reliably and quickly (Zhang et al. 2002). Graves and Tomlin (2003) also found that supply chains with higher levels of process flexibility enhance the overall scale efficiency of the plants. Supply chain flexibility may increase time and cost owing to more controls required; however, flexibility can have a positive impact on the ability to minimise the cost without incurring high cost and large changes (Chan, 2003).

Labour and machine flexibility increase efficiency as they reduces set up time when switching operations (Chan, 2003). Volume flexibility reduces the cost of operation of the supply chain by more than what is required to install the additional capability (Schütz et al., 2009). Routing, operation, mix and new product flexibility can also be measured in terms of incurring low costs or small changes (Chan, 2003). Therefore, supply chain flexibility measures the degree of internal adaptability to respond to the change without suffering high costs or large changes (Chan, 2003). Cost efficiency performance in this thesis refers to the ability to minimise costs associated with managing operations of the supply chain. Based on these notions, flexibility can be defined as the ability of an organisation to efficiently and effectively adapt to foreseen and unforeseen changes (Tummala et al., 2006). In other words, supply chain flexibility can be a potential factor in achieving both efficiency and customer service performance (Vickery et al. 1999).

In addition, agility ensures responsiveness to customer requirements, resource efficiency and high performance, and cost sensitivity to improve competitiveness and the prospects of survival in volatile business environments (Hiroshi and David, 1999). An agile supply chain is necessary to respond to volatile customer demand and high customer need for variety (Agwal et al., 2006) and is related to efficient variety handling, new product agility and differentiation strategy (Hallgren and Olhager, 2009). Therefore, supply chain agility accompanied by improved supply chain flexibility can also enhance both cost efficiency and customer service. Based on the above arguments, one can expect that:

Hypothesis 2-4*: Increased supply chain flexibility improves supply chain cost efficiency.*

Hypothesis 2-5*: Increased supply chain agility improves supply chain cost efficiency.*

Hypothesis 2-6*: Increased supply chain flexibility improves supply chain customer service.*

Hypothesis 2-7*: Increased supply chain agility improves supply chain customer service.*

The level of customisation may affect relationships within the context of supply chain performance. Agarwal et al. (2006) affirmed the necessity of a much higher level of agility given high customer need for variety and analysed the effect of market-winning criteria and market-qualifying criteria in three types of supply chains: lean, agile and leagile. The market winning criterion of the lean supply chain is cost while the market winning criterion of the agile supply chain is the service level. In addition, Hallgren and Olhager (2009) suggested that three factors distinguish an agile from a lean system: high customisation capability, efficient variety handling and new product agility.

Therefore, both flexibility (i.e. internal capability) and agility (i.e. external competence) may have positive impacts on customer service as well as cost efficiency in the case of both high and low customisation. On the other hand, agility in a system with low customisation may play a less important role in cost efficiency and customer service than in a high customisation system since low customisation typically does not focus on an agile supply chain strategy but on a lean supply chain strategy that has the market-winning criterion of cost. Thus, the following hypothesis was developed:

Hypothesis 2-8*: Supply chain agility in a high customisation context has a stronger impact on cost efficiency and customer service than does agility in a low customisation context.*

3.3.3. Strategy and performance differences according to the level of customisation

In general, firms pursue different competitive capabilities within the generic strategies of competing based on cost, quality, time, flexibility and product differentiation, which result in improved business performance (Kim, 2006b, 2006a). Therefore, the connection between ‘qualifiers’/‘winners’ and ‘lean’/‘agile’ is essential (Aitken et al., 2002; Agarwal et al., 2006). The lean paradigm that typically employs a low level of customisation is most powerful when cost is a winning criterion, while flexible and agile paradigm that typically employ a high level of customisation become critical strategies when service and customer value enhancement are prime requirements for market winning (Mason et al, 2000). The level of product and service customisation is often cited as a key factor in determining the required flexibility of a supply chain (Sengupta et al., 2006).

Stavrulaki and Davis (2010) also emphasised alignment between the key aspects of a product and its supply chain processes and highlighted the links between supply chain processes in logistics and production and the supply chain strategy. In addition, the lean supply chain typically mandates a close collaborative relationship with suppliers for cost efficiency (Choi and Wu, 2009). However, a high level of customisation also necessitates a strong partnership with suppliers particularly for product innovativeness (Nieto and

Santamaria, 2007), though in a high level of customisation with a scale inefficient operation, it is typically difficult to establish and maintain close supplier relations based on opportunistic collaboration. Based on our theoretical expectation supported mainly by Stavrulaki and Davis (2010), Agarwal et al. (2006) and Lampel and Mintzberg (1996), Table 3-3 summarises the characteristic differences.

Table 3-3 Characteristics of types of customisation

Type	Customisation	Pure/Segmented standardisation	Customised standardisation	Tailored customisation	Pure customisation
	Structure	Make to Stock	Assembly to Order	Make to Order	Design to Order
Product	Product variety Demand uncertainty Profit margin Order lead time Labour skill	Low	→		High
	Product Life cycle Forecasting accuracy Volume	High	←		Low
	Product type	Functional	↔		Innovative
Manufacturing	Production Process	Continuous , large assembly/batch	Assembly line process	Small batch Job shops	Job shops project
	Product design	Cost conscious	Modular		Specialised
	Direct contact with end user	Uncommon	↔		Common
	Manufacturing process focus	Efficiency	Efficiency / Flexibility focus		Flexibility
	Production cost	Low	→		High
Logistic	Number of intermediaries	Large	←		Small
	Bullwhip effect	Prominent	↔		Less likely
	Supplier relationship	Collaborative High information sharing High volume transactions			Opportunistic collaboration More collaborative barriers Low volume transactions
	Customer relationship	Small number of customer segment		Large number of customer segment	
	Order fulfilment	Cost driven	↔		Time driven
	Logistics process focus	Efficiency	Efficiency / Flexibility focus		Flexibility
SCM	Supply chain strategic capability	Lean	Leagility		Agility
Market	Core competitive focus (market winner)	Low cost (Cost leadership)	↔		High service (Differentiation)
Cost	Dominant cost	Physical costs	↔		Marketability costs

Source: Adapted by Lampel and Mintzberg (1996), Agarwal et al. (2006) and Stavrulaki and Davis (2010)

To sum up, low customisation typically focuses on a cost leadership strategy (Lampel and Mintzberg, 1996; Agarwal et al., 2006) and a strong partnership with the supplier (Stavrulaki and Davis, 2010) while high customisation types corresponding with high variety focus on differentiation (Lampel and Minzberg, 1996; Agarwal etl al., 2006) and close customer relationships (Stavrulaki and Davis, 2010), and may focus on a variety control strategy. In addition, low customisation that typically employs a lean supply chain leads to cost efficiency (Agarwal et al., 2006; Stavrulaki and Davis, 2010), while high customisation that uses an agile supply chain enhances customer service (Agarwal etl al., 2006), supply chain flexibility (Stavrulaki and Davis, 2010) and supply chain agility (Stavrulaki and Davis, 2010).

Therefore, a company with a high level of customisation (e.g. high customisation cluster such as TC and PC) may focus more on differentiation, customer relationships and variety control, which may lead to higher level of supply chain flexibility, supply chain agility and customer service. Therefore, the following hypotheses were developed:

Hypothesis 3-1: *A high customisation cluster is associated with a higher level of customer service than a low customisation cluster.*

Hypothesis 3-2: *A high customisation cluster is associated with a higher level of differentiation than a low customisation cluster.*

Hypothesis 3-3: *A high customisation cluster is associated with a stronger customer relationships than a low customisation cluster.*

Hypothesis 3-4: *A high customisation cluster is associated with a higher level of variety control than a low customisation cluster.*

Hypothesis 3-5: *A high customisation cluster is associated with a higher level of supply chain flexibility than a low customisation cluster.*

Hypothesis 3-6: *A high customisation cluster is associated with a higher level of supply chain agility than a low customisation cluster.*

On the other hand, a company having a low level of customisation (e.g. low customisation cluster such as PS and SS) focuses more on cost leadership and its partnership with suppliers, which may lead to cost efficiency. Therefore, the following hypotheses were developed:

Hypothesis 3-7: *A low customisation cluster is associated with a higher level of cost efficiency than a high customisation cluster.*

Hypothesis 3-8: *A low customisation cluster is associated with a higher level of cost leadership than a high customisation cluster.*

Hypothesis 3-9: *A low customisation cluster is associated with a stronger partnership with suppliers than a high customisation cluster.*

3.3.4 A comparison of the impact of product variety, strategy and performance between the UK and South Korea

Hypotheses 3-1 to 3-8 were designed to investigate general differences according to the level of customisation. This research then applies a comparative analysis to the case of the UK and Korea considering the different economic environment and strategic focus of the country concerned. The following comparison between the UK and Korea aims to both validate the research outcomes and suggest implications for both countries. To compare the UK and Korea in terms of impact of product variety, strategies and performance, the thesis considered the level of customisation of each country. In addition, different national characteristics in economics and supply chain characteristics were employed for comparison.

Particularly based on the literature reviews and results of the T-test (see Table 5-17), a high level of customisation corresponding with a high level of product variety typically focuses on differentiation, variety control strategies and customer relationships that enhance supply chain flexibility and agility, while a low level of customisation corresponding with a low level of product variety generally focuses on cost leadership. Thus, by applying the results to the UK and Korea, the thesis included the following hypotheses:

Hypothesis 4-1*: A country with less product variety is associated with increased focus on cost leadership.*

Hypothesis 4-2*: A country with more product variety is associated with an increased focus on differentiation, variety control strategies, customer relationships, supply chain flexibility and agility*

According to Silveira (1998), the three most significant factors that motivate an increase in product variety are the ability to customise the product, the demands made by customers and the level of competition. Thus, the finding that a higher level of product customisation and market competition increased product variety led to the following hypothesis:

Hypothesis 4-3*: A higher level of competition and product customisation are associated with a higher level of product variety.*

3.4. CHAPTER SUMMARY

This chapter was focused on developing the conceptual framework for the research. Four steps were considered; 1) the impact of product variety on business function performance, 2) the supply chain design to support the management of product variety increases (the relative relationship between a strategy for variety control and supply chain performance), 3) strategy and performance differences based on the degree of product customisation, 4) a comparison between the UK and Korea. A series of hypotheses were formulated.

Section 3.2.1 introduced conceptual framework to investigate the possible impact of product variety on business function performance according to level of customisation. The research conceptual model in Section 3.2.2 was developed by adopting a variety control strategy concept to support the management of the trade-off between product variety and supply chain performance. Based on the review of relevant literature (Chapter 2), the research model framework is comprised of several factors (i.e. variety control strategy, supply chain flexibility, supply chain agility) which have a significant impact on supply chain performance (i.e. cost efficiency, customer service). Furthermore, Section 3.2.3 and 3.2.4 compared the proposed strategies and performance depending on the level of customisation and countries. Finally, Section 3.3 was dedicated to developing the research hypotheses by presenting some evidence from the pertinent literature for each framework.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 INTRODUCTION

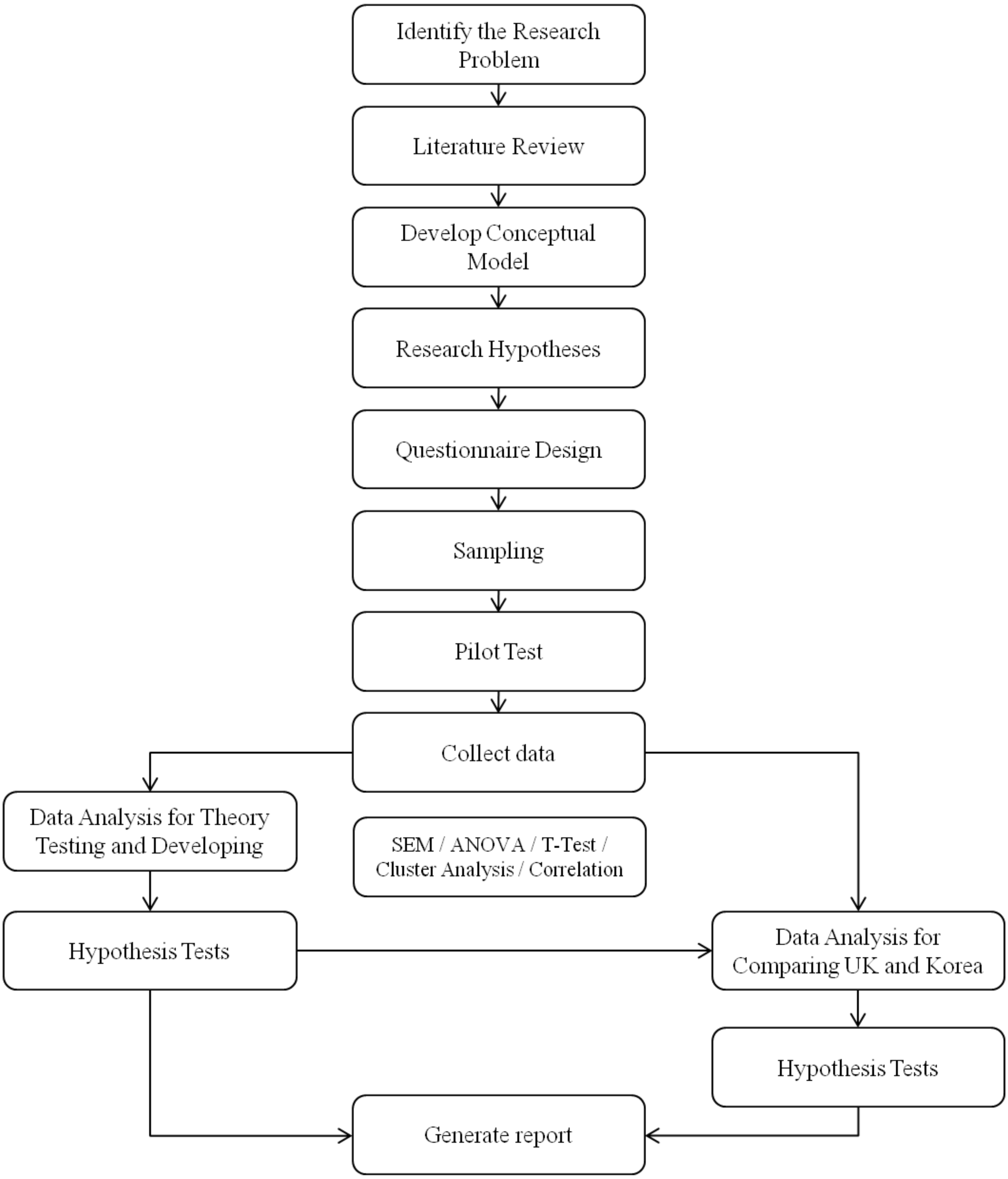
This chapter presents a review of methodological approaches and proposes the adopted research methodology. It begins with a description of the research design. The research strategies used to test the hypotheses are then presented, including the data sources and questionnaire designs. In the questionnaire design section, construct measurement, scale development regarding the level of variety and customisation, and the question development procedure are explained. The data collection strategies are then discussed. The chapter closes with a discussion of statistical strategies for data analysis.

4.2 RESEARCH DESIGN

A research design is a plan for research that provides guidance on the collection and analysis of data (Churchill and Iacobucci, 2005). Research design includes a number of related sub-processes to fill a gap in published literature, including the translation of the theoretical domain into the empirical domain, the design and pilot testing processes, the process of collecting data, the data analysis process and the process of interpreting results (Forza, 2002).

The research design for this study is depicted in Figure 4.1. Firstly, the research problem was identified and then the research question was formulated based on the literature review. Next, the conceptual model and research hypotheses were developed, then the questionnaire was designed and lastly, after the sampling process and the pilot test, the process of collecting data was executed. The data analysis, for both theory testing/development and comparing the UK and Korea, was then conducted. Finally, the conclusions were drawn from the findings and directions for future research were identified.

Figure 4-1 Research design



4.3. RESEARCH STRATEGIES

To reflect the nature of the research aims, a quantitative survey approach was adopted in order to comprehensively address the research objectives and questions outlined in Section 1.4 and Section 1.5, respectively. Confirmatory survey research is undertaken when knowledge of a phenomenon has been articulated in a theoretical form using well-defined concepts, models and propositions to test and develop the theory, while exploratory survey research is appropriate when the objective is to gain preliminary insight into a topic in order to provide evidence of association among concepts of interest (Forza, 2002). Thus, this study is an example of confirmatory survey research. In particular, this research focuses on theory testing (Hypotheses group 3 and 4) and developing (Hypotheses group 1 and 2), and compares the UK and Korea. Therefore confirmatory survey research is a suitable methodology to generalise the research findings using well-defined concepts in order to approach the research aims (i.e. to explore the relationship between variety control strategy and supply chain performance and compare the impact of product variety on business function performance under different levels of customisation). Case studies can be employed as a follow-up to a survey in an attempt to examine them more deeply and validate previous empirical results (Voss et al., 2002).

4.3.1 Sources of data

The methodological option with respect to the sources of data is broadly a choice between primary and secondary. Primary data is “originated by the researcher for the purpose of the immediate investigation at hand” (Churchill and Iacobucci, 2005) which can lead to new insights and greater confidence in the outcomes (Easterby-Smith et al., 2001). Secondary data is existing data and statistics, and therefore provides advantages over primary data in terms of cost and time (Churchill and Iacobucci, 2005). “The disadvantages of secondary data are related to the fact that their selection and quality, and the methods of their collection, are not under the control of the researcher, and that they are sometimes impossible to validate" (Sorensen et al., 1996). However, some secondary data may have questionnaire relevance as it was collected for other research purposes. In this study, primary sources of data were used to test the hypotheses. To compare the UK and South Korea, both primary data from the survey questionnaire and secondary data earned from national statistics (e.g. The world bank and IMF) and some authorised organisations' data (e.g. Central intelligence Agency and Gartner Inc) were used.

Across the principal methods available to collect primary data (e.g. observation, interview and questionnaire), a questionnaire-based survey was selected as the means of investigating the impact of product variety on business functions, addressing the existing causal relationships between approaches to variety control and supply chain performance that have been enacted in order to manage variety increases, and testing strategy and performance differences according to the level of customisation. Furthermore, secondary data was also collected to contrast the UK and Korea in terms of economics, logistics and the supply chain environment.

4.3.2 Questionnaire design

Kumar et al. (2002) have asserted that questionnaire design is "a very imperfect art" with no known processes capable of leading consistently to a "good" questionnaire. An effective design to achieve the research objectives typically follows a sequence of logical steps: "(1) plan what to measure, (2) formulate questions to obtain the needed information, (3) decide on the order and wording of questions and on the layout of the questionnaire, (4) using a small sample, test the questionnaire for omissions and ambiguity and (5) correct the problems and pre-test again, if necessary" (Kumar et al., 2002).

4.3.2.1. Measurements for constructs

With regard to questions concerning the impact of product variety on business function performance, a questionnaire was formulated then it was composed of 37 questions (items) grouped into five business function dimensions: Engineering (E1-4 items), Manufacturing (M1-16 items), Purchasing (P1-3 items), Logistics (L1-9 items) and Marketing (MA1-5 items). Thirty seven detailed aspect of business function performance were conceived in accordance with the extant literature (see Table 2-2 in Chapter 2).

Regarding the proposed model to manage variety increases and compare differences in strategy and performance depending on the level of customisation, a questionnaire was developed, composed of 45 questions concerning partnership with suppliers (PAS1-4 items), variety control strategies (VCS1-3 items), the customer relationships (CR1-4 items), supply chain flexibility (FL1-6 items), supply chain agility (AG1-7 items), cost leadership (CL1-2 items), differentiation (D1-3 items), cost efficiency (CE1-4 items), customer service (CUS1-8 items) and business performance (BP1-4 items). In addition, respondents were asked to rate the extent of their agreement on a 5-point Likert scale (1=strongly disagree, 5=strongly agree) regarding partnership with suppliers, variety control strategy and customer service, as well as the extent of performance on the 5-point Likert scale (1= poor, 5= excellent) regarding supply chain flexibility, supply chain agility, cost leadership, differentiation, cost efficiency, customer service and business performance. Since all measurement items for the constructs employed in this study were widely disseminated in relevant literature, a selection of existing measures was adapted to achieve the research objectives.

4.3.2.2. Scale development for the degree of customisation and product variety offered

Primarily based on the framework of Lampel and Mintzberg (1996), each manufacturer was classified as having a degree of product customisation that corresponded to pure standardisation (PS), segmented standardisation (SS), customised standardisation (CS), tailored customisation (TC) or pure customisation (PC). PS was defined as "providing standard products that have pre-defined options and designs. Product customisation happens at the sales stage." SS was defined as "providing products in which customers may customise product packaging, delivery schedules, or delivery location. The actual product is standard with pre-defined options and designs. Customisation works at the sales and distribution stages." CS was defined as "providing various types of products, in which customers are offered a number of pre-defined options. Products are assembled to customer order using standard components. Customisation is achieved at the assembly stage." TC was defined as "providing various types of products, in which customers are offered a number of pre-defined designs. Products are manufactured to customer order. Customisation is achieved at the fabrication stage." PC was defined as "providing a unique product design, in which customer input is integrated at the start of the design process. Products are designed to order. Customisation is achieved at the design stage." In addition, the respondents were required to indicate only one main customisation type within the company.

Product variety was measured in terms of fundamental (number of different core models and designs for the manufacturer's products), intermediate (number of different technical options, sizes and colours dependent on core design) and peripheral variety (number of particular options and accessories independent of core design) using a 5-point scale (1= 0-5, 2= 6-10, 3= 11-15, 4= 16-20, 5= above 20) based on the core product family. The actual internal product variety is a combination of three dimensions. External variety is related to customisation in terms of the choices customer have. In short, actual customised product variety (external variety) is a possible combination minus restrictions (e.g. technical incompatibilities) (Stablein et al., 2011). Since the research focuses on the manufacturer's perspective, variety is defined internally: fundamental, intermediate and peripheral variety (MacDuffie et al., 1996).

4.3.2.3. Questionnaire development procedure

Several particular techniques were employed in the development of the questionnaire such as the question formation process (Groves et al., 2004). First, some non-sensitive questions concerning the company profile information were embedded at the start of the questionnaire. These questions were followed by sensitive questions which were listed to cover all relevant variables. Lastly, the most sensitive part, that is, questions on the degree of impact of product variety on business function performance, was incorporated into the final section of the questionnaire. This final section is designated as *Survey 1* since this section can be answered by companies that have had recent increases in their product variety, while the section for the structural equation modeling is designated as *Survey 2* in Chapter 5.

The questionnaire was developed through a comprehensive assessment procedure to achieve reliability and validity prior to its distribution to respondents. First, the questionnaire was reviewed by a supervisor so as to evaluate the clarity and sequence of the questions employed. After all of the questions were framed in readily understandable terms, a pilot test based on interviews with three professional colleagues in the UK and managers who work in five different manufacturing companies in Korea was conducted to ensure that they were comprehensible to the respondent without any uncertainty or confusion. Consequently, based on the comments provided by the informants, the structure of the covering letter was modified and the problematic questions were rephrased. With regard to the Korean questionnaire, following the method of Craig and Douglas (1999), a professional translator translated the original version of the questionnaire into Korean and another individual then translated the questionnaire into English. Two translators then agreed upon a version of the questionnaire.

The final questionnaire was composed of five pages with personal information related to the firms and respondents collected in a separate section. In addition, a five-point Likert scale approach was employed to develop these questions in order to provide a straight forward mechanism for informants to respond (Malhotra and Birks, 2007) and minimise missing data. The questionnaire employed 10 scales for questions concerning the impact of variety on business function performance to identify concrete impact differences. Matell and Jacoby (1972) demonstrated that as the number of scale steps is increased, respondents' choice of the mid-point category decreases. The detailed criteria associated with all of the questions are presented in Appendix 1.

4.4. DATA COLLECTION STRATEGIES

4.4.1. Sampling

The stages of selecting respondents for a methodologically sound sample are: “(1) examine the objective of the study, (2) define the people of interest, (3) find suitable source for the population members, (4) decide on the sampling type and approach, (5) decide on the sample size, (6) proceed with the fieldwork and (7) correct sampling errors ready for reporting” (Bradley, 2007).

The industry classification is an especially important aspect of framing the population (Forza, 2002). A study objective was to target various manufacturers that produce products with different levels of customisation. Manufacturing companies were randomly selected based on the standard industrial classification (SIC) code in the FAME database (2010) that contains descriptive data on over a quarter of a million major private and public UK firms and is widely available as a source in the UK. In Korea, manufacturing firms were identified from “The top 1000: the largest corporation in South Korea” presented by the Korea Chamber of Commerce & Industry (2010) and the database of the R&D performance fair hosted by the Korea Evaluation Institute of Industrial Technology (2011).

Sample designs can be grouped into two families: probabilistic and non-probabilistic sampling. In probabilistic sampling (i.e. random sampling), the population elements have some known probability of being selected, which differs from non-probability sampling (Forza, 2002). In probabilistic sampling, stratified random sampling is a very useful type of sampling since it provides more information for a given sample size. Strata are identified on the bases of meaningful criteria such as industry type, size and performance (Forza, 2002). Thus, to collect data from various manufacturing sectors (see the SIC code) and appropriately-sized firms with an established culture, the surveys follow a stratified random sampling procedure based on several criteria:

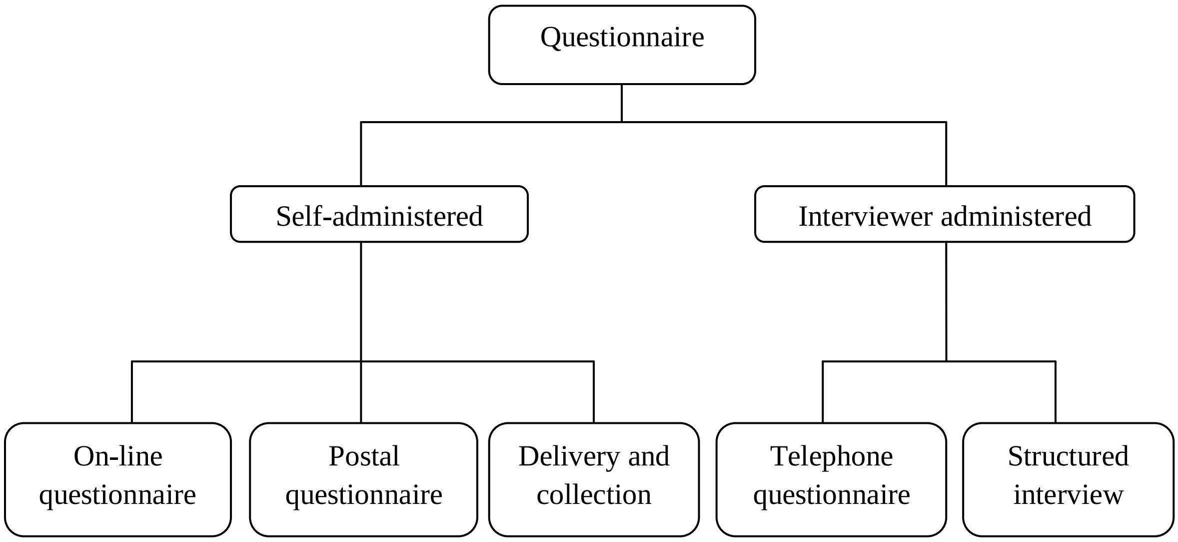
- Industry type: firms which belong to one of 15 major manufacturer types (excluding holding companies).
- Industry size: turnover (more than £100,000), employees (more than 5).
- Date of registration: over five years.

After purifying the initial list, the total number of selected firms in the list was 1,950. In addition, a single informant was targeted within each manufacturing firm included in the sample and served as the sole respondent for each firm that participated in this study. In particular, this research tried to select the person in charge of operations, supply chain management or business strategy with a good level of general knowledge regarding the firm's business environment. Thus, the positions of the target respondents were intended to be above the managerial level. The data collected from Korea and the UK employed as a combined data set to test theory and model.

4.4.2. Data collection

There are several available classifications for the collection of data in questionnaire-based survey research (Saunders et al., 2009), as illustrated in Figure 4-2.

Figure 4-2 Types of questionnaires



Source: Saunders et al. (2009)

Among these data collection options, the postal and structured interview surveys were chosen to serve as the data-collection vehicles. Postal and email questionnaires have several advantages. These include minimal staff requirements and respondents' time to think about questions (Cooper and Schindler, 2008). In addition, there are other reasons to utilise a postal and mail survey in this research: 1) a wide geographic area must be covered, 2) with the constraints imposed by cost and time, mail surveys are the cheapest method among other methods and 3) the survey is perceived as more anonymous (Saunders et al., 2009).

Therefore, in the UK, the final version of the questionnaire was sent to manufacturing companies, by postal mail. The survey package sent by post included a covering letter and a pre-stamped return envelope. The covering letter contained some details regarding the goals, objectives and scope of the study, and guaranteed the confidentiality of information obtained from participants. Respondents who had difficulty grasping the concept of some questions or experienced any problem asked questions via the email address presented in the covering letter and were given direct feedback by email.

In Korea, in order to obtain an acceptable level of response, an email and structured interview survey were chosen. Questionnaires were emailed with a covering letter describing the purpose and significance of the study. Then, as suggested by Weisberg et al. (1996), two weeks later, a follow-up phone call or email was sent to each of the target respondents to increase the response rate. In addition, when questions were administered in face-to-face interviews, this permitted the interviewer to guide respondents through the questionnaire and deal with any procedural questions (Saunders et al., 2009). Therefore, explanations of some concepts, such as the level of customisation and variety, were provided during the interviews.

Sample size is a complex issue which is linked to the level of significance, the statistical power of the test and the size of the researched relationship, such as the association strength (Forza, 2002). High statistical power is required to reduce the probability of failing to detect an effect when it is present. A reasonable and realistic value for research in social science is 0.8 (Verma and Goodale, 1995), which means only 20 percent of the repeated studies will not yield a significant result. Therefore, following the received wisdom that the sample size should be more than 271 to investigate relationships, including small effects with a 0.8

statistic power at a 0.05 significance level (see Table 4-1), the target sample size was thus at least more than 300, leaving a conservative margin for error, for example to allow unusable questionnaires. The required sample sizes, with desired statistic powers of 0.8 and 0.6, are shown in Table 4-1 as a function of the effect of sample size and significance level.

Table 4-1 Effect of statistical power, significance level and sample size

	Statistic power = 0.6		Statistic power = 0.8	
	α = 0.05	α = 0.01	α = 0.05	α = 0.01
Large effect (strong association)	12	18	17	24
Medium effect (medium association)	30	45	44	62
Small effect (small association)	179	274	**271**	385

Source: Forza (2002)

4.5. DATA ANALYSIS STRATEGIES

4.5.1. General measurement concepts

This sub-section describes the statistical tools employed to test the research hypotheses on the basis of the response data collected. The usefulness of measures is generally evaluated in terms of reliability and validity (Forza, 2002). Reliability indicates dependability, stability, predictability, consistency and accuracy and refers to the extent to which a measuring procedure yields the same results across repeated trials (Kerlinger, 1986). The three most common methods used to estimate reliability are the test-retest method, alternative form method and internal consistency method. Among the three, the internal consistency method assesses the equivalence, homogeneity and inter correlation of the items used in a measure, which means that the items of a measure should hang together as a set and should be capable of independently measuring the same construct (Forza, 2002). Therefore, reliability in terms of internal consistency is measured by employing Cronbach's alpha or a composite reliability score (O'Leary-Kelly and Vokurka, 1998; Hair et al., 2010). A construct with reliability above a value of 0.7 exhibits acceptable reliability (Nunnally, 1978).

Content validity (i.e. face validity) measures whether or not “the content of the items adequately represents the concepts” (Cooper and Schindler, 2008). The presence of content validity is argued through a discussion of existing literature supporting the construct concept and its item measures. Construct validity basically focuses on the convergence between measures of the same construct (convergent validity) and separation between measures of different constructs (discriminant validity). In short, convergent validity represents how well the item measures relate to each other with respect to a common concept, while discriminant validity represents how well an item measure relates to its hypothesised construct versus other constructs in the model (Kerlinger, 1986). These two construct validities can be assessed through both exploratory and confirmatory factor analysis. Exploratory factor analysis (EFA) is particularly appropriate for scale development or when there is little theoretical basis for specifying the number and patterns of common factors, while confirmatory factor analysis (CFA) would be preferred where measurement models have a well-developed underlying theory for hypothesised loading patterns (Hurley et al., 1997). In CFA, the presence of significant factor loadings and the average variance extracted (AVE > 0.5) exhibit convergent validity (Anderson and Gerbing, 1988). Besides, discriminant validity can be established using procedures outlined by Fornell and Larcker (1981), who prescribed that the squared multiple correlations (SMC) between constructs must be less than the average variance extracted (AVE) of each underlying construct for the constructs to have discriminant validity.

Cluster analysis aims to classify a sample of entities into a smaller number of mutually exclusive subgroups based on the similarities among the entities (Forza, 2002). Two distance measures (i.e. straight line distance) are frequently used as a measure of similarity: Euclidean and Squared Euclidean distance (Hair et al., 2010). In addition, there are two approaches that are commonly used to select cluster algorithms: the hierarchical method and the non-hierarchical method (i.e. K-Means cluster analysis). Therefore, of the most commonly recognised measures suitable for a small number of clusters with large data (Hair et al., 2010), K-means cluster analysis based on Euclidean distance was employed to assign the respondents into the most appropriate clusters for the current research.

The ANOVA tests evaluate whether there are significant differences in the mean scores of the dependent variable against different groups (e.g. five types of customisation) and the post-hoc test shows where the differences exist. A probability of 0.05 (p-value) was chosen as the appropriate level of significance in this thesis; researchers traditionally reject a null hypothesis if the p-value is smaller than 0.05 (Cooper and Schindler, 2008; Saunders et al., 2009). On the other hand, the T-test was employed to assess the statistical significance of the difference between the two groups (e.g. high and low customisation) since the T-test is a special case of ANOVA for the two groups (Hair et al., 2010).

4.5.2. The measurement concept for the structural equation model (SEM)

Multiple regression is the method that was used to predict changes in the dependent variable in response to changes in the several independent variables (Forza, 2002). While regression considers only one dependent variable and one aggregate error term, SEM can handle multiple dependent variables as well as error terms for all dependent and independent variables in the structural model (Kline, 2011). Thus, SEM can estimate a series of interrelated dependence relationships simultaneously. Although multiple regression is useful to examine the relationship between independents and a dependent variable, it cannot directly propose potential relationships in a model that are justified and interpreted substantively by theories (Cheng, 2001).

Based on the work of Anderson and Gerbing (1988), the model was tested using a two-stage structural equation model. First, confirmatory factor analysis (CFA) was performed to evaluate construct validity regarding convergent and discriminant validity using AMOS 18.0. In this stage, construct reliability (CR) and the average variance extracted (AVE) for the validity test were considered. In the second stage, structural equation model (SEM) analysis was employed to test the research hypotheses empirically.

CFA is generally used to provide a confirmatory test of a study's measurement theory and test how well the measured variables represent a smaller number of constructs (Hair et al., 2010). Therefore, the study used confirmatory factor analysis since a proposed model was formed by a theory based on links between structures and item measures. CFA examines the relationships between proposed item measures and a related latent construct to assess the unidimensionality of each construct (Kim and Mueller, 1978). In other words, the proposed item measures may load only on the one proposed associated construct (Swafford et al., 2008).

After examining the reliability and validity across the constructs, this research examined how well the data fit the model by proving that badness or goodness-of-fit measurements met recommended levels. Root mean square error approximation (RMSEA) and standardised root mean residual (SRMR) consider the levels of residuals in measurements. RMSEA is an estimate of the discrepancy between the model, with optimally chosen parameter estimates, and the population covariance matrix. SRMR reflects the discrepancy between the predicted (i.e. model-implied) and observed (i.e. sample) covariance matrix. RMSEA is an especially typical measure for overall model fit and a smaller value of RMSEA represents a better model fit. The recommended maximum values for SRMR and RMSEA is 0.08 (Hair et al., 2010).

The other two measures typically used, the comparative fit index (CFI) and the goodness-of-fit index (GFI), both have recommended minimum thresholds of 0.90 (Hair et al., 2010; Kline, 2011). The goodness-of-fit index (GFI) indicates the overall degree of fit (measure of fit between the hypothesised model and the observed covariance metrics). In addition, Segars and Grover (1993) recommend the ratio of χ^2 to the degree of freedom as less than 3.0 to indicate a reasonable fit.

4.6. CHAPTER SUMMARY

This chapter began by presenting the research design employed in this research. Then, research strategies for testing hypotheses in this study were explained in terms of which data sources and questionnaire designs were presented. In the section on questionnaire design, construct measurements, scale development of the type of customisation and the level of product variety, and the questionnaire development procedure were explained. In addition, the items and resources employed for the research's constructs were presented. It has to be noted that all of the items used in this research were adapted from the relevant literature to eliminate concerns regarding the reliability and validity of the constructs. Furthermore, the questionnaire went through a comprehensive assessment procedure to guarantee its efficiency and validity prior to being formally utilised in this study.

In the next section on data collection strategy, the sample used for the study, the data collection methodology and the sample size were described. In this process, the questionnaire was sent to 1,950 potential informants and as a result 364 usable responses were received. The final section of this chapter illustrated statistical strategies for data analysis. General measurement concepts employed in this research, such as reliability, validity, ANOVA and cluster analysis, were explained. Then, measurement concepts for SEM, such as CFA, CR, AVE, GFI, CFI, SRMR and RMSEA, were also described.

CHAPTER FIVE

SURVEY APPLICATION AND RESULTS

5.1. INTRODUCTION

The main objectives of the survey were to investigate the impact product variety has on business functions with respect to a type of customisation, and also to investigate the supply chain design to support the management of variety increases by testing the relationship between a variety control strategy (VCS) and supply chain performance. The survey also aimed to determine how variety-related strategy and supply chain performance differences depend on the level of customisation. These are achieved by evaluating: (1) the extent of product variety effects on business function performance for various types of customisation; (2) how variety control strategies influence supply chain performance depending on the level of customisation; and (3) the differences in variety-related strategy and supply chain performance that depend on the level of customisation.

This chapter contains four sections. Section 5.2 provides general descriptive statistics for respondents' and manufacturers' characteristics. After data screening in Section 5.3, Section 5.4 presents the analysis of the impact of increasing variety on business function performance, as determined through the use of the ANOVA test on the data gathered by the UK's manufacturers. Section 5.5 presents the results of a structural equation model (SEM) used to manage an increase in variety, which was applied using confirmatory factor analysis (CFA) on all of the data gathered in the UK and Korea. Next, Section 5.6 presents the results of differences in strategy and performance, as determined through the use of EFA and the t-test on all of the data gathered in the UK and Korea. Combined samples (Korea and the UK) are employed for investigating Q2 and Q3, while separated sample is used for answering Q1 and Q4. Therefore, differences between the two countries were investigated separately and can not affect the analysis of SEM in Section 5.5 and t-test in Section 5.6. Finally, Section 5.7 summarises the survey results and the related findings.

5.2. GENERAL DESCRIPTIVE STATISTICS

This section presents the demographic characteristics and details of the response rate of respondents in the UK and Korea. For manufacturers, respondents' information includes job title, total sales volume, number of full-time employees, geography of service provision, number of major competitors, profit margin and industry type. The data collection phase of the research began in the January of 2011 and completed in the July of 2011.

5.2.1 Demographic characteristics

In terms of job titles in the UK, 98.9% of survey participants had positions higher than manager (only three respondents held other positions), while 55.3% of the Korean survey respondents had positions above assistant manager: 13.8% were sales representatives and 30.3% were section managers or clerks. When all of the data from the UK and Korea were considered as a whole, 84.1% of the participants had positions over assistant manager and sales representative. With regard to the participating firms' sales volumes in 2010, a total of 85.3% of the responding firms had a sales volume of more than £10 million in the UK, while 67.8% of the responding firms in Korea reported total sales volumes of more than £10 million (equivalent).

Regarding full-time employees, 6.1% of UK firms had fewer than 50 employees (small sized), 41.5% had more than 250 employees (large sized), and almost 52.4% had 50-250 employees (medium sized). In Korea, 22.4% had fewer than 50 employees, 40.2% had more than 250 employees, and 37.5% had 50- 250 employees. With regard to the total sample, 59.1% of the firms were small and medium-sized firms (SMEs); 40.9% were large firms (LEs).

The data collected on the geography of service provision for firms in the UK shows that 21.2% of firms serve only in the domestic sphere, 73.6% of firms offer international and domestic services and 5.2% of firms provide only international services. In Korea, 30.3% of firms offer only domestic services, 67.1% of firms offer international and domestic services, and 2.6% of firms offer strictly international services.

With regard to the number of major competitors, most (68.4%) of the manufacturers in the UK had to compete with 2-10 competitors. Similarly, 79.6% had to compete with 2-10 competitors in Korea. With respect to profit margin in the UK, 25.9% had profit margins (%) between 0-5, followed by 20.8% with profit margins of 6-10, 16% that were above 25, 13.2% that were 11-15, 12.3% that were 16-20 and 8.5% that were 21-25. In Korea, 27.6% had profit margins of 6-10, followed by 23% at 11-15, 11.2% at 0-5, 7.9% at 16-20, 5.9% above 25, and 3.3% at 21-25.

The preliminary analysis of the responses indicated that the participating firms spanned a diverse group of manufacturing industries, which allowed for generalisation of the findings (Gatignon and Xuereb, 1997). The study population included 15 industry types. In the UK, 1.4% of the respondent companies were involved in the manufacture of paper products; this represented the smallest sector of the population. The largest sector of the population (13.7%) comprised companies involved in the fabrication of metal products. In Korea, 2.0% of companies were involved in the production of basic metal products; this represented the smallest group. The largest group (14.5%) were involved in the production of electronic parts and components. Table 5-1 displays the detailed demographic characteristics.

Table 5-1 Descriptive analysis

Characteristics	UK Frequency	UK Valid (%)	UK Cumulative (%)	Korea Frequency	Korea Valid (%)	Korea Cumulative (%)
Job Title						
Above Director	65	30.7	30.7	12	7.9	7.9
Director / Deputy Director	86	40.6	71.2	10	6.6	14.5
Manager / Assistant Manager	58	27.4	98.6	62	40.8	55.3
Sales Representative	1	.5	99.1	21	13.8	69.1
Section manager (Korea) / Clerk	1	.5	99.5	46	30.3	99.3
Other	1	.5	100.0	1	.7	100.0
Total	212			152		
Total Sales Volume (Million UK pound)						
Less than 0.25	0	.0	.0	6	3.9	3.9
0.25 to 0.5	0	.0	.0	5	3.3	7.2
0.5 to 1	0	.0	.0	4	2.6	9.9
1 to 2	1	.5	.5	4	2.6	12.5
2 to 10	30	14.2	14.7	30	19.7	32.2
10 to 50	100	47.4	62.1	43	28.3	60.5
More than 50	80	37.9	100.0	60	39.5	100.0
Total	211	(Missing=1)		152		
Full-time Employees						
Less than 50	13	6.1	6.1	34	22.4	22.4
51-150	65	30.7	36.8	36	23.7	46.1
151-250	46	21.7	58.5	21	13.8	59.9
250-1000	61	28.8	87.3	21	13.8	73.7
More than 1000	27	12.7	100.0	40	26.3	100.0
Total	212			152		
Service provision						
Domestic service	45	21.2	21.2	46	30.3	30.3
International and Domestic service	156	73.6	94.8	102	67.1	97.4
International Service	11	5.2	100.0	4	2.6	100.0
Total	212			152		
Number of Major Competitors						
1	5	2.4	2.4	4	2.6	2.6
2 to 5	90	42.5	44.8	75	49.3	52.0
6 to 10	55	25.9	70.8	46	30.3	82.2
11 to 20	36	17.0	87.7	13	8.6	90.8
More than 20	26	12.3	100.0	14	9.2	100.0
Total	212			152		
Profit Margin (%)						
0 to 5	55	25.9	25.9	17	11.2	11.2
6 to 10	44	20.8	46.7	42	27.6	38.8
11 to 15	28	13.2	59.9	35	23.0	61.8
16 to 20	26	12.3	72.2	12	7.9	69.7
21 to 25	18	8.5	80.7	5	3.3	73.0
Above 25	34	16.0	96.7	9	5.9	78.9

Don’t know	7	3.3	100.0	32	21.1	100.0
Total	212			152		
Manufacturing industry type						
Food, beverage, tobacco	17 (15) [a]	8.0	8.0	9 (9) [a]	5.9	5.9
Wood and furniture	21 (18) [a]	9.9	17.9	11 (11) [a]	7.2	13.2
Chemical materials and products	15 (9) [a]	7.1	25.0	13 (11) [a]	8.6	21.7
Non-metal mineral products	10 (6) [a]	4.7	29.7	5 (5) [a]	3.3	25.0
Fabricated metal products	29 (21) [a]	13.7	43.4	4 (3) [a]	2.6	27.6
Computer and communication products	9 (6) [a]	4.2	47.6	17 (15) [a]	11.2	38.8
Electronic parts and components	19 (17) [a]	9.0	56.6	22 (22) [a]	14.5	53.3
Electrical machinery and equipment	18 (15) [a]	8.5	65.1	21 (17) [a]	13.8	67.1
Transport equipment	23 (16) [a]	10.8	75.9	15 (15) [a]	9.9	77.0
Textiles and leather	5 (4) [a]	2.4	78.3	3 (3) [a]	2.0	78.9
Paper products	3 (3) [a]	1.4	79.7	8 (8) [a]	5.3	84.2
Machinery and equipment	23 (17) [a]	10.8	90.6	10 (9) [a]	6.6	90.8
Basic metal products	5 (3) [a]	2.4	92.9	3 (3) [a]	2.0	92.8
Clothing and footwear	5 (5) [a]	2.4	95.3	6 (6) [a]	3.9	96.7
Other	10 (8) [a]	4.7	100.0	5 (5) [a]	3.3	100.0
Total	212 (163)[a]			152 (142)[b]		

Note: a. Respondent number of survey 1 in the UK
b. Respondent number of survey 1 in Korea
One missing data in total sales volume in the UK
One missing data in the type of customisation in the UK (see Table 6-3)

5.2.2 Response rate

In the UK, the survey questionnaire was mailed to the respondents along with a covering letter and a return envelope with pre-paid postage. Out of 1500 questionnaires mailed to manufacturers, 225 were returned and 85 were non-deliverable due to incorrect contact information. Thus, the effective population size was reduced to 1415. After eliminating six invalid questionnaires including blank questionnaires (4) and those with answers in an unsuitable format (2), 219 usable questionnaires were obtained. Seven of the 219 usable questionnaires were discarded because of missing values. Thus, the overall response rate was almost 15%. In addition, the UK Survey 1 showed that 163 companies responded to the impact of product variety questions from the survey questionnaire, yielding a 12% overall response rate, which was considered as acceptable (Frohlich, 2002).

In Korea, two types of data collection were conducted in order to improve the response rate. Survey questionnaires and covering letters were e-mailed after each study participant had received a pre-notice e-mail stating the research objectives and requesting co-operation with the study. In addition, face-to-face survey interviews were conducted in June 2011. This increased the individual response rate and reduced the amount of missing data.

Among the 450 questionnaires sent out to manufacturers, 157 were returned and 7 were non-deliverable due to incorrect contact information. This reduced the effective population size to 443. Two questionnaires were blank and one had responses in an unsuitable format, which ultimately resulted in 154 usable questionnaires. Two of the 154 usable questionnaires were discarded because data were missing. There were ultimately 152 questionnaires including the face-to-face surveys; the overall response rate was almost 34%. In addition, 142 companies responded to the Survey 1 questions, which was 32% response rate.

The overall response rate for the UK and Korea was 19.6%, which is reasonably high compared to similar studies in operations management. According to Frohlich (2002), the highest rate of response to surveys in the field of operations management performed from 1989 to 2000 was 15-23%. Table 5-2 shows the details of the response rate in the UK and Korea.

Table 5-2 Response rate

		UK	Korea
Number distributed	(1)	1500	450
Returned	(2)	225	157 (116+41)c
Non-deliverable (Wrong address)	(3)	85	7
Effective population	(4)=(1)-(3)	1415	443
Blank questionnaire	(5)	4	2
Answer in unsuitable format	(6)	2	1
Usable response	(7)=(2)-(5)-(6)	219	154
Discard for too many missing data point	(8)	7	2
Effective questionnaire	(9)=(7)-(8)	212 / (163)a	152 (111+41)c / (142)d
Response rate	(10)=(9)/(4)	15% / (12%)b	34% (32%)e

Note: a. Effective questionnaire of survey 1 in the UK
b. Response rate of survey 1 in the UK
c. E-mail survey (116) + Face to face interview (41)
d. Effective questionnaire of survey 1 in Korea
e. Response rate of survey 1 in Korea

5.3 DATA SCREENING

5.3.1. Normality

Normality, as one of the essential assumptions in multivariate analysis (Raykov and Marcoulides, 2008), is related to the distribution form of the collected data. Following the procedure suggested by Pallant (2007), the Kolmogorov-Smirnov test was conducted to address the normality of the score distribution in the survey sample. The Kolmogorov–Smirnov (KS) test is a nonparametric test for the equality of continuous, one-dimensional probability distributions that can be used to compare a sample with a reference probability distribution (Pallant, 2007). The Kolmogorov-Smirnov test showed that the significant values for research variables were 0.000, which suggested violation of the assumption of normality.

However, according to Pallant (2007) and Hair et al. (2010), this is quite common in large samples (364 samples here). In large samples, the normality assumption is ideally tested by using the univariate normality approach (Hair et al., 2010). According to this procedure, the normality test was conducted for each variable by employing the “normal probability-probability” plot. The univariate normality assumption for each variable was supported, because none of the variables diverged considerably from the normal distribution. Examples of the “normal probability-probability” plots are presented in Figures 5-1, 5-2, and 5-3 for three items associated with the variety control strategy construct. Furthermore, all variables had no skewness values falling outside the range of -1 to +1 that indicate a substantially skewed distribution (Hair et al., 2010).

Figure 5-1 Univariate normality plot (VCS 1)

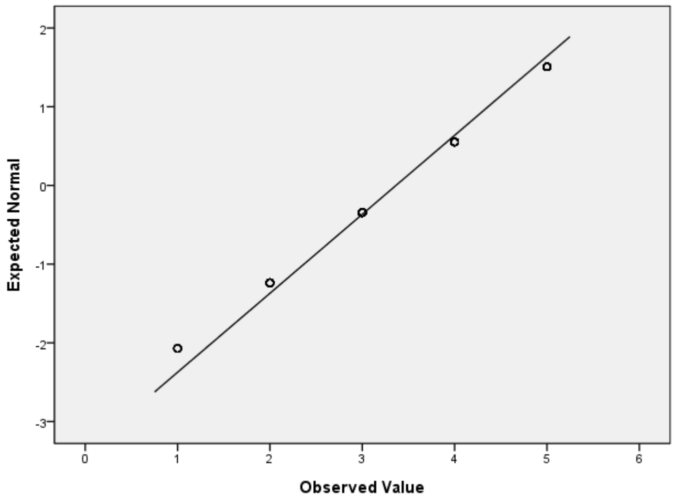


Figure 5-2 Univariate normality plot (VCS 2)

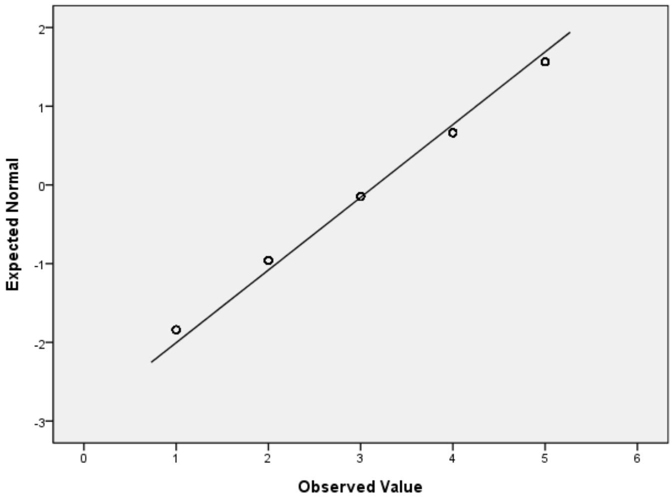
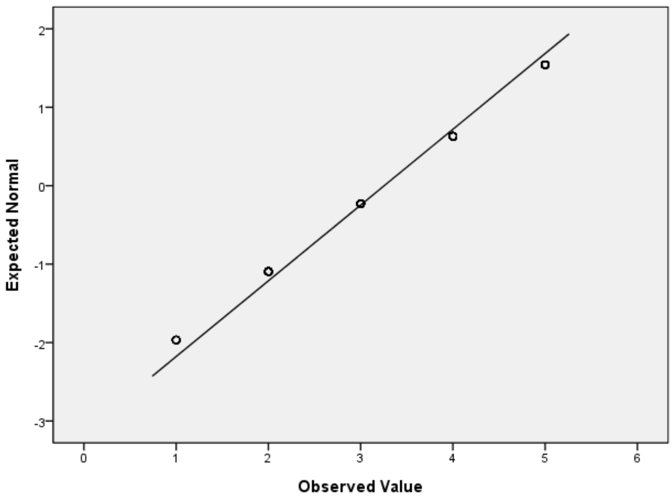


Figure 5-3 Univariate normality plot (VCS 3)



5.3.2. Missing data

Empirical research studies are rarely able to obtain a complete dataset from every case (Pallant, 2007). According to Schafer and Olsen (1998), there are important explanations for the frequency of missing values: (1) the sensitive nature of the questions; (2) the inability of study participants to understand the questions; (3) insufficient knowledge to answer the questions on the part of respondents. One of the main concerns in conducting empirical research is how to remedy the missing values (Unnebrink and Windeler, 2001).

Here two techniques to deal with missing values were considered. First, for the SEM analysis in Section 5.5 (i.e. performing CFA, SEM via AMOS 18), the maximum likelihood estimation (MLE) was employed. MLE can be established using structural equation model (SEM) software packages (e.g., AMOS, LISREL) and tend to be more powerful than traditional data techniques because no data are "thrown out" (Baraldi and Enders, 2010). In this approach, missing values are not imputed, but all observed information is used to produce the maximum likelihood estimation. According to Baraldi and Enders (2010), *"Maximum likelihood estimation identifies the population parameter values that have the highest probability of producing the sample data. This estimation process uses a mathematical function called a log likelihood to quantify the standardized distance between the observed data points and the parameters of interest (e.g., the mean), and the goal is to identify parameter estimates that minimize these distances."*

Second, regarding the analysis in Sections 5.4 and 5.6 (i.e. performing ANOVA, t-tests and correlation via SPSS 19), the "pair-wise exclusion" method was employed to compensate for the missing data. This approach was possible because of the minimal amount of missing data, which did not affect the study results due to the large sample size. This method "*excludes the case (person) only if they are missing the data required for the specific analysis. They will still be included in any of the analysis for which they have the necessary information*" (Pallant, 2007, p. 57). A pair-wise approach is suitable for simple analysis and can maximise the use of valid data without replacing values (McKnight et al., 2007).

5.3.3. Common method, non-response and late response bias

The existence of common method bias significantly challenges the validity of findings in behavioural research. This bias results from common method variance (CMV), which refers to the amount of spurious covariance shared among variables (Podsakoff et al., 2003). To test for the potential existence of a common method bias with regard to statistical remedies after conducting the survey, the study used Harman's one-factor test (Podsakoff et al., 2003) for the proposed model. Common method variance (CMV) is a major concern if a single factor accounts for most of the total variance. A principal components factor analysis was conducted on all measurement items in this research, which resulted in the extraction of 10 factors with eigenvalues above 1 (which accounted for 66.1% of the total variance, with the first factor accounting for 30.0%). Because no single factor was apparent in the unrotated factor structure, common method bias was not an issue in this research.

Non-response bias is argued to be a significant source of error in survey-based research (Dillman, 2007). Non-response bias occurs when those who participated in the survey differ significantly from those who did not (e.g. unit non-response, item non-response), mainly in terms of key characteristics of interest to the study. This study followed a simple method suggested by Gerbing and Anderson (1988) to check the existence of non-response bias in the research. The study sample was investigated to determine whether non-respondent firms differed significantly from the responding firms in terms of key firm characteristics (e.g., sales and the number of employees). The comparison revealed no statistical differences, so non-response bias was absent.

To estimate the likelihood of a late response bias, the procedure suggested by Armstrong and Overton (1977) was conducted. Participants were divided into two groups: early responders and late responders. Early responders were those responding on the basis of the first three months. In contrast, late responders were those firms that responded after the first three months. The t-tests showed that there was no significant difference at the 0.05 level between early and late respondents with regard to specific survey structures including variety control strategies and supply chain performance.

5.4. THE IMPACT OF INCREASING PRODUCT VARIETY ON BUSINESS FUNCTION PERFORMANCE (*SURVEY 1*)

5.4.1 Item and scale development

Both the cost and non-cost-related aspects of a business function performance can be considered. Cost-related items include R&D costs, the unit cost of the product, engineering design/change cost, manufacturing costs, set-up costs, direct labour costs, material costs, overhead costs, process technology investment costs, purchasing costs, inventory costs, material handling costs, market mediation costs, transportation costs and retailers' costs. Non-cost-related performance can be either positive or negative. A positive performance involves competitive advantage, customer satisfaction, market share, manufacturing flexibility, the utilisation of standardised parts, postponement, and/or outsourcing. A negative performance involves demand forecast uncertainty, scheduling complexity, design complexity, manufacturing complexity, part variety, supervision efforts, total quality control, manufacturing lead time, process variety, work-in-process inventory, finished goods inventory, purchased component/part variety, purchased part inventory, delivery time, and/or order processing.

Regarding scale development, respondents were asked to "If you have had recent increases in your product variety please indicate the impact of product variety on each of the following" using a 1-10 scale (from 0 to above 46%), on which 1 indicated the lowest increase and 10 the highest increase. As proposed by Matell and Jacoby (1972), the purpose of this scale is to allow respondents to express a specific choice rather than choose intermediate positions on a scale.

5.4.2. Product variety according to the level of customisation

To test H1-1, one-way analysis of variance (ANOVA) was conducted for the three dimensions of variety (fundamental, intermediate and peripheral) in relation to each type of customisation (see Table 5-3). The results show significant statistical differences at the .05 and .01 levels. Typically, high-customisation types are expected to display greater product variety than low-customisation types with a general increase in variety across the pure standardisation (PS) to pure customisation (PC) continuum. Unexpectedly, tailored customisation (TC) displayed the highest level of product variety. This can be explained by the fact that PC industries do not typically use their full variety-producing capabilities. The general belief that a high level of customisation has more product variety than a low level of customisation (Silveira, 1998; Agarwal et al., 2006; Hallgren and Olhager, 2009) is rejected. Therefore, H1-1 is rejected.

Table 5-3 ANOVA analysis of variety differences according to customisation type

Variety	Mean							
	PS	SS	CS	TC	PC	Total	F	Sig
Fundamental variety	3.19	3.09	3.75	4.14	3.77	3.67	4.400**	.002
Intermediate variety	3.23	3.47	4.02	4.24	3.80	3.83	3.016*	.019
Peripheral variety	2.94	3.29	4.02	4.05	3.70	3.69	3.885**	.005

* represents significant level $p<0.05$, ** $p<0.01$

5.4.3. The impact of increasing product variety according to the level of customisation

Each function is captured from a number of individual items: 4 in the category of Engineering ($\alpha = 0.866$), 16 in Manufacturing ($\alpha = 0.952$), 3 in Purchasing ($\alpha = 0.883$), 9 in Logistics ($\alpha = 0.946$) and 5 in Marketing ($\alpha = 0.891$). The Cronbach's alpha value indicated that each structure in Survey 1 had acceptable reliability. Notably, each item was drawn from previously published research (see Table 2-5), which supports the existence of content validity. The homogeneity variance test (Levene's test) also confirmed that the ANOVA could be performed on 37 dependent variables ($p > 0.05$).

An ANOVA was undertaken once more to examine the impacts of increased product variety on the performance of the different business functions. The ANOVA results (see Table 5-4) indicate the existence of statistically significant differences among various customisation types. PS is typically impacted most by an increase in product variety, followed by SS, CS, TC and PC. Overall, 7 items showed differences according to customisation type that were significant at $p < 0.01$, and 12 items showed differences significant at $p < 0.05$. These items were as follows. In the Engineering category, the unit cost of each product was significant. Significant items in the Manufacturing category included: manufacturing cost, the utilisation of standardised parts, postponement, manufacturing flexibility, process variety, part variety, manufacturing complexity, material costs, and manufacturing lead time. With regard to Purchasing, purchasing costs and purchased components/parts were significant. In terms of Logistics, the significant items were: the inventory of work in process and delivery time. For Marketing, the significant items were: demand forecast uncertainty, customer satisfaction, market share, competitive advantage, and retailers' costs.

The degree of product variety impact is typically high in continuous-process type followed by flow-shop type and project type manufacturing environments in terms of cost, quality, delivery and flexibility (Yeh and Chu, 1991). In this thesis, the impact of increased product variety typically decrease across the PS to PC continuum for 17 business function performance. Therefore, H1-2 is partly supported. The correlations with cost-related items are displayed in Table 5-5. Table 5-6 shows the correlations for positive-performance items.

Table 5-4 ANOVA analysis of impact differences according to customisation type

Business function		Item	Customisation type PS (n=16)	SS (n=23)	CS (n=40)	TC (n=51)	PC (n=32)	Total (n=162)	F	Sig
Engineering (α=0.866)	E1	Design complexity	5.19	5.13	5.03	4.84	4.31	4.86	.476	.753
	E2	R&D cost	4.88	5.35	4.45	4.82	4.56	4.76	.430	.787
	E3	Unit cost of product	5.63	4.57	4.53	4.06	3.19	4.23	3.529**	.009
	E4	Engineering design and change cost	5.31	5.13	4.88	4.67	3.84	4.69	1.451	.220
Manufacturing (α=0.952)	M1	Total quality (control)	4.75	4.70	4.75	4.12	3.25	4.25	1.937	.107
	M2	Manufacturing cost	5.94	5.00	4.23	3.94	3.31	4.23	4.702***	.001
	M3	Utilisation of standardised parts	5.31	4.35	4.40	4.31	2.66	4.11	3.889**	.005
	M4	Differentiation postponement	4.44	4.22	4.70	3.96	2.78	3.99	3.273*	.013
	M5	Set-up cost	4.75	4.70	4.13	4.08	3.09	4.05	1.980	.100
	M6	Manufacturing flexibility	5.25	5.26	4.50	4.67	3.45	4.53	2.479*	.046
	M7	Direct labour cost	4.81	4.39	3.45	3.63	3.78	3.84	.760	.553
	M8	Process variety	4.94	4.91	4.13	4.33	3.00	4.16	3.101*	.017
	M9	Part variety	5.50	5.09	4.63	4.51	3.09	4.44	3.527**	.009
	M10	Manufacturing complexity	5.50	5.87	4.63	4.25	3.84	4.62	2.699*	.033
	M11	Supervision effort	5.06	5.30	4.60	4.31	3.47	4.43	1.924	.109
	M12	Scheduling complexity	6.13	5.52	5.48	4.67	4.34	5.07	1.813	.129
	M13	Material cost	6.06	5.09	4.58	4.14	3.28	4.40	4.256**	.003
	M14	Overhead cost	4.88	4.48	4.08	3.86	3.31	3.99	1.432	.226
	M15	Manufacturing lead time	5.25	5.22	4.48	4.00	3.13	4.24	3.359*	.011
	M16	Process technology investment cost	5.13	4.83	3.88	4.78	3.31	4.31	2.315+	.060
Purchasing (α=0.883)	P1	Purchasing cost	5.75	4.43	4.35	4.75	3.28	4.41	2.619*	.037
	P2	Order processing	4.81	3.70	3.90	3.57	2.84	3.65	1.959	.103
	P3	Purchased component / part variety	5.44	4.04	4.10	3.94	3.06	3.97	2.427*	.050
Logistics (α=0.946)	L1	Work in process inventory	5.44	4.74	4.30	3.86	3.19	4.12	2.583*	.039
	L2	Finished goods inventory	5.56	4.09	4.18	3.86	3.22	4.01	2.180+	.074
	L3	Inventory cost	5.63	4.48	4.18	4.00	3.75	4.22	1.655	.163
	L4	Purchased part inventory	5.19	4.04	4.13	3.73	3.16	3.90	2.114+	.082
	L5	Delivery time	5.81	3.87	4.25	3.45	3.19	3.89	3.588**	.008
	L6	Material handling cost	4.94	3.91	3.80	3.73	3.25	3.80	1.339	.258
	L7	Market mediation cost	4.88	3.74	3.75	3.29	2.78	3.52	2.214+	.070
	L8	Outsourcing	4.31	3.70	3.58	3.71	2.78	3.55	1.265	.286
	L9	Transportation cost	4.81	4.22	3.95	3.65	2.81	3.75	2.274+	.064
Marketing (α=0.891)	K1	Demand forecast uncertainty	6.88	6.13	5.05	4.82	4.25	5.15	3.622**	.007
	K2	Customer satisfaction	6.25	5.30	5.30	4.75	3.78	4.92	2.685*	.033
	K3	Market share	6.13	5.09	5.18	4.57	3.78	4.79	2.666*	.034
	K4	Competitive advantage	6.38	6.00	5.70	5.10	4.13	5.31	3.208*	.015
	K5	Retailers' cost	5.25	4.87	4.03	3.86	3.19	4.05	2.695*	.033

+ represents significant level $p<0.1$, * represents significant level $p< 0.05$, ** $p<0.01$, *** $p<0.001$

Table 5-5 Correlation among cost-related performance items

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	R&D cost	1														
2	Unit cost of product	.563*	1													
3	Engineering design and change cost	.669*	.624*	1												
4	Manufacturing cost	.545*	.762*	.624*	1											
5	Set-up cost	.481*	.547*	.544*	.601*	1										
6	Direct labour cost	.367*	.344*	.347*	.421*	.381*	1									
7	Material cost	.422*	.566*	.529*	.622*	.496*	.393*	1								
8	Overhead cost	.437*	.621*	.558*	.671*	.573*	.466*	.590*	1							
9	Process technology investment cost	.586*	.553*	.537*	.589*	.577*	.318*	.570*	.553*	1						
10	Purchasing cost	.452*	.526*	.501*	.546*	.421*	.276*	.725*	.468*	.500*	1					
11	Inventory cost	.447*	.597*	.511*	.547*	.464*	.283*	.629*	.523*	.499*	.625*	1				
12	Material handling cost	.500*	.611*	.634*	.642*	.500*	.416*	.619*	.626*	.636*	.597*	.763*	1			
13	Market mediation cost	.412*	.587*	.559*	.606*	.512*	.381*	.599*	.616*	.599*	.582*	.633*	.788*	1		
14	Transportation cost	.348*	.423*	.415*	.455*	.373*	.270*	.553*	.528*	.507*	.536*	.585*	.634*	.628*	1	
15	Retailers' cost	.383*	.522*	.418*	.544*	.317*	.313*	.528*	.488*	.392*	.607*	.608*	.548*	.504*	.488*	1

* represents significant level p<0.01

Table 5-6 Correlation among positive performance items

		1	2	3	4	5	6	7
1	Utilisation of standardised parts	1						
2	Differentiation postponement	.523*	1					
3	Manufacturing flexibility	.503*	.507*	1				
4	Outsourcing	.455*	.384*	.335*	1			
5	Customer satisfaction	.500*	.397*	.535*	.452*	1		
6	Market share	.470*	.453*	.510*	.449*	.736*	1	
7	Competitive advantage	.465*	.458*	.571*	.412*	.742*	.853*	1

* represents significant level p<0.01

5.4.4. The impact of increasing product variety according to customisation / product variety combinations

Product variety (PV) and customisation (C) may vary according to a manufacturer's approach to product management. Each company's characteristics were divided into four variety-customisation categories using a K-means cluster analysis. The clusters distinguished high product variety with high customisation (PV mean centre = 4.64; C mean centre = 4.34), low product variety with high customisation (PV mean centre = 2.56; C mean centre = 4.50), high product variety with low customisation (PV mean centre = 4.67; C mean centre = 2.44), and low product variety with low customisation (PV mean centre = 2.56; C mean centre = 2.14). Then a one-way ANOVA was used to examine which measurement variables of the different business functions differed across the four clusters. Table 5-7 depicts the results of the ANOVA test.

High variety with low customisation (HVLC) and low variety with low customisation (LVLC) typically exhibited the strongest negative impact on business function performance with an increase in product variety. This cluster was followed by high variety with high customisation (HVHC) or low variety with high customisation (LVHC). In total, 2 items ($p < 0.01$) and 5 items ($p < 0.05$) out of the 37 differed in terms of the combination of incumbent product variety and customisation. Manufacturing cost, manufacturing complexity, material costs, and manufacturing lead time were the items that differed in the Manufacturing category. Transportation cost was the only item that varied in the Logistics category. Demand forecast uncertainty and retailers' cost were the items that differed in the Marketing category; hence, H1-3, '*An increase in product variety impacts business function performance differently depending on the combination of the degree of customisation and the product variety offered'* is partly supported. The mean values across the four clusters indicate that low-customisation clusters are more affected by an increase in product variety than high-customisation clusters.

Moreover, in the case of a low level of customisation, the results indicate that a company with a high level of existing product variety is typically more affected by an increase in product variety than a company with a low level of variety. A detailed analysis of each item is discussed in the Discussion section (Chapter 7).

Table 5-7 ANOVA analysis of impact differences according to customisation-variety combination

Business function	Item	Variety-Customization category HVHC (n=61)	LVHC (n=22)	HVLC (n=43)	LVLC (n=36)	Total (162)	F	Sig
Engineering	Design complexity	4.69	4.50	5.47	4.64	4.86	.306	.821
	R&D cost	4.66	4.91	5.12	4.42	4.76	.532	.661
	Unit cost of product	3.51	4.32	5.02	4.44	4.23	2.000	.116
	Engineering design and change cost	4.33	4.41	5.37	4.64	4.69	1.138	.336
Manufacturing	Total quality (control)	3.72	3.95	4.95	4.47	4.25	1.080	.360
	Manufacturing cost	3.62	3.91	5.05	4.50	4.23	4.978**	.003
	Utilisation of standardised parts	3.70	3.59	4.88	4.19	4.11	1.071	.363
	Differentiation postponement	3.39	3.82	4.53	4.47	3.99	1.038	.377
	Set-up cost	3.80	3.41	4.67	4.11	4.05	1.852	.140
	Manufacturing flexibility	4.23	4.14	5.35	4.31	4.53	2.529+	.059
	Direct labour cost	3.33	4.68	4.35	3.58	3.84	.981	.403
	Process variety	3.66	4.27	4.56	4.47	4.16	2.035	.111
	Part variety	3.89	4.18	5.26	4.56	4.44	2.044	.110
	Manufacturing complexity	4.02	4.32	5.14	5.19	4.62	3.675*	.014
	Supervision effort	3.79	4.55	5.00	4.78	4.43	2.027	.112
	Scheduling complexity	4.36	5.05	5.67	5.56	5.07	1.822	.145
	Material cost	3.90	3.55	5.05	5.00	4.40	3.418*	.019
	Overhead cost	3.79	3.27	4.51	4.17	3.99	2.075	.106
	Manufacturing lead time	3.77	3.36	5.12	4.53	4.24	3.067*	.030
	Process technology investment cost	4.46	3.55	4.63	4.14	4.31	2.238+	.086
Purchasing	Purchasing cost	4.28	3.91	4.91	4.36	4.41	1.316	.271
	Order processing	3.38	3.05	4.19	3.83	3.65	1.403	.244
	Purchased component / part variety	3.59	3.64	4.47	4.22	3.97	1.387	.249
Logistics	Work in process inventory	3.49	3.91	4.70	4.61	4.12	2.370+	.073
	Finished goods inventory	3.59	3.68	4.37	4.50	4.01	1.286	.281
	Inventory cost	3.87	4.00	4.56	4.56	4.22	1.766	.156
	Purchased part inventory	3.48	3.59	4.37	4.25	3.90	1.442	.233
	Delivery time	3.20	3.77	4.63	4.25	3.89	2.090	.104
	Material handling cost	3.46	3.77	4.51	3.53	3.80	1.452	.230
	Market mediation cost	3.08	3.14	4.28	3.61	3.52	1.795	.151
	Outsourcing	3.38	3.27	3.79	3.72	3.55	1.110	.347
	Transportation cost	3.23	3.59	4.63	3.69	3.75	3.563*	.016
Marketing	Demand forecast uncertainty	4.64	4.50	5.74	5.72	5.15	5.192**	.002
	Customer satisfaction	4.39	4.32	5.58	5.39	4.92	1.516	.213
	Market share	4.38	3.95	5.37	5.31	4.79	1.357	.258
	Competitive advantage	4.85	4.36	5.93	5.92	5.31	1.822	.145
	Retailers' cost	3.61	3.59	4.67	4.33	4.05	2.810*	.041

+ represents significant level p<0.1, * represents significant level p< 0.05, ** p<0.01.

5.5. SUPPLY CHAIN DESIGN TO SUPPORT THE MANAGEMENT OF PRODUCT VARIETY INCREASES (*SURVEY 2*)

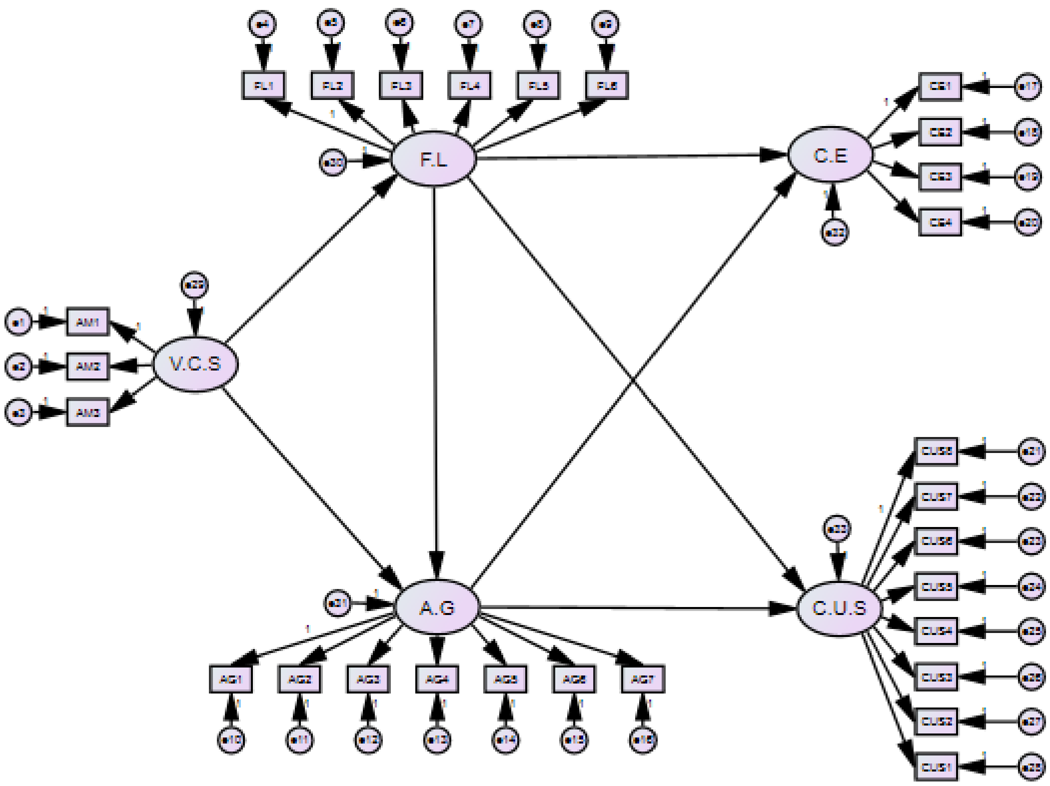
5.5.1 Measurement scale

One aspect of Survey 2 asked how companies perform variety management and control. A variety control strategy represents the policies and activities a company employs to manage and control product variety. Typically there are three types of approach: modularisation (i.e. a product-based strategy), postponement (i.e. a structure-based strategy) and cellular manufacturing (i.e. a process-based strategy). Respondents were asked to "indicate company's level of agreement" using a five-point Likert scale (1 = strongly disagree and 5 = strongly agree). The questions on supply chain flexibility involved measures representing flexibility within each individual supply chain function, including six variables (see Table 5-2) asking respondents to "indicate how well your company and/or its supply chain perform" in each activity using a five-point Likert scale (1 = poor and 5 = excellent). Supply chain agility represents the speed with which a company's internal supply chain can respond to customer expectations (Swafford et al., 2008) and included seven observed variables (see Table 5-2). Respondents were asked to "indicate how well your company and/or its supply chain performs" in terms of responding rapidly using a five-point Likert scale (1 = poor and 5 = excellent). Regarding cost efficiency and customer service, respondents were asked to "indicate how well a company's supply chain performs" using a five-point Likert scale (1 = poor and 5 = excellent). Then, respondent data were divided using cluster analysis into two levels of customisation: low customisation and high customisation.

5.5.2. Model design

In order to manage the negative effect of a variety increase, the study designed a model to investigate the relationships between a variety control strategy and supply chain performance. Figure 5-4 presents the SEM model drawn using Amos 18.0 software. Based on the research framework and hypotheses presented in Chapter 3, a path analysis was designed among certain structures. The measurement validation procedure has two steps. First, the confirmatory factor analysis (CFA) tests reliability and validity. Second, a structural equation model (SEM) was conducted to test hypotheses at each customisation level.

Figure 5-4 SEM model by AMOS



5.5.3. Confirmatory factor analysis (CFA)

The CFA model allows researchers to verify the model's constructs and to identify potential interrelations among the variables. In this study, the CFA model was run to:

- purify the measurements of the constructs (diagnose potential problems with the measurements)
- test construct reliability
- assess construct validity (calculate convergent and discriminant validity)
- ensure that there are no cross-loadings or uncorrelated errors

Using this CFA procedure the theoretical measurement model can achieve reliability and validity, which yields acceptable model fit indices (e.g. GFI and RMSEA). Through this procedure, CFA supplies some diagnostic information that may offer a route to improve fit indices and modify a study's measurement theory. Therefore, to improve these indices, the study applied the diagnostic approach (e.g. path estimates, standardised residuals, modification indices, and specification search) suggested by Hair et al. (2010).

5.5.3.1. Path estimate

According to Hair et al. (2010), one of the easiest ways to recognise a potential problem with a measurement theory is to compare estimated loadings. According to this method, any value associated with loading <0.5 should be removed from the model. In other words, loading should be at least 0.5 and, ideally, 0.7 or higher. Therefore, items loading less than 0.7 on their respective constructs were excluded to obtain good model fit indices in the CFA.

Firstly, all of the observed variables were entered into the CFA model. As can be seen in Table 5.1, the loading estimates for the following items were less than the ideal cut-off point (0.7): FL2 (0.676), FL5 (0.618), CE4 (0.626), CUS5 (0.644), CUS6 (0.587) and CUS8

(0.608). The fit indices for the first model were: GFI = 0.867, CFI = 0.910, RMSEA = 0.060, and SRMR = 0.052. Item measures with insignificant factor loadings were removed from the scale, since content validity was not sacrificed (Swafford et al., 2006). Though FL2 and FL5 are deleted, the supply chain flexibility construct includes measures related to purchasing, manufacturing and distribution. Similarly, the cost efficiency construct covers an ability to minimise a cost in terms of purchasing, manufacturing and distribution without CE4. In the customer service structure CUS5 is related with CUS3, CUS6 with CUS7, and CUS8 with CUS1. Therefore, using the results from purified constructs would not influence content validity and provide more accurate insights for current and future research. In addition, the aforementioned observed variables were eliminated from the CFA model to improve the fit indices. Table 5-8 presents the original model's indicators, as well as their codes and loadings.

After removing the items with disqualified loadings, the confirmatory factor model was re-tested. As predicted, the purification method improved the fit indices significantly. The measurement model offered an acceptable fit to the data (GFI = 0.907, CFI = 0.942, SRMR = 0.042, RMSEA = 0.055). Table 5-9 presents the model's indicators, as well as the codes and loadings obtained after performing the purification process.

Table 5-8 Original model: constructs, items, and related loading values

Structure	Variable (Item)	Code	Factor loading
Variety control strategy (VCS)	Modular production at the assembly stage	VCS1	0.736
	Delaying the process that transforms the form and function of products until customer orders have been received (Postponement)	VCS2	0.725
	Cellular manufacturing which groups parts with similar design and processes	VCS3	0.788
Supply chain flexibility (FL)	Ability to change quantity of suppliers' orders	FL1	0.720
	Ability to change delivery times of orders placed with suppliers	FL2*	0.676
	Ability to change production volume	FL3	0.813
	Ability to accommodate changes in production mix	FL4	0.771
	Ability to implement engineering change orders in production	FL5*	0.618
	Ability to alter delivery schedules to meet changing customer requirements	FL6	0.720
Supply chain agility (AG)	Ability to rapidly reduce product development cycle time	AG1	0.710
	Ability to rapidly reduce manufacturing lead time	AG2	0.775
	Ability to rapidly increase the level of product customisation	AG3	0.729
	Ability to rapidly improve level of customer service	AG4	0.703
	Ability to rapidly improve delivery reliability	AG5	0.747
	Ability to rapidly improve responsiveness to changing market needs	AG6	0.754
	Ability to rapidly reduce delivery lead time	AG7	0.763
Cost efficiency (CE)	Ability to minimise total cost of resources used	CE1	0.751
	Ability to minimise total cost of distribution (including transportation and handling costs)	CE2	0.710
	Ability to minimise total cost of manufacturing (including labour, maintenance, and re-work costs)	CE3	0.729
	Ability to minimise total cost related with held inventory	CE4*	0.626
Customer service (CUS)	Order fill rate	CUS1	0.726
	On-time delivery	CUS2	0.774
	Customer response time	CUS3	0.766
	Quality	CUS4	0.703
	Manufacturing lead time	CUS5*	0.644
	Customer complaints reduction	CUS6*	0.587
	Customer satisfaction	CUS7	0.740
	Stock-out reduction	CUS8*	0.608

Note: Fit indices: GFI=0.867, SRMR=0.052, RMSEA=0.060, CFI=0.910
* Deleted item

Table 5-9 Modified model: constructs, items, and related loading values

Structure	Variable	Code	Factor loading
Variety control strategy (VCS)	Modular production at the assembly stage	VCS1	0.736
	Delaying the process that transforms the form and function of products until customer orders have been received (Postponement)	VCS2	0.724
	Cellular manufacturing which groups parts with similar design and processes	VCS3	0.789
Supply chain flexibility (FL)	Ability to change quantity of suppliers' orders	FL1	0.696
	Ability to change production volume	FL3	0.819
	Ability to accommodate changes in production mix	FL4	0.797
	Ability to alter delivery schedules to meet changing customer requirements	FL6	0.722
Supply chain agility (AG)	Ability to rapidly reduce product development cycle time	AG1	0.709
	Ability to rapidly reduce manufacturing lead time	AG2	0.775
	Ability to rapidly increase the level of product customisation	AG3	0.727
	Ability to rapidly improve level of customer service	AG4	0.704
	Ability to rapidly improve delivery reliability	AG5	0.748
	Ability to rapidly improve responsiveness to changing market needs	AG6	0.754
	Ability to rapidly reduce delivery lead time	AG7	0.764
Cost efficiency (CE)	Ability to minimise total cost of resources used	CE1	0.768
	Ability to minimise total cost of distribution (including transportation and handling costs)	CE2	0.730
	Ability to minimise total cost of manufacturing (including labour, maintenance, and re-work costs)	CE3	0.704
Customer service (CUS)	Order fill rate	CUS1	0.743
	On-time delivery	CUS2	0.810
	Customer response time	CUS3	0.782
	Quality	CUS4	0.697
	Customer satisfaction	CUS7	0.719

Note: Fit indices: $\chi^2/df = 421.326 / 199 = 2.117$, GFI=0.907, SRMR=0.042, RMSEA=0.055, CFI=0.942

5.5.3.2. Standardised residuals and modification indices

Standardised residual and modification index techniques can be employed to further evaluate the measurement model. According to Hair et al. (2010), while standard residuals less than 2.5 do not cause any problem, values higher than 4.0 lead to unacceptable degrees of error. Modification indices can also help researchers to amend the study measurement model. Generally, modification indices of approximately 4 or higher indicate that the fit could be improved considerably by freeing the corresponding path (Hair et al., 2010) . Since the good model fit indices resulted from the first purification step, standardised residuals and modification indices approaches were not necessary in this study.

5.5.4. Model fit evaluation

According to Hair et al. (2010), the combination of goodness-of fit and badness-of-fit indices, in addition to chi-square values and the degrees of freedom, can be used to determine whether the research measurement model has good fit. Therefore, sufficient information for assessment of the measurement model can be obtained by analysing: a) the $\chi2$ value and the degrees of freedom (df), b) the GFI and CFI (representative of goodness-of-fit indices), and c) the RMSEA and SRMR (representative of badness-of-fit indices) (Hair et al., 2010). This research considered five model-fit indices.

First, the ratio of $\chi2$ to df is also commonly used to further evaluate the model (Hair et al., 2010). The CFA model yielded $\chi2$ value of 421.326 (p-value = 0.00) with 199 df. Considering the CFA research model, the ratio of $\chi2$ to df is acceptable ($\frac{\chi^2}{df}$ = 2.117) since it was less than the cut-off of 3.0 suggested by Hu and Bentler (1999).

Second, in terms of goodness-of-fit indices, GFI and CFI are considered as the most general indices in the CFA and SEM model. Generally, fit indices are above the cut-off point of 0.9 (Hair et al., 2010). After conducting a purifying procedure, both indices were above 0.9 (GFI = 0.907, CFI = 0.942). RMSEA and SRMR are considered as badness-of-fit indices in this research. As suggested by Hair et al. (2010), RMSEA and SRMR should be lower than 0.08. The CFA model output indicated acceptable RMSEA and SRMR values lower than the cut-off point (0.055 and 0.042, respectively).

5.5.5. Reliability and construct validity

Several approaches can be employed in order to assess the reliability and validity of a model; these typically involve measurement accuracy. In this study, convergent validity and discriminant validity (suggested by Hair et al., 2010) were employed to assess the construct's validity. Composite reliability (CR) was used to verify the reliability of the construct. As a result, the associated statistical analysis revealed strong evidence of reliability, discriminant and convergent validity.

5.5.5.1. Composite reliability

Reliability, representing the degree of stability (consistency) of a construct (O'Leary-Kelly and Vokurka, 1998), is measured by using Cronbach's alpha or a composite reliability (CR) score. A CR (or construct reliability) indicator should be 0.7 or higher if the study model is reliable (Bagozzi et al., 1991). Following CRs can be calculated according to the formula suggested by Bagozzi et al. (1991) as follows:

$$CR = \frac{(\sum_{i=1}^{n} \lambda_i)^2}{(\sum_{i=1}^{n} \lambda_i)^2 + \sum_{i=1}^{n} \delta_i}$$

(The λ indicates the standardised factor loadings. δ depicts the error variance terms for a construct and i represents the number of items.)

Using this formula, CR was calculated for the variety control strategy as follows:

CR = $(0.736+ 0.724 + 0.789)^2$ / $[(0.736+ 0.724 + 0.789)^2 + (0.453+0.556+0.404)]$ = 0.781641 (0.782)

As a result, each of the three criteria for CR were satisfied by the variety control strategy construct (CR >0.7).

Then CRs for all five constructs were investigated. As a result, CRs were 0.782 for variety control strategy, 0.870 for supply chain flexibility, 0.906 for supply chain agility, 0.851 for cost efficiency and 0.914 for customer service. Accordingly, all results for all criteria address the requirements of composite reliability for each construct including VCS, FL, AG, CE and CUS. That is, composite reliability (CR) showed acceptable internal consistency for the proposed model (CRs>0.782).

5.5.5.2. Convergent validity

The construct's items should cover or share a high proportion of variance in common, which is known as convergent validity (Hair et al., 2010). Convergent validity is commonly assessed using factor loading and average variance extracted (AVE). First, the standardised loading estimates for all items in the model should exceed the cut-off point of 0.5 and, ideally, 0.7. Second, the average variance extracted (AVE) should be equal to or more than 0.5, in order to achieve sufficient convergence. Following the formula suggested by Bagozzi et al. (1991) AVEs can be calculated as follows:

$$AVE = \frac{\sum_{i=1}^{n} \lambda_i^2}{\sum_{i=1}^{n} \lambda_i^2 + \sum_{i=1}^{n} \delta_i}$$

(The λ symbolises the standardised factor loadings. δ depicts the error variance terms for a construct and i presents the number of items.)

The AVE for variety control strategies was calculated as follows:

AVE = $0.736^2 + 0.724^2 + 0.789^2$ / [($0.736^2 + 0.724^2 + 0.789^2$) + (0.453+0.556+0.404)] = 0.544398 (0.544)

As a result, each of the three criteria for convergent validity are satisfied by the variety control strategy construct (AVE >0.5).

Using this formula, the convergent validity for each of the five constructs was calculated. The AVEs were 0.544 for variety control strategy, 0.627 for supply chain flexibility, 0.579 for supply chain agility, 0.656 for cost efficiency and 0.682 for customer service. Thus the minimum level (0.5) for AVE (Bagozzi et al., 1991; Hair et al., 2010) was exceeded by all constructs in the model (from 0.544 to 0.682). Also, all item loadings were above 0.7 and significant at the 0.01 level, which indicated convergent validity (Bagozzi et al., 1991; Hair et al., 2010). That is, convergent validity exists because all item factor loadings were greater than 0.7 with acceptable AVEs. Table 5-10 presents the factor loadings, error variance terms, CRs and AVEs along with fit indices.

Table 5-10 Confirmative factor analysis for reliability and validity

Structure	Code	Factor loading (λ)	Error variance(δ)	CR	AVE
Variety control strategy (VCS)	VCS1	0.736	0.453	0.782	0.544
	VCS2	0.724	0.556		
	VCS3	0.789	0.404		
Supply chain flexibility (FL)	FL1	0.696	0.405	0.870	0.627
	FL3	0.819	0.263		
	FL4	0.797	0.317		
	FL6	0.722	0.393		
Supply chain agility (AG)	AG1	0.709	0.502	0.906	0.579
	AG2	0.775	0.394		
	AG3	0.727	0.464		
	AG4	0.704	0.400		
	AG5	0.748	0.348		
	AG6	0.754	0.335		
	AG7	0.764	0.352		
Cost efficiency (CE)	CE1	0.768	0.237	0.851	0.656
	CE2	0.730	0.303		
	CE3	0.704	0.308		
Customer service (CUS)	CS1	0.743	0.288	0.914	0.682
	CS2	0.810	0.245		
	CS3	0.782	0.234		
	CS4	0.697	0.322		
	CS7	0.719	0.229		

Note: Fit indices: χ^2/df = 421.326 /199 =, GFI=0.907, SRMR=0.042, RMSEA=0.055, CFI=0.94

5.5.5.3. Discriminant validity

Discriminant validity is the "*the extent to which a construct is truly distant from other variables*" (Hair et al., 2010, p. 778). Discriminant validity was established using the procedures outlined by Fornell and Larcker (1981). This method is based on a comparison between the AVE and the square of the correlation estimate of any other constructs in the model. The AVE should always be higher than the squared inter-construct correlation estimates (SIC).

This research revealed no case for which the square of the correlation between constructs was greater than the AVE of the constructs. For example, the highest squared value of correlation between flexibility and agility (0.701×0.701 = 0.491) was not higher than the AVE (0.627) of flexibility. Hence, discriminant validity was not problematic in this study. Table 5-11 illustrates correlations between the latent variables and AVEs of each construct with means and standard deviations.

Table 5-11 Inter-construct correlation estimates and related AVEs

	1	2	3	4	5
1 Variety Control Strategy	0.544+				
2 Flexibility	0.501**	0.627+			
3 Agility	0.504**	0.701**	0.579+		
4 Cost Efficiency	0.217**	0.436**	0.451**	0.656+	
5 Custormer Service	0.264**	0.524**	0.514**	0.466**	0.682+
Mean	3.26	3.49	3.24	3.39	3.81
SD	0.872	0.708	0.731	0.640	0.591

+ =Average variance extracted, * = Correlation coefficients are significant at α=0.05 level, ** = Correlation coefficients are significant at α=0.01 level

5.5.6. Model analysis

The first step in evaluating the SEM model results was to determine how well the data fit the model based on multiple fit indices including the RMSEA, SRMR, GFI and CFI. The next step considered the statistical significance of the coefficients on the paths in the model. The model was used to investigate hypotheses 2-1 to 2-7 using the entire dataset. The same model with the same path links was then tested according to levels of customisation in order to test hypothesis 2-8. Therefore, K-mean cluster analysis was conducted according to the level of customisation. The mean centre for the low-customisation group was 2.15 (n = 207); the mean centre for the high-customisation group was 4.43 (n = 156).

5.5.6.1. Total sum model

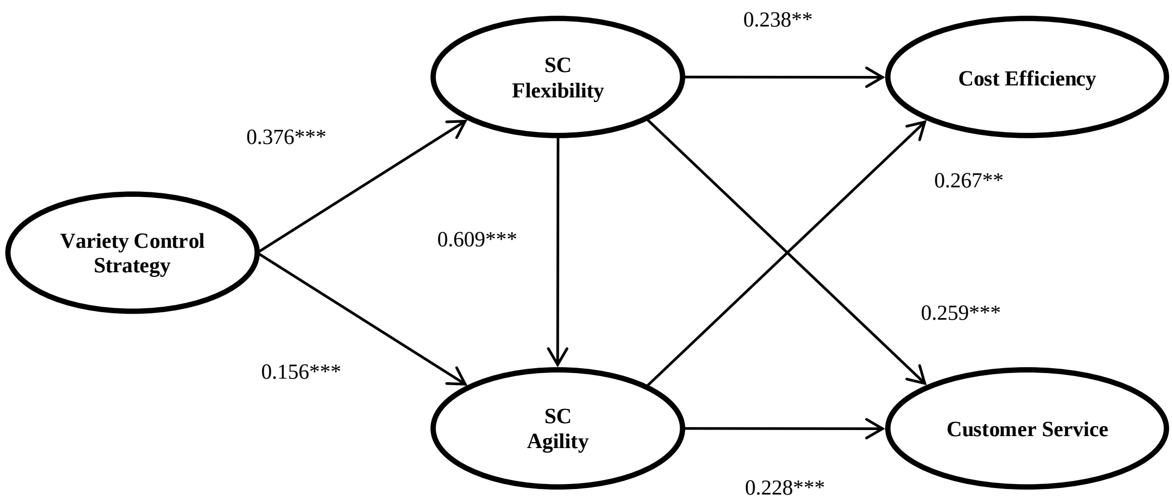
The total model exhibited an acceptable model fit, and the paths demonstrated higher t-values with acceptable p-values. According to multiple fit indices, the data fit the proposed model. That is, GFI (0.904), CFI (0.939), RMSEA (0.057) and SRMR (0.051) exhibited acceptable fit in the model. The coefficient on the path between variety control strategy and supply chain flexibility had a value of 0.376 at the 0.001 significance level. The result supported the hypothesis H2-1 that variety control strategy improves supply chain flexibility (see Yeh and Chu, 1999; Van Hoek, 1999; Salvador et al., 2004; Nair, 2005). The path coefficient between variety control strategy and supply chain agility had a value of 0.156 at the 0.001 level of statistical significance, which supported hypothesis H2-2 that variety control strategy improves supply chain agility (see Yeh and Chu, 1991; Davila and Wouters, 2007; Jacobs et al., 2011b). For the path between supply chain flexibility and agility, the coefficient was 0.609 and was significant at the 0.001 level. This result also supported hypothesis H2-3, that supply chain flexibility improves supply chain agility (Swafford et al., 2006; Agarwal et al., 2006). Coefficients on the path from supply chain flexibility to cost efficiency and from supply chain flexibility to customer service had values of 0.238 and 0.259 at the 0.01 and 0.001 levels of significance, respectively. Hence, the results also supported hypotheses H2-4 that increased supply chain flexibility improves supply chain cost efficiency (see Narasimhan and Jayaram, 1998; Graves and Tomlin, 2003 Chan, 2003) and H2-6 that increased supply chain flexibility improves supply chain customer service (see Narasimhan and Jayaram, 1998; Vickery et al., 1999; Zhang et al., 2002). Coefficients on the paths from supply chain agility to cost efficiency and from supply chain agility to customer service had values of 0.267 and 0.228 at the 0.01 and 0.001 levels, respectively, which revealed that supply chain agility improves cost efficiency (see Hiroshi and David, 1999; Hallgren and Olhager, 2009) and customer service (see Hiroshi and David, 1999; Agarwal et al., 2006; Hallgren and Olhager, 2009) (H2-5 and H2-7). Table 5-12 displays regression weight with t and p-values. Figure 5-5 represents the SEM diagram with path coefficients, levels of significance and fit indices.

Table 5-12 Result of regression weights for the overall dataset

	Hypothesis	Weight (Path Coefficient)	t-value	p-value
H2-1	Variety control strategy → SC Flexibility	.376***	7.247	.000
H2-2	Variety control strategy → SC Agility	.156***	3.303	.000
H2-3	SC Flexibility→ SC Agility	.609***	8.219	.000
H2-4	SC Flexibility → SC Cost Efficiency	.238**	2.651	.008
H2-5	SC Agility→ SC Cost Efficiency	.267**	3.056	.002
H2-6	SC Flexibility→ Customer Service	.259***	3.769	.000
H2-7	SC Agility → Customer Service	.228***	3.472	.000

* represents significant level p<0.05, ** p<0.01, *** p<0.001

Figure 5-5 Structural equation model for the overall dataset



Note: Fit indices: Ch-sq / df = 438.044/202=2.16, GFI = 0.904, SRMR = 0.051, RMSEA = 0.057, CFI = 0.939
* represents significant level p<0.05, ** p<0.01, *** p<0.001

5.5.6.2. Model for low customisation

In the low customisation cluster, the item measure had statistically significant factor loadings (>0.60) after the deletion of six item measures: FL2, FL5, CE4, CUS5, 6 and 8. Regarding fit indices, the CFA model had acceptable fit indices ($\chi^2/df = 340.658/199 = 1.71$, GFI = 0.873, CFI = 0.937, SRMR = 0.049, RMSEA = 0.059). Moreover, CFA showed acceptable CRs (>0.792) and AVEs (>0.56). In addition, each squared correlation between constructs was less than the AVE. Thus, the resulting statistics revealed strong evidence of both discriminant and convergent validity.

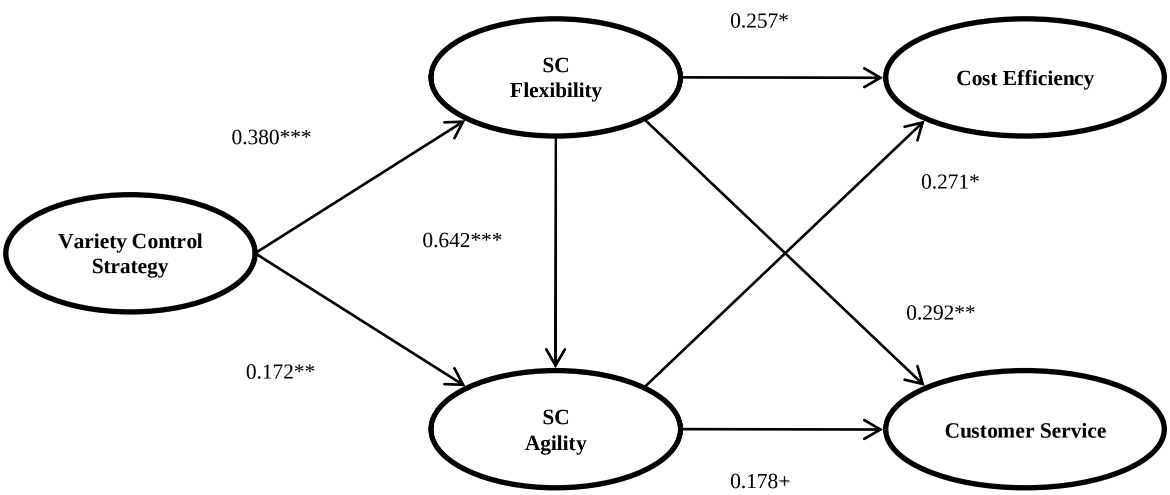
The fit of the structural equation model was examined with multiple fit indices (Ch-sq/df = 349.782/202 = 1.73, GFI = 0.870, SRMR = 0.055, RMSEA = 0.060, CFI = 0.934). Then, the significance of the coefficients on individual paths was considered statistically. Between variety control strategy and supply chain flexibility, the coefficient had a value of 0.380 at the 0.001 significance level, while the coefficient between variety control strategy and supply chain agility had a value of 0.172 ($p < 0.01$). The coefficient between supply chain flexibility and supply chain was 0.642 ($p < 0.001$). The coefficient on the path from flexibility to cost efficiency and from flexibility to customer service had values of 0.257 ($p < 0.05$) and 0.292 ($p < 0.01$), respectively. The coefficient between supply chain agility and cost efficiency had a value of 0.271 at the 0.05 significance level. In addition, supply chain agility also has a significant direct impact on customer service; however, the coefficient was relatively low (0.178) at the 0.1 level of significance (close to the 0.05 significance level). The results also indicate that supply chain flexibility and agility mediate the impact of a variety control strategy on cost efficiency and customer service. Table 5-13 displays regression weight with t and p-values. Figure 5-6 presents a diagram for the SEM with path coefficients, significance levels and fit indices.

Table 5-13 Result of regression weights for low customisation

	Hypothesis	Weight (Path Coefficient)	t-value	p-value
H2-1	Variety control strategy → SC Flexibility	.380***	5.358	.000
H2-2	Variety control strategy → SC Agility	.172**	2.827	.005
H2-3	SC Flexibility→ SC Agility	.642***	6.720	.000
H2-4	SC Flexibility → SC Cost Efficiency	.257**	2.119	.008
H2-5	SC Agility→ SC Cost Efficiency	.271*	2.341	.034
H2-6	SC Flexibility→ Customer Service	.292**	2.941	.003
H2-7	SC Agility → Customer Service	.178+	1.893	.058

+ represents significant level p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Figure 5-6 Structural equation model for low customisation



Note: Fit indices: Ch-sq/df = 349.782/202 = 1.73, GFI = 0.870, SRMR = 0.055, RMSEA = 0.060, CFI = 0.934
+ represents significant level p<0.1, * p<0.05, ** p<0.01, *** p<0.001

5.5.6.3. Model for high customisation

In the high customisation cluster, the item measures had statistically significant factor loadings (>0.60) after the deletion of six item measures: FL5, AG3, CE4, CUS4, 6 and 8. The CFA also yielded acceptable fit criteria (Ch-sq/df = 336.775/199 = 1.69, GFI = 0.842, CFI = 0.911, SRMR = 0.065, RMSEA = 0.067). In addition, CFA showed acceptable CRs (>0.745) and AVEs (>0.50). Each squared correlation between constructs was less than the AVE. Hence, the results indicate evidence of both discriminant and convergent validity.

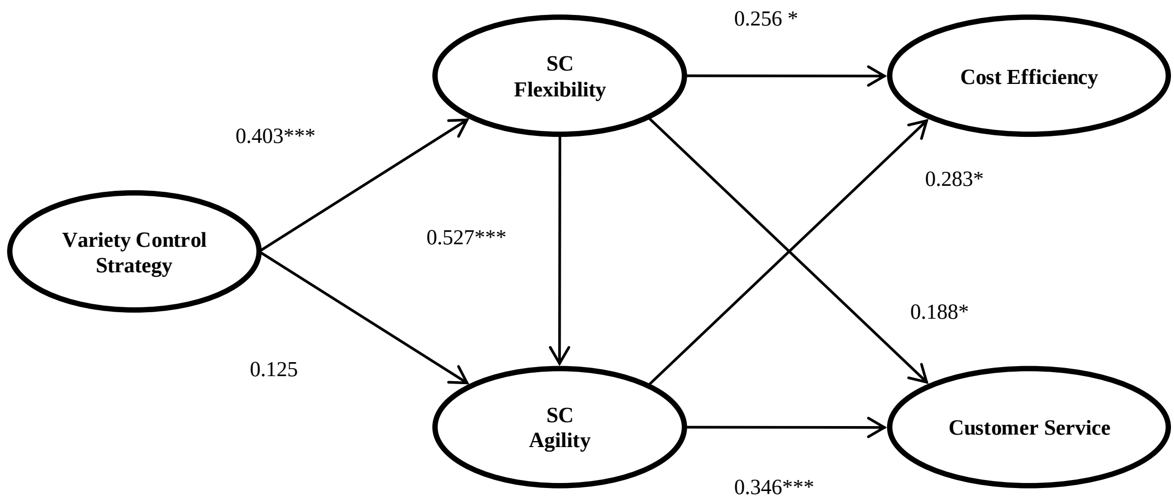
First, fit of SEM was confirmed through the use of acceptable fit indices (Ch-sq/df = 344.734/202 = 1.70, GFI = 0.840, SRMR = 0.071, RMSEA = 0.068, CFI = 0.908). Then the significance of coefficients was checked by path analysis. The coefficient between variety control strategy and supply chain flexibility had a value of 0.403 at the 0.001 significance level. Supply chain flexibility and agility showed a high coefficient value (0.572) at the 0.001 significance level. However, variety control strategy does not have a direct impact on supply chain agility ($p>0.1$). This explains that supply chain flexibility mediates the impact of a variety control strategy on supply chain agility. The coefficients on the path from supply chain flexibility to cost efficiency and from supply chain flexibility to customer service had values of 0.256 and 0.188, respectively, at the 0.05 level. The coefficients on the path from supply chain agility to cost efficiency and from supply chain agility to customer service represented values of 0.283 ($p<0.05$) and 0.346 ($p<0.001$), respectively. Furthermore, agility in a high customisation context has a stronger impact on cost efficiency (0.283>0.271) and customer service (0.346>0.178) than does agility in a low customisation context. Therefore, H2-8 was supported. Table 5-14 and Figure 5-7 display path coefficients, significance level, t values and fit indices.

Table 5-14 Result of regression weights for high customisation

	Hypothesis	Weight (Path Coefficient)	t-value	p-value
H2-1	Variety control strategy → SC Flexibility	.403***	3.830	.000
H2-2	Variety control strategy → SC Agility	.125	1.366	.172
H2-3	SC Flexibility→ SC Agility	.527***	5.049	.000
H2-4	SC Flexibility → SC Cost Efficiency	.256*	1.991	.047
H2-5	SC Agility→ SC Cost Efficiency	.283*	1.989	.047
H2-6	SC Flexibility→ Customer Service	.188*	2.200	.028
H2-7	SC Agility → Customer Service	.346***	3.470	.000

* represents significant level p<0.05, ** p<0.01, *** p<0.001

Figure 5-7 Structural equation model for high customisation



Note: Fit indices: Ch-sq / df = 344.734/ 202= 1.70, GFI = 0.840, SRMR = 0.071, RMSEA = 0.068, CFI = 0.908,
* represents significant level p<0.05, ** p<0.01, *** p<0.001

5.6. STRATEGY AND PERFORMANCE DIFFERENCES ACCORDING TO THE LEVEL OF CUSTOMISATION

Based on the cluster analysis in the proposed model, significant differences of all structures in this study according to level of customisation were investigated by employing the T-test. Therefore, exploratory factor analysis (EFA) for all variables was conducted first to test validity. The t-test and correlation analysis were performed subsequently. Table 5-15 displays a descriptive representation of the main products for each cluster.

Table 5-15 Main products for each cluster

Manufacturing industry type	Low customisation	High customisation	Total	Valid %
Food, beverage, tobacco	17	9	26	7.2
Wood and furniture	17	15	32	8.8
Chemical materials and products	21	7	28	7.7
Non-metal mineral products	8	7	15	4.1
Fabricated metal products	14	19	33	9.1
Computer and communication products	16	10	26	7.2
Electronic parts and components	21	20	41	11.3
Electrical machinery and equipment	20	19	39	10.7
Transport equipment	27	11	38	10.5
Textiles and leather	2	6	8	2.2
Paper products	9	2	11	3.0
Machinery and equipment	14	18	32	8.8
Basic metal products	5	3	8	2.2
Clothing and footwear	6	5	11	3.0
Other	10	5	15	4.1
Total	207	156	363	100%

5.6.1 Measurement scale

First, partnership with suppliers (4 items) and customer relationships (4 items) represent the extent to which a company has partnered closely with suppliers and customers to provide products and services, respectively. Respondents were asked to "indicate the company's level of agreement" using a five-point Likert scale (1 = strongly disagree and 5 = strongly agree). Second, competitive capability was investigated using two constructs: cost leadership (2 items) and differentiation (3 items). Respondents were asked to "indicate how well the company performs in each of the following compared to competitors" using a five point

Likert scale ranging from "poor" to "excellent". Last, the business performance measures included four variables: the return on sales, the return on assets, market share growth and sales growth. Respondents were asked to "indicate how well the company performs" using a five point Likert scale (1 = poor and 5 = excellent).

5.6.2. Exploratory factor analysis

Prior to the EFA, a Cronbach's alpha test was carried out to measure the internal consistency (reliability) of the scale items. The results yielded acceptable alpha values (Nunnally, 1978). As a result, all structures showed acceptable reliability (>0.793).

To compare differences in strategies and performance by employing t-test among different 10 constructs, EFA is conducted. EFA seeks to uncover the underlying structure of a relatively large set of variables (Hair et al., 2010). EFA can also be used to check construct validity (McDonald, 1981; Hattie, 1985). EFA was used here to achieve three main goals:

- To determine whether all items are loaded on their predefined 10 constructs
- To underline any potential cross-loadings in the developed constructs
- To test differences among constructs depending on level of customisation

EFA was performed for each of the 26 variables; 10 factors were extracted with eigenvalues greater than 1, and 10 structures explained 66.0% of the total variance. All of the loadings except PAS1 and FL5 were above the cut-off (Hair et al., 2010) and loaded on their expected constructs. Thus, after excluding PAS1 and FL5, the results show the items with high within-factor loading as well as low cross-factor loading, which indicates that the measures are consistent and separate. Table 5-16 presents the EFA pattern matrix for the t-test and correlation.

Table 5-16 Exploratory factor analysis

Item	Component 1 (α=0.800)	2 (α=0.793)	3 (α=0.870)	4 (α=0.838)	5 (α=0.806)	6 (α=0.795)	7 (α=0.835)	8 (α=0.835)	9 (α=0.835)	10 (α=0.835)
PAS1	.447	.446	-.076	.171	.000	.121	.181	-.136	.272	.028
PAS2	.787	.189	.086	.131	.226	.127	.102	-.097	.036	.045
PAS3	.750	.282	.122	.076	.164	.036	.191	-.006	.142	.028
PAS4	.797	-.055	.161	.065	.113	.049	.061	.186	-.047	.038
CR1	.110	.682	.073	.142	.202	.122	.170	-.139	.165	.105
CR2	.103	.737	.204	.183	.106	-.030	.213	.084	.077	.131
CR3	.076	.833	.122	.137	.080	.019	.198	.138	.070	.112
CR4	.102	.784	.046	.086	.089	.045	.195	.138	.054	.133
VCS1	.181	.115	.725	.072	.303	.202	.043	-.020	-.028	-.002
VCS2	.068	.066	.762	.197	.126	-.014	.025	-.172	.151	.119
VCS3	.103	.178	.799	.168	.148	-.024	.085	.060	.029	.086
FL1	.069	.163	.037	.723	.221	.207	.134	.033	-.032	.100
FL2	.072	.182	.036	.657	.225	.247	.114	.112	-.031	.082
FL3	.076	.082	.113	.722	.302	.121	.184	-.010	.115	.100
FL4	.103	.076	.137	.716	.227	.050	.194	-.040	.201	.048
FL5	.160	.101	.197	.461	.404	-.025	.069	.100	.154	.054
FL6	.016	.127	.180	.649	.249	.040	.170	.084	.199	.078
AG1	.101	-.027	.135	.156	.737	.046	.078	.164	.041	.094
AG2	.075	-.006	.128	.229	.714	.142	.183	.172	.057	.065
AG3	.046	.118	.176	.171	.705	.026	.167	.001	.163	.005
AG4	.086	.274	-.024	.082	.684	.119	.215	-.082	.135	.103
AG5	.108	.125	-.044	.203	.710	.102	.203	.037	.084	.076
AG6	.108	.113	.134	.197	.702	.151	.098	-.081	.154	.096
AG7	.074	.036	.166	.297	.673	.100	.145	.129	.051	.047
CE1	.095	.027	.071	.155	.133	.729	.077	.217	.019	.142
CE2	.003	.073	-.100	.124	.178	.698	.126	.151	.052	.185
CE3	.043	.010	.095	.090	.090	.764	.205	.043	.138	.099
CE4	.110	.054	.072	.126	.071	.581	.182	.195	.082	.186
CUS1	.087	.120	-.058	.174	.127	.017	.695	.275	.056	.215
CUS2	.116	.062	.020	.157	.184	.063	.762	.083	.051	.116
CUS3	.129	.129	.056	.137	.138	.039	.788	.021	-.034	.079
CUS4	.059	.181	.026	.140	.043	.228	.638	-.073	.182	.239
CUS5	.095	.105	.164	.172	.332	.186	.523	.184	.091	.042
CUS6	.037	.338	.054	.023	.169	.308	.509	-.161	-.027	.076
CUS7	.031	.186	.050	.064	.167	.231	.684	-.186	.148	.183
CUS8	.014	.181	.035	.096	.168	.076	.585	.133	.147	.100

CL 1	.088	.084	-.058	.085	.112	.378	.093	.720	.091	.041
CL 2	-.029	.083	-.073	.067	.155	.298	.096	.765	.114	.050
D 1	.067	.180	.108	.280	.187	.078	.250	.058	.678	.152
D 2	.114	.076	.146	.164	.358	.153	.096	.029	.584	.232
D 3	.028	.150	-.002	.059	.186	.110	.098	.138	.725	.127
BP 1	.099	.093	.005	.075	.092	.151	.176	.059	.112	.751
BP 2	.007	.137	.022	.094	.049	.134	.154	.030	.030	.801
BP 3	-.020	.046	.086	.033	.097	.097	.186	.062	.178	.730
BP 4	.031	.140	.095	.107	.097	.158	.132	-.047	.049	.770

5.6.3. T-test of structures according to the level of customisation

The t-test was used to investigate differences in structures associated with the level of customisation. Variety control strategies, customer relationships, flexibility, agility, cost leadership and differentiation varied significantly between low and high levels of customisation ($p < 0.05$). However, partnership with suppliers (close to 0.05 level), customer service, cost efficiency and business performance did not display significant differences across clusters at the $p < 0.05$ level.

A high level of customisation was more closely associated with customer relationships (H3: 4.130 >3.948, $p < 0.05$), with a variety control strategy (H4: 3.622>2.993, $p < 0.001$), with supply chain flexibility (H5: 3.684>3.361, $p < 0.001$), with supply chain agility (H6: 3.379>3.117, $p < 0.01$) and with differentiation (H2: 3.633>3.306, $p < 0.001$) when compared to low customisation. These results support H3-2, 3, 4, 5 and 6 ,and allow for the rejection of H3-1 that a high customisation cluster is associated with a higher level of customer service than a low customisation cluster (Agarwal etl al., 2006; Stavrulaki and Davis, 2010).

As expected, cost leadership exhibited a higher value in a low customisation context (3.428 >3.090) when compared to a high customisation context ($p < 0.001$); therefore, H3-8 is supported. Though cost efficiency had a higher value in a low customisation context than it does in a high customisation context (0.416 >0.380), the result was not significant (p >0.05); therefore, H3-7 is rejected. Interestingly, partnership was more strong in a high customisation context when compared to a low-customisation context (3.590>3.419, p <0.1). Hence, H3-9 that a low customisation cluster is associated with a stronger partnership with suppliers than a high customisation cluster (see Stavrulaki and Davis, 2010) is rejected. Table 5-17 displays the t-test results.

Table 5-17 T-test of strategies and performance across clusters of customisation

	Mean				
	LC (n = 207)	HC (n = 156)	Total (n = 363)	T	Sig
Partnership with suppliers	3.419	3.590	3.492	1.922+	.055
Customer relationships	3.948	4.130	4.026	2.276*	.023
Variety control strategy	2.993	3.622	3.264	7.247***	.000
Supply chain flexibility	3.361	3.684	3.500	4.420**	.000
Supply chain agility	3.117	3.379	3.230	3.407**	.001
Cost efficiency	3.416	3.380	3.400	-.507	.612
Customer service	3.743	3.858	3.792	1.878+	.061
Cost leadership	3.428	3.090	3.282	-4.473***	.000
Differentiation	3.306	3.633	3.446	4.314***	.000
Business Performance	3.588	3.678	3.627	1.303	.194

* represents significant level p<0.05, ** p<0.01, *** p<0.001

5.6.4. Correlation among structures

Table 5-18 and 5-19 present the construct inter-correlations. At a low level of customisation, a variety control strategy is positively and significantly (p <0.01) correlated with partnership with suppliers, customer relationships, flexibility, agility, cost efficiency, customer service, differentiation and business performance, but not with cost leadership. Cost efficiency and cost leadership are closely correlated. Business performance is correlated most tightly with customer service and differentiation.

In a high-customisation context, the variety control strategy is positively and significantly (p <0.01) correlated with partnership with suppliers, customer relationships, flexibility, agility, cost efficiency, cost leadership, differentiation and business performance, but not with customer service. Agility and differentiation are closely correlated. Business performance is most closely correlated with close customer relationships and differentiation.

Table 5-18 Correlations among constructs in low customisation contexts

		1	2	3	4	5	6	7	8	9	10
1	Partnership with Suppliers	1									
2	Customer Relationships	.329**	1								
3	Variety Control Strategy	.372**	.288**	1							
4	Flexibility	.297**	.362**	.363**	1						
5	Agility	.395**	.406**	.429**	.624**	1					
6	Cost Efficiency	.212**	.234**	.183**	.421**	.421**	1				
7	Customer Service	.309**	.480**	.238**	.456**	.437**	.401**	1			
8	Cost Leadership	.139*	.194**	.021	.312**	.337**	.524**	.268**	1		
9	Differentiation	.295**	.456**	.251**	.466**	.521**	.385**	.427**	.324**	1	
10	Business Performance	.224**	.326**	.240**	.362**	.383**	.362**	.459**	.238**	.450**	1

* represents significant level p<0.05, ** p<0.01.

Table 5-19 Correlations among constructs in high customisation contexts

		1	2	3	4	5	6	7	8	9	10
1	Partnership with Suppliers	1									
2	Customer Relationships	.398**	1								
3	Variety Control Strategy	.281**	.336**	1							
4	Flexibility	.367**	.447**	.341**	1						
5	Agility	.344**	.284**	.341**	.535**	1					
6	Cost Efficiency	.267**	.263**	.203*	.383**	.338**	1				
7	Customer Service	.321**	.451**	.140	.424**	.454**	.403**	1			
8	Cost Leadership	.219**	.280**	.234**	.316**	.368**	.453**	.306**	1		
9	Differentiation	.266**	.322**	.255**	.423**	.497**	.378**	.416**	.390**	1	
10	Business Performance	.093	.374**	.176*	.231**	.169*	.431**	.434**	.225**	.370**	1

* represents significant level p<0.05, ** p<0.01.

5.7. CHAPTER SUMMARY

This chapter presented the results of the data analysis. The chapter began with a general descriptive analysis that included demographic and response rate characteristics. The chapter then presented preliminary concerns regarding the survey research such as normality, missing data, and bias issues.

With regard to data analysis, first, an ANOVA test was conducted to investigate the impact of product variety on business function performance according to the type of customisation. Second, in order to manage these negative impacts of product variety, a proposed SEM was tested. The result of a confirmatory factor analysis CFA using AMOS 18 was presented to assess the dimensionality, reliability, and validity (including convergent and discriminant validity) of the scales employed in the research model. Then SEM was tested according to the level of customisation. Finally, EFA was used to investigate differences in terms of strategies (e.g. variety control strategy, competitive strategy, partnership with suppliers and customer relationships) and performances (e.g. supply chain flexibility, agility, cost efficiency, customer service and business performance) according to the level of customisation. Table 5-20 summarises the major findings and hypotheses testing.

Table 5-20 Summary of the results of hypotheses testing

Hypothesis 1-1	*A high level of customisation has more product variety than a low level of customisation.*	*Rejected*
Hypothesis 1-2	*An increase in product variety impacts business function performance differently depending on the degree of customisation.*	*Partly Supported*
Hypothesis 1-3	*An increase in product variety impacts business function performance differently depending on the combination of the degree of customisation and the product variety offered.*	*Partly Supported*
Hypothesis 2-1	*A variety control strategy improves supply chain flexibility.*	*Supported*
Hypothesis 2-2	*A variety control strategy improves supply chain agility.*	*Supported*
Hypothesis 2-3	*Increased supply chain flexibility improves supply chain agility.*	*Supported*
Hypothesis 2-4	*Increased supply chain flexibility increases supply chain cost efficiency.*	*Supported*
Hypothesis 2-5	*Increased supply chain agility improves supply chain cost efficiency.*	*Supported*
Hypothesis 2-6	*Increased supply chain flexibility improves supply chain customer service.*	*Supported*
Hypothesis 2-7	*Increased supply chain agility improves supply chain customer service.*	*Supported*
Hypothesis 2-8	*Supply chain agility in a high customisation context has a stronger impact on cost efficiency and customer service than does agility in a low customisation context.*	*Supported*
Hypothesis 3-1	*A high customisation cluster is associated with a higher level of customer service than a low customisation cluster.*	*Rejected*
Hypothesis 3-2	*A high customisation cluster is associated with a higher level of differentiation than a low customisation cluster.*	*Supported*
Hypothesis 3-3	*A high customisation cluster is associated with a stronger customer relationships than a low customisation cluster.*	*Supported*
Hypothesis 3-4	*A high customisation cluster is associated with a higher level of variety control than a low customisation cluster.*	*Supported*

Hypothesis 3-5	*A high customisation cluster is associated with a higher level of supply chain flexibility than a low customisation cluster.*	*Supported*
Hypothesis 3-6	*A high customisation cluster is associated with a higher level of supply chain agility than a low customisation cluster.*	*Supported*
Hypothesis 3-7	*A low customisation cluster is associated with a higher level of cost efficiency than a high customisation cluster.*	*Rejected*
Hypothesis 3-8	*A low customisation cluster is associated with a higher level of cost leadership than a high customisation cluster.*	*Supported*
Hypothesis 3-9	*A low customisation cluster is associated with a stronger partnership with suppliers than a high customisation cluster.*	*Rejected*

CHAPTER SIX

COMPARISON BETWEEN THE UK AND KOREA

6.1. INTRODUCTION

The main objective of this chapter is not only to compare the differences between the UK and Korea in terms of the impact of variety, strategy and performance but also to confirm and adapt any research findings by applying them to both countries. This is achieved by evaluating: (1) differences in the prevailing economic and supply chain (SC) characteristics, (2) differences in the impact of variety, strategy and performance between the UK and Korea; (3) differences in the level of customisation and variety. We also examine how differences between the UK and Korea influence the impact of variety, strategy and performance.

This chapter contains three further sections. Section 6.2 presents the relevant general background on economics and the supply chain. Section 6.3 presents the results of the comparison between the two countries through the use of ANOVA, t-tests and correlation analysis. The following parameters are examined: (1) the general characteristics of variety and customisation; (2) the impact of product variety on business function performance; (3) product variety, lead time and the number of competitors according to customisation type; (4) strategies according to the type of customisation; (5) performance according to the type of customisation; (6) overall comparisons across factors; and (7) correlations across factors. Finally, Section 6.4 summarises the results and findings obtained from the comparison.

6.2. ECONOMICS AND SC BACKGROUND FOR THE UK AND KOREA

6.2.1 Economic background: South Korea

South Korea, located in eastern Asia, comprises the southern half of the Korean Peninsula bordering the Sea of Korea and the Yellow Sea, with an area of 99,720 square kilometres. South Korea is a very densely populated country with approximately 50 million inhabitants.

Over the past four decades, South Korea has demonstrated incredible growth and global integration, becoming a high-tech industrialised economy. In the 1960s, gross domestic product (GDP) per capita was comparable with levels in the poorer countries of Asia. However, South Korea now has a market economy that ranks 15th in the world in terms of nominal GDP and 12th by purchasing power parity (PPP), identifying it as one of the group of 20 (G20) major economies (IMF, 2012). It is a high-income developed country with a developed market and is a member of the Asia Pacific Economic Cooperation (APEC) and the Organisation for Economic Cooperation and Development (OECD). The main export partners are China (24.4%), the US (10.1%), and Japan (7.1%). The primary import partners are China (16.5%), Japan (13%), the US (8.5%), Saudi Arabia (7.1%), and Australia (5%).

The CIA world fact book describes economy overviews of Korea as follows:

"The Asian financial crisis of 1997-98 exposed longstanding weaknesses in South Korea's development model including high debt/equity ratios and massive short-term foreign borrowing. GDP plunged by 6.9% in 1998, and then recovered by 9% in 1999-2000. Korea adopted numerous economic reforms following the crisis, including greater openness to foreign investment and imports. Growth moderated to about 4-5% annually between 2003 and 2007. With the global economic downturn in late 2008, South Korean GDP growth slowed to 0.3% in 2009. In the third quarter of 2009, the economy began to

recover, in large part due to export growth, low interest rates, and an expansionary fiscal policy, and growth was 3.6% in 2011. In 2011, the US-South Korea Free Trade Agreement was ratified by both governments and went into effect in early 2012. The South Korean economy's long term challenges include a rapidly aging population, inflexible labour market, and heavy reliance on exports."

6.2.2 Economic background: the UK

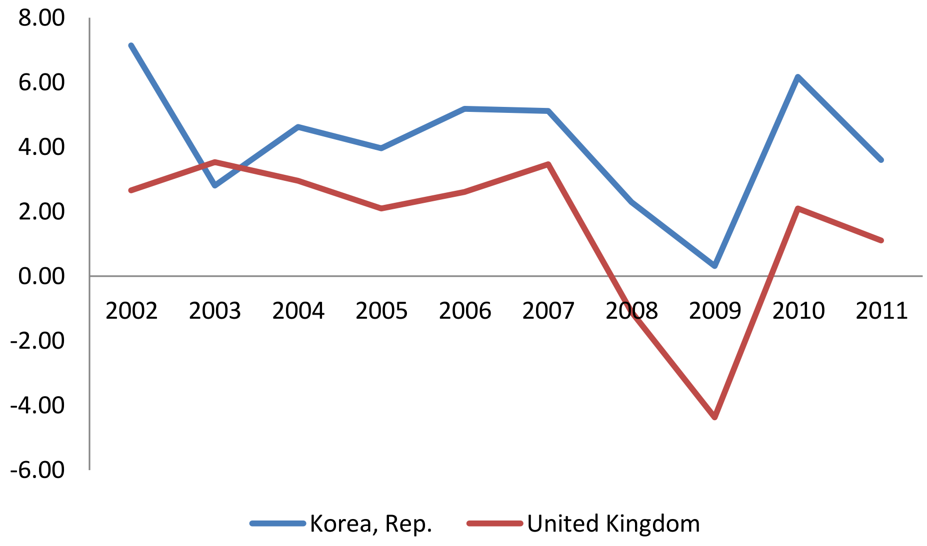
The UK, located off the north-western coast of mainland Europe, is an island country including Great Britain and the north-eastern part of Ireland. The total area of the UK is 243,610 square kilometres. The UK has large coal, natural gas, and oil resources, but its oil and natural gas reserves are declining; the UK became a net importer of energy in 2005. The UK is densely populated with a population of approximately 63 million. This population comprises English (83%), Scottish (9%), and Welsh individuals (5%) as well as people from Northern Ireland (3%).

The UK, a leading trading power and financial centre, is the third largest economy in Europe after Germany and France; it is the 7th largest economy in the world by nominal GDP and 8th by PPP, identifying it as one of the group of 8 (G8) major economies that comprise 53% of global nominal GDP. The UK is a member of the OECD, one of five permanent members of the United Nations (UN) Security Council and a founding member of the North Atlantic Treaty Organisation (NATO) and the Commonwealth (IMF 2011). The main export partners are the US (11.4%), Germany (11.2%), the Netherlands (8.5%), France (7.7%), Ireland (6.8%), and Belgium (5.4%). The major import partners as Germany (13.1%), China (9.1%), the Netherlands (7.5%), France (6.1%), the US (5.8%), Norway (5.5%), and Belgium (4.9%). GDP growth dropped to about 2-4% annually between 1993 and 2007. With the global economic downturn in late 2008, the UK GDP growth declined to -4.4% in 2009. The economy began to recover in 2010: growth was 2.2% in 2010 and 0.7% in 2011. Figure 6-1 illustrates the rate of GDP growth in the UK and Korea over the past 10 years.

The CIA world fact book presents an economic overview for the UK as follows:

"Services, particularly banking, insurance, and business services, account by far for the largest proportion of GDP while industry continues to decline in importance. After emerging from recession in 1992, Britain's economy enjoyed the longest period of expansion on record during which time growth outpaced most of Western Europe. In 2008, however, the global financial crisis hit the economy particularly hard, due to the importance of its financial sector. Sharply declining home prices, high consumer debt, and the global economic slowdown compounded Britain's economic problems, pushing the economy into recession in the latter half of 2008 and prompting the then Labour government to implement a number of measures to stimulate the economy and stabilize the financial markets; these include nationalizing parts of the banking system, temporarily cutting taxes, suspending public sector borrowing rules, and moving forward public spending on capital projects. Facing burgeoning public deficits and debt levels, in 2010, the Prime Minister initiated a five-year austerity program, which aims to lower London's budget deficit from over 10% of GDP in 2010 to nearly 1% by 2015. The government raised the value added tax from 17.5% to 20% in 2011."

Figure 6-1 GDP growth rate over late 10 years



Source: The World Bank (2011)

6.2.3 Economic, logistics and supply chain environment comparisons

A comparison of the economics and demographic differences between the UK and Korea is shown in Table 6-1 (Central Intelligence Agency 2011, IMF 2011). The total area of the UK is 2.4 times larger than that of Korea, while the population of the country is 1.3 times that of Korea.

The economic size (GDP) of the UK is 2.1 times larger than that of Korea. However, the PPP of GDP per capita, a 'measure most economists prefer when looking at per-capita welfare and when comparing lining conditions' in the UK is 1.1 times higher than in Korea. In terms of GDP composition, the UK is more dependent than Korea on service factors. The rate of industry versus service in the UK is 1:3.6, while the rate in Korea is 1:1.5. Both the UK and Korea are highly dependent on foreign trade. In 2011, exports accounted for a higher percentage of the GDP in Korea (48%) as compared to the UK (20%). The rate of unemployment in the UK is 2.3 times higher than in Korea, while the rate of investment in

GDP is 1.9 times higher in Korea than in the UK. The UK (0.35) has a slightly higher gap in income distribution than does Korea (0.31).

Table 6-1 Economic background for the UK and Korea

	UK	South Korea
Area (sq km)	243,610	99.720
Population (millions)	63	50
Three year (2009-2011) averaging economic growth rate (%)	-0.5	3.36
GDP (billions $)	2,418	1,164
Purchasing Power Parity (PPP)of GDP (billions $)	2,250	1,549
GDP per capita ($)	39,604	23,749
Purchasing Power Parity (PPP) of GDP per capita ($)	35,974	31,753
GDP sector composition (%)		
Agriculture	0.7	2.6
Industry	21.6	39.2
Services	77.7	58.2
Industrial production growth rate (%)	-1.2	3.8
Exports (billion $)	495.4	556.5
Imports (billion $)	654.9	524.4
Inflation rate (%)	4.5	4
Unemployment rate (%)	8.1	3.4
Investment (%)	14.4 of GDP	27.4 of GDP
Income distribution (Gini coefficient, ranking in OECD)	0.35 (23 / 30)	0.31 (17 / 30)

Source: 1. Central intelligence Agency (2011)
2. IMF (2011)

Table 6-2 shows the comparison between the UK and Korea in terms of transportation facilities, logistics performance and representative manufacturers in the supply chain. Domestic freight transportation can be sub-divided into five categories of transport including air, pipeline, rail, road and waterway transport. In terms of total area, airport, road and waterway transportation facilities are similar in both the UK and Korea, while the UK has more pipeline and railway transportation facilities. However, most of the inland freight in both the UK and Korea is moved by roadway.

Second, Arvis et al. (2012) surveyed short-term logistics development and policies in 155 countries to provide an international assessment of logistics performance based on a five-point scale. As indicated in the table, the UK ranked highly in all criteria of logistics performance including customs, infrastructure, international shipments, logistics quality and competence, tracking/tracing and timeliness. South Korea ranked lower than the UK in terms of logistics.

Lastly, Gartner Inc. investigated supply chain performance in terms of demand-driven excellence. The evaluation was based on expert opinion, ROA, inventory turns and revenue growth. In terms of supply chain performance (AMR 2011), eight UK companies are ranked in the top 60 around the world. These include Unilever, Tesco, Rio Tinto, BHP Billiton, British American Tobacco, Diageo, Marks & Spencer and J. Sainsbury. Only three Korean companies are in the top 60: Samsung, Hyundai Motor and LG. General logistics performance and the number of manufacturers with a reputation for supply chain excellence fall below the UK figures.

Table 6-2 Logistics and supply chain performance rankings in the UK and Korea

	UK	Korea
Transportation facility		
Airport	505	116
Pipelines (km)	19,640	3,003
Railway (km)	16,454	3,381
Roadway (km)	394,428	103,029
Waterway (km)	3,200	1,608
Logistic performance ranking (Total=155 countries)	10	21
Customs	10	23
Infrastructure	15	22
International shipments	13	12
Logistics quality and competence	11	22
Tracking and tracing	10	22
Timeliness	10	21
Manufacturer's supply chain ranking (2011)	Unilever (13) Tesco (23) Rio Tinto (33) BHP Billiton (37) British American Tobacco (42) Diageo (50) Marks & Spencer (54) J. Sainsbury (57)	Samsung (10) Hyundai Motor (28) LG (55)

Source: 1. Arvis et al. (2012)
2. CIA (2011)
3. Gartner Inc (AMR) (2011)

6.3. COMPARISON BETWEEN THE UK AND KOREA

Here the study compared product variety, customisation, variety-related strategies, supply chain performance, competitive capability, and business performance between the UK and Korea. The impact of product variety on business function performance differed between the UK and Korea. These differences may stem from the evaluation of customisation, SC strategies, SC performance, and competitive capability.

In this section, general trends of variety and customisation were compared between the UK and Korea. Then, the impact degree of product variety on business performance was compared. General comparisons in terms of product variety, lead time, demand uncertainty, and numbers of competitors were performed according to types of customisation. Variety-related strategies (e.g., partnership with suppliers, customer relationships, variety control strategies, cost leadership and differentiation), SC performance (e.g., SC flexibility, agility, cost-efficiency and customer service), and business performance were compared in the same manner. The overall factors were then compared.

6.3.1 General trends for variety and customisation

A general descriptive analysis was conducted and presented in Table 6-3 in terms of the types of products provision, variety trends, demand for variety, major customisation and actual mixed customisation types.

In the UK, almost 95% of manufacturing companies produce a range of products; in Korea, this figure is 94%. Furthermore, 84.4% and 86.2% of respondents had experience with increasing product variety in the UK and Korea, respectively. Demand for variety from customers has increased over the last five years; <10% of respondents experienced a decrease in demand.

Several companies in both countries exhibited a mixed level of customisation. In the UK, the use of three types of mass customisation (SS+CS+TC) was most common (27), followed by CS+TC (16) and SS+CS (9). In Korea, the use of three types of mass customisation (SS+CS+TC) was most common (17), followed by SS+TC (8) and SS+CS (7). Each type of customisation for companies accounted for 14.7–27.5% of UK respondents and 15.1–28.9% of Korean respondents.

Table 6-3 General trends in variety and customisation

Characteristics	UK Frequency	UK Valid (%)	UK Cumulative (%)	Korea Frequency	Korea Valid (%)	Korea Cumulative (%)
Product provision						
Various	203	95.8	95.8	143	94.1	94.1
Single	9	4.2	100.0	9	5.9	100.0
Total	212			152		
Product variety trend						
Increased	179	84.4	84.4	131	86.2	86.2
Decreased (Including same)	33	15.6	100.0	21	13.8	100.0
Total	212			152		
Demand for variety						
-10%	12	5.7	5.7	3	2.0	2.0
-5%	8	3.8	9.4	5	3.3	5.3
Same	42	19.8	29.2	16	10.5	15.8
+5%	59	27.8	57.1	68	44.7	60.5
+10%	91	42.9	100.0	60	39.5	100.0
Total	212			152		
Mixed customisation						
Single customisation (including no response)	128	60.4	60.4	98	64.5	64.5
1+2	4	1.9	62.3	4	2.6	67.1
1+2+3	2	0.9	63.2	4	2.6	69.7
1+2+3+4	2	.9	64.2	1	0.7	70.4
1+2+4	1	.5	64.6	0	0	70.4
1+3	3	1.4	66.0	0	0	70.4
1+3+4	1	.5	66.5	0	0	70.4
1+5	0	0	66.5	1	0.7	71.1
2+3	9	4.2	70.8	7	4.6	75.7
2+3+4	27	12.7	83.5	17	11.2	86.8
2+3+4+5	2	.9	84.4	0	0	86.8
2+3+5	1	.5	84.9	2	1.3	88.2
2+4	4	1.9	86.8	8	5.3	93.4
2+4+5	1	.5	87.3	0	0	93.4
2+5	2	.9	88.2	0	0	93.4
3+4	16	7.5	95.8	4	2.6	96.1
3+4+5	4	1.9	97.6	2	1.3	97.4
4+5	5	2.4	100.0	4	2.6	100.0
Total	212			152		
Type of main customisation						
PS	31	14.7	14.7	26	17.1	17.1
SS	34	16.7	30.8	28	18.4	35.5
CS	44	20.9	51.7	44	28.9	64.5
TC	58	27.5	79.1	31	20.4	84.9
PC	44	20.9	100.0	23	15.1	100.0
Total	211	(missing = 1)		152		

6.3.2 Differences of the impact of product variety on business function performance

An ANOVA was performed to investigate whether Korea and the UK differ in terms of the impact of product variety on business performance. As shown in Table 6-4, 10 items out of 37 showed significant differences between the UK and Korea ($p < 0.05$): unit cost of the product, manufacturing cost, direct labour cost, process variety, material cost, process technology investment cost, order processing, market mediation cost, outsourcing and demand forecasting uncertainty.

All mean values of cost-related items in Korea were higher than those in the UK. Korea displayed the highest impact on manufacturing cost (mean = 5.17) followed by material costs (mean = 4.95) and the cost of investment in process technology (mean = 4.94). In terms of non-cost-related performance, only demand forecasting uncertainty was lower in Korea (mean = 4.14) than in the UK (mean = 5.15). The results support the expectation that the UK employs a higher level of customisation compared to Korea.

In comparison of simple mean value, for the UK manufacturers, the strongest impact (i.e., mean value) of increased product variety was observed for competitive advantage, followed by demand forecast uncertainty, scheduling complexity, customer satisfaction and design complexity (mean scores >4.88). Among Korean manufacturers, customer satisfaction was impacted most strongly by increased product variety, followed by manufacturing costs, R&D costs, market share and material costs (mean scores >4.95).

Table 6-4 Differences in the impact degree by countries

Business function	Code	Item	Country: The UK (n=163)	Korea (n=142)	Total (n=305)	F	Sig
Engineering (α=0.857)	E1	Design complexity	4.88	4.40	4.66	2.846+	.093
	E2	R&D cost	4.77	5.04	4.90	.889	.346
	E3	Unit cost of product	4.24	4.74	4.47	3.948*	.048
	E4	Engineering design and change cost	4.70	4.77	4.73	.066	.797
Manufacturing (α=0.968)	M1	Total quality (control)	4.27	4.65	4.45	1.954	.163
	M2	Manufacturing cost	4.25	5.17	4.68	12.870***	.000
	M3	Utilisation of standardised parts	4.13	4.56	4.33	2.352	.126
	M4	Differentiation postponement	4.01	3.94	3.97	.076	.783
	M5	Set-up cost	4.06	4.54	4.29	3.331+	.069
	M6	Manufacturing flexibility	4.54	4.50	4.52	.019	.889
	M7	Direct labour cost	3.85	4.51	4.16	4.305*	.039
	M8	Process variety	4.17	4.72	4.43	4.173*	.042
	M9	Part variety	4.46	4.76	4.60	1.136	.287
	M10	Manufacturing complexity	4.64	4.71	4.67	.065	.799
	M11	Supervision effort	4.46	4.55	4.50	.093	.760
	M12	Scheduling complexity	5.09	4.56	4.85	3.374+	.067
	M13	Material cost	4.40	4.95	4.66	4.241*	.040
	M14	Overhead cost	3.99	4.46	4.21	3.247+	.073
	M15	Manufacturing lead time	4.25	4.44	4.33	.505	.478
	M16	Process technology investment cost	4.31	4.94	4.60	4.690*	.031
Purchasing (α=0.912)	P1	Purchasing cost	4.43	4.86	4.63	2.229	.137
	P2	Order processing	3.66	4.63	4.11	12.218**	.001
	P3	Purchased component / part variety	3.99	4.39	4.18	2.188	.140
Logistics (α=0.957)	L1	Work in process inventory	4.13	4.24	4.18	.162	.687
	L2	Finished goods inventory	4.02	4.16	4.09	.234	.629
	L3	Inventory cost	4.23	4.23	4.23	.000	.998
	L4	Purchased part inventory	3.92	4.13	4.02	.654	.419
	L5	Delivery time	3.90	4.08	3.99	.445	.505
	L6	Material handling cost	3.80	4.14	3.96	1.679	.196
	L7	Market mediation cost	3.54	4.23	3.86	6.859**	.009
	L8	Outsourcing	3.56	4.17	3.85	4.803*	.029
	L9	Transportation cost	3.75	4.02	3.88	.977	.324
Marketing (α=0.890)	K1	Demand forecast uncertainty	5.15	4.44	4.82	6.476*	.011
	K2	Customer satisfaction	4.94	5.24	5.08	1.008	.316
	K3	Market share	4.82	4.97	4.89	.301	.583
	K4	Competitive advantage	5.33	4.85	5.11	2.914+	.089
	K5	Retailers’ cost	4.07	4.25	4.16	.437	.509

+ represents significant level p<0.1, * represents significant level p< 0.05, ** p<0.01.

6.3.3. Product variety, lead time and number of competitors according to customisation type

With regard to product variety, the UK had relatively higher total mean scores than Korea on all observed variables. Most companies surveyed in the UK and Korea exhibited the highest intermediate variety. The UK presented the lowest total mean score in terms of fundamental variety, while Korea presented the lowest total mean score in terms of peripheral variety.

In the UK, TC had the highest fundamental variety, followed by PC, CS, SS and PS (p <0.01). In addition, TC had the highest level of intermediate (p <0.05) and peripheral variety (p <0.01), followed by CS, PC, SS and PS. Korea companies did not show significant differences according to customisation type. Table 6-5 shows the results of the ANOVA test.

Table 6-5 ANOVA analysis of product variety according to customisation type

Variety type	Mean								
	County	PS	SS	CS	TC	PC	Total	F	Significance
Fundamental variety	UK	3.19	3.09	3.75	4.14	3.77	3.67	4.400**	.002
	Korea	2.62	2.86	3.25	3.19	3.39	3.08	1.391	.240
Intermediate variety	UK	3.23	3.47	4.02	4.24	3.80	3.83	3.016*	.019
	Korea	2.81	2.57	3.36	3.16	3.35	3.08	2.244^{+}	.067
Peripheral variety	UK	2.94	3.29	4.02	4.05	3.70	3.69	3.885**	.005
	Korea	2.50	2.54	3.30	3.03	3.17	2.95	2.297^{+}	.062

$^{+}$ represents significant level p< 0.1, * represents significant level p< 0.05, ** p<0.01

Regarding order lead time, the UK had relatively higher mean scores than Korea for all types of customisation. The UK had a mean 8.3 days of order lead time; the mean in Korea was 5.5 days. Table 6-6 shows that order lead-time differed significantly across the five types of customisation at the 1 and 0.1 % significance levels in the UK and Korea, respectively. In the UK, order lead time was highest for PC, followed by CS, TC, PS and SS. Order lead time was highest for PC, followed by TC, CS, SS and PC in Korea.

With regard to the number of major competitors, the UK had higher mean scores than Korea. The UK reported five major competitors (average), while Korea reported 4.5 major competitors. In Korea, the number of major competitors was highest for PS, followed by SS, PC, TC and CS (p <0.001). As expected, the UK exhibited higher levels of product variety as well as more competitors and longer order lead time.

Table 6-6 ANOVA analysis of order lead time and competitors according to customisation type

Dependent Variable	Mean								
	County	PS	SS	CS	TC	PC	Total	F	Significance
Order lead time	UK	3.58	3.38	4.50	4.32	4.73	4.18	4.540**	.002
	Korea	2.81	3.11	3.98	4.16	4.68	3.75	5.610***	.000
Major competitor	UK	2.87	2.94	3.11	2.66	3.22	2.95	2.155^{+}	.080
	Korea	3.38	2.90	2.20	2.71	2.78	2.72	7.127***	.000

$^{+}$ represents significant level p< 0.1, * represents significant level p< 0.05, ** p<0.01
Note: Order lead time 1 represents within 1day, 2: 2-3 days, 3: 4-6days, 4: 7-14 days, 5: 15-30 days, 6: above 30 days / Major competitor 1 represents 1 competitor, 2: 2-5, 3: 6-10, 4: 11-20, 5: above 20

6.3.4. Strategies according to customisation type

In order to investigate the differences in strategies in terms of variety control strategy, cost leadership and differentiation, partnership with suppliers and close customer relationships according to the type of customisation, an ANOVA was undertaken.

The UK had higher total mean scores than Korea for postponement (VCS2) and cellular manufacturing (VCS3), while Korea had slightly higher total mean scores than the UK for modularisation (VCS1). The UK scored highest for cellular manufacturing, while Korea scored highest for modularisation.

The ANOVA results presented in Table 6-7 show that modularisation, postponement and cellular manufacturing differ significantly across the five types of customisation in both the UK and Korea (p <0.01). In the UK, modularisation was rated as the highest mean score by CS, followed by TC, PC, SS and PS. Postponement displayed the highest mean score in PC, followed by TC, CS, SS and PS. Cellular manufacturing was highest for TC, followed by PC, CS, SS and PS. In Korea, TC appeared to have the highest level of modularisation, followed by PC, CS, SS and PS. TC also displayed the highest level of postponement, followed by PC, CS, PS and SS. Cellular manufacturing scored highest for TC, followed by PC, CS, PS and SS.

Table 6-7 ANOVA analysis of variety control strategies according to customisation type

Item		Mean						F	Sig
	UK Korea	PS (N=31) (N=26)	SS (N=34) (N=28)	CS (N=44) (N=44)	TC (N=58) (N=31)	PC (N=44) (N=23)	Total (N=211) (N=152)		
Modularisation	UK	2.65	2.88	3.73	3.59	3.32	**3.31**	7.393***	.000
	Korea	2.96	3.21	3.39	3.84	3.83	**3.44**	6.654***	.000
Postponement	UK	2.26	2.79	3.52	3.60	3.80	**3.30**	14.775***	.000
	Korea	2.19	2.14	3.23	3.65	3.61	**2.99**	25.635***	.000
Cellular manufacturing	UK	2.55	3.00	3.41	3.67	3.59	**3.33**	7.598***	.000
	Korea	2.85	2.82	3.09	3.55	3.52	**3.16**	4.237**	.003

* represents significant level p< 0.05, ** p<0.01, *** p<0.001

With regard to partnership with suppliers, the UK had higher total mean scores than Korea on PAS1 and PAS3, while Korea had higher total mean scores than the UK on PAS2 and PAS4. PAS1 was the highest variable in both countries; PAS4 was the lowest.

Table 6-8 shows that only PAS2 differed significantly across the five types of customisation in Korea. PAS2 was rated highest by PC, followed by TC, CS, PS and SS.

Table 6-8 ANOVA analysis of partnership with suppliers according to customisation type

Item	Mean								
	Country	PS	SS	CS	TC	PC	Total	F	Sig
Trustworthy relationships with suppliers (PAS1)	UK	4.19	4.47	4.45	4.19	4.43	**4.34**	1.188	0.317
	Korea	3.54	3.75	3.73	4.06	4.04	**3.82**	1.984	0.100
Close relationships in product development with suppliers (PAS2)	UK	3.35	3.56	3.93	3.74	3.82	**3.71**	2.149+	0.076
	Korea	3.73	3.36	3.73	3.90	4.22	**3.77**	2.778*	0.029
Joint problem solving and performance evaluation with suppliers (PAS3)	UK	3.26	3.62	3.82	3.74	3.73	**3.66**	1.753	0.140
	Korea	3.23	3.36	3.66	3.84	3.61	**3.56**	2.092+	0.085
Share sensitive information (financial, production, design, research) with suppliers (PAS4)	UK	2.81	2.76	3.02	3.10	2.82	**2.93**	0.897	0.466
	Korea	3.08	3.18	3.55	3.61	3.39	**3.39**	1.531	0.196

+ represents significant level p< 0.1, * represents significant level p< 0.05, ** p<0.01

An ANOVA analysis was undertaken in order to determine if the type of customisation differs in terms of customer relationships. The results (see Table 6-9) show that no relevant variable was dependent on customisation type in either the UK or Korea.

The UK had higher total mean scores than Korea for all customer relationship variables. Furthermore, the UK displayed the highest total mean score for CR2, while Korea showed the highest total mean score for CR4. The lowest total mean score in the UK was CR4; in Korea, CR3 was lowest.

Table 6-9 ANOVA analysis of customer relationships according to customisation type

Item	Mean								
	Country	PS	SS	CS	TC	PC	Total	F	Sig
We anticipate and respond to customers' evolving needs (CR1)	UK	4.06	3.94	4.23	4.26	4.25	**4.17**	1.054	.380
	Korea	3.50	3.96	3.84	3.97	4.00	**3.86**	1.397	.238
We emphasise the evaluation of formal and informal customer complaints (CR2)	UK	3.87	4.12	4.25	4.26	4.30	**4.18**	1.503	.202
	Korea	3.62	3.79	3.80	4.06	3.70	**3.80**	1.025	.397
We monitor and measure customer service levels (CR3)	UK	3.94	4.32	4.16	4.29	4.30	**4.22**	1.248	.292
	Korea	3.73	3.86	3.70	3.97	3.48	**3.76**	1.172	.326
We follow up with customers for quality/service feedback (CR4)	UK	3.97	4.12	4.00	4.17	4.27	**4.12**	0.762	.551
	Korea	3.65	4.07	3.86	4.06	3.65	**3.88**	1.487	.209

Competitive capability comprises two latent variables: cost leadership and differentiation. Korea had relatively higher total mean scores on cost leadership than the UK. CL1 was higher in both countries than CL2. Table 6-10 shows that CL1 varied with customisation in the UK and Korea at the 0.05 significance level. In the UK, CL1 was rated as the highest mean score by PS, followed by CS, SS, TC and PC. In Korea, CL1 was rated as the highest mean score by PS, followed by CS, SS, TC and PC. In both countries, low customisation companies focused more on CL1 than high customisation companies.

Table 6-10 ANOVA analysis of cost leadership capability according to customisation type

Item	Mean								
	County	PS	SS	CS	TC	PC	Total	F	Sig
Low manufacturing unit cost (CL1)	UK	3.55	3.47	3.16	3.07	3.11	**3.23**	2.939*	.022
	Korea	3.77	3.54	3.57	3.45	3.04	**3.49**	3.019*	.020
Low product price (CL2)	UK	3.35	3.32	3.05	2.97	2.98	**3.10**	1.777	.136
	Korea	3.50	3.46	3.48	3.23	3.00	**3.36**	2.400^{+}	.053

$^{+}$ represents significant level p< 0.1, * represents significant level p< 0.05, ** p<0.01

Regarding differentiation, the UK had relatively higher total mean scores than Korea for all observed variables except D2. The UK and Korea displayed the highest total mean scores for D1and D2, respectively. In the UK, D2 was lowest; in Korea, D3 was lowest. Table 6-11 shows that D2 varied with customisation in the UK at the 0.001 significance level, while D1 ($p < 0.05$) and D2 ($p < 0.01$) varied with customisation in Korea. In the UK, D2 scored highest among PC, followed by TC, CS, PS and SS. In Korea, D1 was highest for PC, followed by TC, CS, SS and PS. D2 was rated as the highest mean score by PC, followed by CS, TC, SS and PS. In both countries, high customisation companies were more focused on D1 and D2 than low customisation companies.

Table 6-11 ANOVA analysis of differentiation capability according to customisation type

Item	Mean								
	County	PS	SS	CS	TC	PC	Total	F	Sig
Customer service differentiation (D1)	UK	3.45	3.44	3.82	3.84	3.73	**3.69**	2.146^{+}	.076
	Korea	3.08	3.29	3.52	3.45	3.87	**3.44**	3.150*	.016
Technology differentiation (D2)	UK	3.03	2.85	3.39	3.66	3.73	**3.39**	7.668***	.000
	Korea	3.04	3.29	3.57	3.52	3.96	**3.47**	3.841**	.005
Marketing differentiation (D3)	UK	3.32	3.38	3.36	3.59	3.41	**3.43**	.591	.669
	Korea	2.92	2.93	3.23	3.39	3.39	**3.18**	1.911	.112

$^{+}$ represents significant level $p< 0.1$, * represents significant level $p< 0.05$, ** $p<0.01$ *** $p<0.001$

6.3.5. SC performance according to customisation type

To investigate whether types of customisation differ in terms of supply chain performance (including SC flexibility, agility, cost efficiency, customer service and business performance), another ANOVA was performed.

In the SC flexibility dimension, the UK had slightly higher total mean scores than Korea for FL3, FL4 and FL6, while Korea had slightly higher total mean scores than the UK for FL2 and FL5. Furthermore, the UK scored FL6 highest, while Korea scored FL1 highest. FL2 and FL5 scored lowest in the UK, while FL2 scored lowest in Korea. Table 6-12 shows that all observed variables differed with customisation type in the UK, while only FL5 differed in Korea. In the UK, FL1 was rated highest by CS, followed by TC, PC, SS and PS. FL2 displayed the highest mean score in PC, followed by TC / CS, PS and SS. FL3 showed the highest mean score in CS, followed by TC, PC, SS and PS. FL4 displayed the highest mean score in TC, followed by CS, PC, SS and PS. FL5 showed the highest mean score in PC, followed by TC, CS, SS and PS. FL6 showed the highest mean score in TC, followed by PC, CS, SS and PS. In Korea, FL5 was rated highest by TC, followed by PC, CS, SS and PS.

Table 6-12 ANOVA analysis of supply chain flexibility according to customisation type

Item	Mean								
	Country	PS	SS	CS	TC	PC	Total	F	Sig
Change quantity of suppliers order (FL1)	UK	3.16	3.35	3.75	3.71	3.59	**3.55**	2.700*	.032
	Korea	3.27	3.46	3.57	3.71	3.70	**3.55**	1.356	.252
Change delivery times of orders placed with suppliers (FL2)	UK	2.81	3.21	3.41	3.41	3.50	**3.31**	3.290*	.012
	Korea	3.27	3.43	3.41	3.52	3.57	**3.43**	.482	.749
Change production volume (FL3)	UK	3.10	3.38	3.84	3.76	3.66	**3.60**	4.90**	.001
	Korea	3.23	3.50	3.50	3.68	3.57	**3.50**	0.830	.508
Accommodate changes in production mix (FL4)	UK	3.06	3.41	3.73	3.91	3.70	**3.63**	5.210**	.001
	Korea	3.19	3.32	3.52	3.55	3.74	**3.47**	1.372	.246
Implement engineering change orders in production (FL5)	UK	2.84	2.91	3.34	3.55	3.61	**3.31**	5.200**	.001
	Korea	2.81	3.21	3.55	3.84	3.74	**3.45**	6.427***	.000
Alter delivery schedules to meet changing customer requirements (FL6)	UK	3.23	3.35	3.61	3.91	3.84	**3.64**	4.220**	.003
	Korea	3.38	3.43	3.39	3.81	3.78	**3.54**	1.964	.103

*represents significant level p< 0.05, ** p<0.01, *** P<0.001

Regarding supply chain agility, it is interesting to note that Korea had higher total mean scores than the UK on all agility-related variables. AG4 was highest in the UK; AG6 was highest in Korea. AG1 was lowest in the UK and Korea.

Table 6-13 shows that AG1, AG2, AG3, AG6 and AG7 differed with customisation type in both countries. In the UK, AG1 was rated as the highest mean score in PC, followed by CS, TC, PS and SS. AG2 was highest for CS, followed by TC, PC, SS and PS. AG3 was highest for TC, followed by PC, CS, PS and SS. AG6 showed the highest mean score in TC, followed by PC/CS, SS and PS. Lastly, AG7 showed the highest mean score in TC, followed by CS, PC, SS and PS. In Korea, AG1 was rated as the highest mean score by PC, followed by TC, CS, SS and PS. AG2 displayed the highest mean score in TC, followed by PC, CS, SS and PS. AG3 showed the highest mean score in PC, followed by TC, SS, CS and PS. AG6 showed the highest mean score in PC, followed by TC, CS, SS and PS. Lastly, AG7 displayed the highest mean score in TC, followed by PC, CS, SS and PS.

Table 6-13 ANOVA analysis of agility according to customisation type

Item	Mean								
	Country	PS	SS	CS	TC	PC	Total	F	Sig
Ability to rapidly reduce product development cycle time (AG1)	UK	2.48	2.26	2.86	2.83	2.91	**2.71**	3.46**	.009
	Korea	2.69	3.04	3.39	3.52	3.57	**3.26**	3.953**	.004
Ability to rapidly reduce manufacturing lead time (AG2)	UK	2.48	2.68	3.18	2.95	2.91	**2.88**	2.93*	.022
	Korea	2.96	3.11	3.30	3.71	3.65	**3.34**	3.327*	.012
Ability to rapidly increase the level of product customisation (AG3)	UK	2.71	2.62	3.07	3.40	3.20	**3.06**	4.71**	.001
	Korea	2.85	3.25	3.16	3.65	3.74	**3.31**	4.413**	.002
Ability to rapidly improve level of customer service (AG4)	UK	3.29	3.26	3.41	3.43	3.55	**3.40**	.63	.643
	Korea	3.19	3.36	3.39	3.65	3.57	**3.43**	1.111	.354
Ability to rapidly improve delivery reliability (AG5)	UK	3.19	3.29	3.39	3.29	3.39	**3.32**	.31	.873
	Korea	3.31	3.29	3.52	3.65	3.83	**3.51**	1.655	.164
Ability to rapidly improve responsiveness to changing market needs (AG6)	UK	2.94	3.21	3.48	3.50	3.48	**3.36**	3.04*	.018
	Korea	3.19	3.21	3.55	3.74	3.91	**3.52**	3.469*	.010
Ability to rapidly reduce delivery lead time (AG7)	UK	2.58	3.03	3.18	3.21	3.09	**3.06**	2.69*	.032
	Korea	3.00	3.21	3.39	3.68	3.61	**3.38**	2.898*	.024

* represents significant level $p < 0.05$, ** $p < 0.01$

Supply chain cost efficiency comprises four observed variables (CE1–4). Korea had higher total mean scores than the UK on all cost efficiency variables. In both countries, CE3 was highest and CE2 was lowest. Table 6-14 shows that only CE3 varied with customisation in the UK at the 0.05 significance level. Interestingly, CE3 was rated as the highest mean score by CS, followed by TC, PC, PS and SS.

Table 6-14 ANOVA analysis of cost efficiency according to customisation type

Item	Mean								
	Country	PS	SS	CS	TC	PC	Total	F	Sig
Ability to minimise total cost of resources used (CE1)	UK	3.10	3.24	3.34	3.34	3.25	**3.27**	.658	.622
	Korea	3.54	3.64	3.55	3.52	3.52	**3.55**	.135	.969
Ability to minimise total cost of distribution (CE2)(including transportation and handling costs)	UK	3.19	3.21	3.41	3.17	3.27	**3.25**	.582	.676
	Korea	3.38	3.68	3.45	3.23	3.43	**3.43**	1.385	.242
Ability to minimise total cost of manufacturing (CE3)(including labour, maintenance, and re-work costs)	UK	3.26	3.15	3.64	3.52	3.43	**3.43**	2.605*	.037
	Korea	3.54	3.71	3.48	3.65	3.48	**3.57**	.518	.723
Ability to minimise total cost related with held inventory (CE4)	UK	3.29	3.29	3.45	3.36	3.25	**3.34**	.419	.795
	Korea	3.69	3.43	3.32	3.55	3.39	**3.46**	1.179	.322

* represents significant level $p < 0.05$, ** $p < 0.01$

For customer service, the UK had higher total mean scores than Korea for all variables except CUS5. CUS4 was highest in both countries. CUS5 was lowest in the UK; CUS8 was lowest in Korea. Table 6-15 shows that CUS5 ($p < 0.01$), CUS6 ($p < 0.05$) and CUS8 ($p < 0.05$) vary with customisation in the UK, while only CUS2 ($p < 0.05$) significantly varies with customisation in Korea. In the UK, CUS5 and CUS6 were highest in CS, followed by TC, PC, SS and PS. CUS8 was highest for CS, followed by TC, SS, PC and PS. In Korea, CUS2 was rated as the highest mean score by PC, followed by PS, CS, TC and SS.

Table 6-15 ANOVA analysis of customer service according to customisation type

Item	Mean								
	Country	PS	SS	CS	TC	PC	Total	F	Sig
Order fill rate (CUS1)	UK	3.94	4.00	3.86	3.79	3.93	**3.89**	.449	.773
	Korea	3.81	3.82	3.55	3.84	4.04	**3.78**	1.568	.186
On-time delivery (CUS2)	UK	3.71	3.79	4.09	3.93	3.98	**3.92**	1.089	.363
	Korea	3.85	3.64	3.70	3.65	4.30	**3.80**	3.198*	.015
Customer response time (CUS3)	UK	3.87	3.88	4.05	3.93	3.86	**3.92**	.399	.810
	Korea	3.69	3.68	3.66	3.81	4.13	**3.77**	1.674	.159
Quality (CUS4)	UK	4.03	3.85	4.27	4.24	4.25	**4.16**	2.327+	.057
	Korea	3.96	3.96	3.73	3.81	3.87	**3.85**	.511	.728
Manufacturing lead time (CUS5)	UK	3.26	3.35	3.89	3.66	3.64	**3.59**	3.852**	.005
	Korea	3.46	3.50	3.61	3.74	3.74	**3.61**	.623	.647
Customer complaints reduction (CUS6)	UK	3.48	3.50	3.89	3.84	3.73	**3.72**	2.462*	.046
	Korea	3.54	3.68	3.55	3.68	3.74	**3.63**	.438	.781
Customer satisfaction (CUS7)	UK	3.81	3.79	4.11	4.03	3.89	**3.95**	1.827	.125
	Korea	3.81	3.96	3.61	3.81	4.09	**3.82**	2.092+	.085
Stock-out reduction (CUS8)	UK	3.35	3.59	3.91	3.69	3.50	**3.63**	2.639*	.035
	Korea	3.35	3.43	3.34	3.74	3.57	**3.47**	1.323	.264

* represents significant level $p< 0.05$, ** $p<0.01$

With regard to business performance, the UK had relatively higher total mean scores than Korea for all observed variables. BP4 was higher in both countries. BP1 and BP2 were lowest in the UK; BP1 was lowest in Korea. Table 6-16 shows that only BP4 ($p <0.05$) varied with customisation in the UK. In the UK, BP4 was rated as the highest mean score for TC, followed by CS, PC, PS and SS. BP1, BP2 and BP3 did not show significant differences in business performance according to types of customisation in both countries.

Table 6-16 ANOVA analysis of business performance according to customisation type

Item	Mean								
	County	PS	SS	CS	TC	PC	Total	F	Significance
Return on sales (ROS) (BP1)	UK	3.58	3.41	3.82	3.60	3.75	3.64	1.444	.221
	Korea	3.46	3.50	3.39	3.39	3.52	3.44	.198	.939
Return on Assets (ROA) (BP2)	UK	3.68	3.32	3.80	3.60	3.77	3.64	2.045	.089
	Korea	3.38	3.61	3.50	3.42	3.70	3.51	.734	.570
Market share growth (BP3)	UK	3.65	3.47	3.84	3.83	3.68	3.72	1.582	.180
	Korea	3.54	3.50	3.55	3.61	3.48	3.54	.123	.974
Sales growth (BP4)	UK	3.77	3.44	3.82	4.02	3.80	3.80	2.659*	.034
	Korea	3.42	3.61	3.73	3.45	3.74	3.60	1.192	.317

* represents significant level $p<0.05$

6.3.6. Overall comparison between the UK and Korea

The previous section investigated differences in all items (observed variables) between the UK and Korea according to types of customisation. Here, the study investigates direct differences in terms of all the constructs examined. Thus, the study compared all latent variables that may differ significantly between the UK and Korea including product variety, customisation, variety-related strategies, supply chain performance, and business performance. The exploratory factor analysis (EFA) conducted in Chapter 5 showed that no reliability or validity problem would be associated with such an analysis.

As can be seen in Table 6-17, product variety differs between the UK and Korea ($p <0.001$). The overall level of product variety in the UK (mean = 3.74) is much higher than that in Korea (mean = 3.04). With respect to strategy, customer relationships ($p <0.001$) and cost leadership ($p <0.01$) varied between the countries. Partnership with suppliers, variety control strategy and differentiation did not show significant differences. Regarding performance measures including supply chain flexibility, agility, cost efficiency, customer service and business performance, agility ($p <0.001$), cost efficiency ($p <0.01$), customer service ($p < 0.05$) and business performance ($p < 0.05$) showed significant differences. Flexibility was similar in both countries.

With regard to strategies, UK firms (mean = 4.17) tended to have closer customer relationships than Korean firms (mean = 3.82), while Korea (mean = 3.57) had stronger partnership with suppliers than the UK (mean = 3.43). In addition, the UK (mean = 3.31) exhibited superior variety control strategies in manufacturing (VCS) than Korea (mean = 3.20). In terms of competitive capability, the UK (mean = 3.51) exhibited a sharper focus on differentiation than Korea (mean = 3.36), while Korea (mean = 3.42) focused more on cost leadership than the UK (mean = 3.18).

With regard to performance, the UK (mean = 3.51) and Korea (mean = 3.49) were similar in terms of supply chain flexibility, while Korea (mean = 3.39) exhibited superior supply chain agility (3.11). The UK (mean = 3.85) exhibited customer service superiority to that in Korea (mean = 3.72), while Korea scored better on cost efficiency than the UK. Lastly, it is interesting to note that the UK (mean = 3.70) had superior business performance in comparison to Korea (mean = 3.52). Figure 6-2 reports the comparative graph between the UK and Korea.

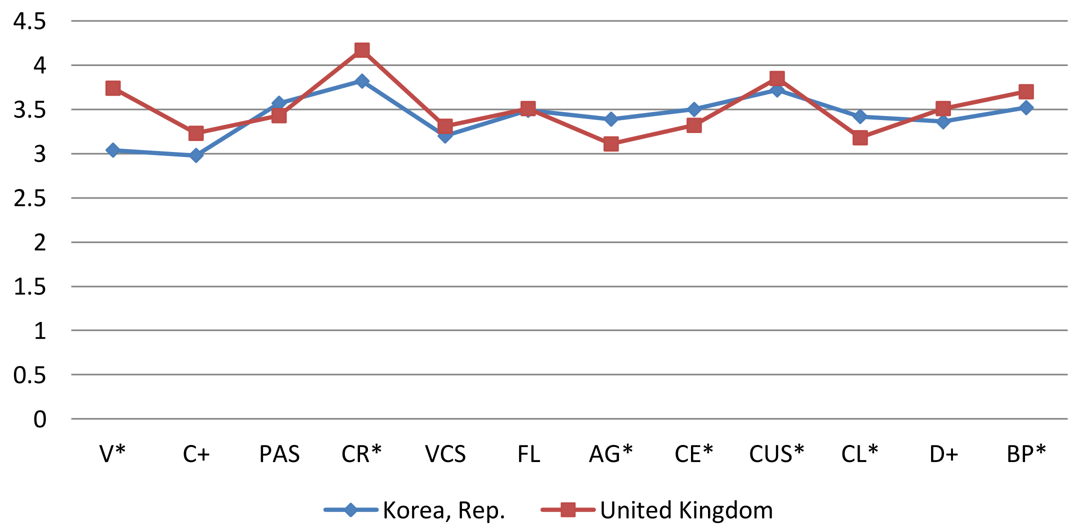
The results imply that the UK focuses on customer relationships with a higher level of product variety, which leads to superior customer service and business performance compared with Korea. Korea focuses more on cost leadership with lower level product variety, which leads to higher cost efficiency compared with the UK. These results support hypothesis H 4-1 that a county with less product variety is associated with increased focus on cost leadership (see Stavrulaki and Davis, 2010). Supplier partnerships, customisation level, variety control strategy, flexibility and differentiation did not show significant differences between the two countries; hence, hypothesis H 4-2 that a country with more product variety is associated with an increased focus on differentiation, variety control strategies, customer relationships, supply chain flexibility and agility was rejected.

Table 6-17 T-test of all factors according to country type

Dependent Variable	Mean				
	UK	Korea	Total	T	Significance
Product variety	3.74	3.04	3.44	5.195***	.000
Customisation	3.23	2.98	3.13	1.819+	.070
Partnership with suppliers	3.43	3.57	3.50	-1.533	.126
Customer relationships	4.17	3.82	4.03	4.389***	.000
Variety control strategy	3.31	3.20	3.26	1.229	.220
Flexibility	3.51	3.49	3.50	.261	.794
Agility	3.11	3.39	3.23	-3.581***	.000
Cost efficiency	3.31	3.52	3.40	-2.963**	.003
Customer service	3.85	3.72	3.79	2.174*	.030
Cost leadership	3.18	3.42	3.28	-3.156**	.002
Differentiation	3.51	3.36	3.45	1.858+	.064
Business performance	3.70	3.52	3.63	2.591*	.010

+ represents significant level p<0.1, * p< 0.05, ** p<0.01, *** p<0.001

Figure 6-2 Comparison of T-test according to the country



+ represents significant level p<0.1, * p< 0.05

An increase in product variety is often motivated by a high level of customisation and intense competition (Silveira, 1998). The level of customisation is higher in the UK (mean = 3.23) than in Korea (mean = 2.98) at the 0.1 significance level. Competition is also more intense in the UK (mean = 2.94) than in Korea (mean = 2.72) at the 0.05 significance level; therefore, H 4-3 that a higher level of competition and product customisation are associated with a higher level of product variety (Silveira, 1998) is supported.

6.3.7. Correlation across factors

In order to investigate the relationships across all latent variables, correlation analysis was conducted. Tables 6-18 and 6-19 present the correlation among the latent variables used for comparison between the UK and Korea.

In the UK, 54 correlations showed direct and positive correlations between latent variables. Product variety and customisation did not show correlations with PAS, CR, CE, CUS or BP. There was no correlation of PAS with CL or BP, and VCS with CL. As expected, the level of customisation displayed a negative correlation with cost leadership (-0.225).

In Korea, there were more strong correlations between latent variables than observed in the UK analysis. Seven correlations out of 72 did not display significant relationships at the 0.05 level: V with CE and CL; C with CR, CUS, CE and BP; and VCS with CL. The level of customisation also presented a negative correlation with cost leadership (-0.251) at a level of 0.01.

Table 6-18 Correlation in the UK

		1	2	3	4	5	6	7	8	9	10	11	12
1	Product Variety	1											
2	Customisation	.222**	1										
3	Partnership with Suppliers	.113	.125	1									
4	Customer Relationships	-.032	.116	.301**	1								
5	Variety Control Strategy	.272**	.402**	.302**	.285**	1							
6	Flexibility	.178**	.308**	.245**	.318**	.381**	1						
7	Agility	.203**	.216**	.287**	.302**	.395**	.587**	1					
8	Cost Efficiency	.107	.058	.181**	.161*	.179**	.314**	.308**	1				
9	Customer Service	.052	.107	.246**	.438**	.210**	.436**	.469**	.392**	1			
10	Cost Leadership	-.044	-.225**	.079	.160*	.009	.222**	.239**	.456**	.228**	1		
11	Differntiation	.175*	.233**	.220**	.293**	.196**	.399**	.475**	.333**	.409**	.268**	1	
12	Business Performance	.038	.106	.064	.228**	.146*	.198**	.240**	.362**	.349**	.164*	.281**	1

* represents significant level p< 0.05, ** p<0.01

Table 6-19 Correlation in Korea

		1	2	3	4	5	6	7	8	9	10	11	12
1	Product Variety	1											
2	Customisation	.186*	1										
3	Partnership with Suppliers	.279**	.223**	1									
4	Customer Relationships	.368**	.055	.504**	1								
5	Variety Control Strategy	.299**	.501**	.458**	.368**	1							
6	Flexibility	.177*	.239**	.541**	.580**	.523**	1						
7	Agility	.230**	.304**	.516**	.532**	.535**	.760**	1					
8	Cost Efficiency	.089	-.066	.375**	.505**	.241**	.550**	.450**	1				
9	Customer Service	.164*	.113	.561**	.588**	.331**	.592**	.633**	.619**	1			
10	Cost Leadership	.026	-.251**	.235**	.400**	.062	.366**	.304**	.530**	.427**	1		
11	Differntiation	.263**	.285**	.442**	.513**	.483**	.654**	.655**	.501**	.517**	.358**	1	
12	Business Performance	.215**	.041	.404**	.492**	.362**	.508**	.454**	.568**	.589**	.344**	.585**	1

* represents significant level p< 0.05, ** p<0.01

6.4. CHAPTER SUMMARY

The chapter began by explaining the general economics, supply chain, variety and customisation background of the UK and Korea. T-tests, then, were conducted to investigate the differences between the UK and Korea on the impact of product variety on business performance.

Next, all observed variables of the following factors were examined by ANOVA according to the level of customisation: product variety, lead time and number of competitors, as well as various variety-related strategies (e.g., variety control strategy, competitive strategy, partnership with suppliers and customer relationships) and performance measures (e.g., supply chain flexibility, agility, cost efficiency, customer service and business performance).

Finally, a T-test was used again to investigate the differences in factors (i.e. latent variable) including variety, customisation, strategies and performances between the UK and Korea. Table 6-20 presents a summary of the results of the hypotheses.

Table 6-20 Summary of the results of hypothesis testing

Hypothesis 4-1	*A country with less product variety is associated with increased focus on cost leadership.*	*Supported*
Hypothesis 4-2	*A country with more product variety is associated with an increased focus on differentiation, variety control strategies, customer relationships, supply chain flexibility and agility (only customer relationships was supported between two countries).*	*Rejected*
Hypothesis 4-3	*A higher level of competition and product customisation are associated with a higher level of product variety.*	*Supported*

CHAPTER SEVEN

DISCUSSION OF RESULTS

7.1. INTRODUCTION

The purpose of this chapter is to discuss further and consolidate the findings of the empirical analysis presented in the previous chapters (Chapters 5 and 6). The first section provides a brief introduction to the Chapter and a summary of the previous results. The second section is devoted to exploring the results of the impact of product variety on business function performance depending on the type of customisation and variety offered. The results show that a low degree of product customisation has, typically, a more significant effect on business function performance than a high degree of customisation. In addition, high variety with low customisation (HVLC) has a significant negative impact on business function performance than other clusters (i.e. LVLC, HVHC and HVLC) due to the mismatch between the levels of variety and customisation. The advantages of variety control strategies (VCS) are discussed with the analysis of the findings.

Then, the third section interprets the results in terms of a supply chain design model that supports the management of increases in variety (i.e. the relationship between the strategies of controlling variety and supply chain performance). This relationship is further explored by considering the level of customisation (e.g. high or low customisation). The results indicate that supply chain flexibility and agility resulting from a variety control strategy have a positive impact on supply chain cost efficiency and customer service. However, supply chain agility plays a relatively insignificant role when customisation is low compared with when it is high.

The fourth section is dedicated to discussing the findings regarding the differences in variety-related strategies and supply chain performance depending on the level of customisation. This is followed by discussion on gaps in the literature regarding customisation and variety management. The results show that a high customisation context is associated with higher levels of differentiation, customer relationships, variety control, flexibility and agility than a low customisation context whilst a low customisation context is associated with a higher level of cost leadership than a high customisation context.

The final section is devoted to a comparison of the results between the UK and Korea. First, the research makes a comparison at each item level between the UK and Korea depending on the type of customisation. Then, a further comparison at the structural level is conducted based on the findings of this research. The results show that the UK exhibits a higher level of product variety, customer relationships and customer service than Korea, while Korea exhibits higher cost leadership, cost efficiency and agility than the UK.

7.2. THE IMPACT OF PRODUCT VARIETY ON BUSINESS FUNCTION PERFORMANCE

7.2.1. Impact according to customisation type

Business functions in this research are composed of five dimensions including Engineering, Manufacturing, Purchasing, Logistics and Marketing; business function performance comprises 37 sub-items. The results indicated that the impact of increased product variety typically decreased across the PS to PC continuum. This is as expected and is attributable to an increase of the business-function flexibility and agility in the highly customised types. Manufacturers providing highly customised products employ postponement strategies with small lots and modular production, initiatives that have been devised to support the inculcation of product variety into a manufacturing business. The average impact of an increase in product variety on each of the different business functions was found to be as follows: Marketing (m=4.84), Engineering (m =4.62), Manufacturing (m =4.29), Purchasing (m =4.01), and Logistics (m =3.86) (see Appendix 2). A detailed discussion follows on each item showing the significant differences.

The unit cost of the product exhibits a significant difference across the continuum of customisation types. Increased overheads, direct labour and material costs owing to increased product variety lead to a higher unit cost (Yeh and Chu, 1991). However, high level customisation types (e.g. PC and TC) typically utilise combinatorial modularity (see Salvador et al., 2004) in the design of product families with component sharing, which reduces the overhead cost, and the increase in the unit cost of a product can be reduced compared to low level customisation types (e.g. PS and SS) even allowing for PS and SS making use of appropriate economies of scale. PC rarely affects the unit cost of the product, as individually designed products ordered by customers have only minor fluctuations achieved through the use of a highly flexible job shop manufacturing methodology.

Manufacturing and material costs display statistically significant differences across the customisation types, and are in accordance with the expected trend across the continuum. PS incurs the highest escalation in manufacturing and material costs, followed by SS, CS, TC, and PC. The results highlight that a flexible manufacturing system (e.g. cellular, platform-based manufacturing) and supporting business-function designs are essential factors in mitigating the trade-off between product variety and increased manufacturing cost. By employing product-based strategies such as modularity and material standardisation, set-up cost, manufacturing cost, manufacturing overhead cost and lead time can be reduced and the flexible manufacturing processes can be enhanced (Fisher et al., 1999; Anderson, 2004).

Standardisation of parts and materials, together with postponement have become a dominant strategy for managing product variety (Martin and Ishii, 1997; Fisher et al., 1999; Davila and Wouters, 2007; Scavarda et al., 2010). Form postponement requires modular product architectures, and modularity is supported by the standardisation of materials (Feitzinger and Lee, 1997). Utilisation of standardised parts facilitates a reduction in set-up and new product introduction time in addition to increasing productivity. A postponement strategy also enables manufacturers to improve inventory turns, asset productivity, value chain flexibility and facilitate fast delivery, as well as delivery and customer service performance (Nair, 2005; Davila and Wouters, 2007). The ANOVA test demonstrates the highest increase in the use of standardised parts for PS, followed by CS, SS, TC, and PC. In addition, it is worthy of note that CS had the highest increase in the use of postponement, followed by PS, SS, TC, and PC. The result implies that the CS environments typically employ an assemble-to-order (ATO) production logic and are heavily reliant on postponement strategies and modularisation.

As expected, with respect to manufacturing (e.g. product) flexibility, low customisation types such as PS and SS are affected more than high customisation types due to an increase in the use of standardised materials. Process and part variety, manufacturing complexity and lead time are most adversely affected for low customisation types such as PS and SS with an increase in product variety. In such environments, product variety increases lead time significantly to allow for the additional process and manufacturing complexity (for example, set-up time) in the product innovation and/or introduction process. Therefore, the use of modularity not only shortens product development time but also lessens manufacturing complexity, thus reducing manufacturing lead time (Novak and Eppinger, 2001). According to Child et al. (1991), complexity costs range from ten to forty per cent of total costs, depending on the number of items, tasks, flows and inventory.

PS displays the highest increase in purchasing costs as product variety increases. The low customisation type suffers from a policy that typically requires the purchase of high volumes from selected suppliers and is consequently more adversely affected by increased parts and material variety than the more customised types. Further down the continuum, TC demonstrates the greatest increase in purchasing costs. Similarly, PS displays the highest increase in purchased components and parts, followed by CS, SS, TC and PC.

Market mediation costs including inventory holding, mark-down, and lost sales, are primarily influenced by demand uncertainty (Randall and Ulrich, 2001). Although uncertainty of demand increases and forecasting accuracy decreases generally from a make-to-stock (MTS) to a design-to-order (DTO) strategy, the PS type may be affected more in the cost of inventory holding, mark-downs, and lost sales due to the position of its de-coupling point. PC typically has low market mediation cost because of the upstream de-coupling point that allows inventory holding and stock-out costs to be affected less by an increase in variety. Work-in-process inventory such as semi-finished parts, exhibited the highest increases in cost under the low-level customisation types.

Longer average lead and delivery times due to high product variety require retailers to hold more inventories resulting in higher retailers' costs (Thonemann and Bradley, 2002). Thus, PS, in suffering from a low level of supply chain agility, displays the highest increase in terms of retailers' costs. However, low customisation types such as PS and SS also display the highest positive upsurge in customer satisfaction, market share, and competitive advantage. Therefore, the results reveal that an increase in product variety in low customisation types increases market competitive capability more than in high customisation types, however, the increase in product variety in low customisation types also imposes higher negative impact such as costs than high customisation types.

7.2.2. Impact according to the combinations of product variety and customisation

The high product variety with low customisation (HVLC) cluster displayed the highest increase in manufacturing cost with a product variety increase, followed by low variety with low customisation (LVLC), low variety with high customisation (LVHC) and high variety with high customisation (HVHC). Material costs are highest in the case of the HVLC cluster, followed by LVLC, HVHC, and LVHC clusters. HVLC manufacturing environments are influenced more than LVLC environments when variety increases. This is due to a more challenging set-up and higher material, labour, and overhead costs. Thus, as product variety increases, HVLC companies encounter a significant trade-off with manufacturing and material costs. HVLC and LVLC manufacturers typically supply long lifecycle products and focus on operational efficiencies with low margins via lean supply chain strategies. Such manufacturers require judicious decision-making when increasing product variety (for example, by focusing on peripheral rather than fundamental variety) and need to be cognisant of the position of the break-even point. In contrast, HVHC and LVHC clusters are not appreciably affected by product variety increases.

HVLC demonstrated a higher increase than LVLC in terms of manufacturing lead time due to the longer set-up times required to deal with process variety. Additionally, HVLC and LVLC exhibit a similar high increase in manufacturing complexity. Platform-based product development and cellular manufacturing systems (i.e. process flexibility) can be employed to reduce manufacturing lead time and manufacturing complexity, as well as to broaden product differentiation (Krishnan and Gupta, 2001; Qiang et al., 2001).

HVLC exhibited the highest increase in transportation costs for an increase in product variety followed by LVLC, LVHC, and HVHC. HVLC suffers from a requirement to deliver a higher proportion of less-than-truckload (LTL) transportations than LVLC. Thus, transportation costs increase mainly due to the complexity and imbalance between the level of customisation and product variety offered. In contrast, HVHC and LVHC clusters are not affected considerably by increases in product variety: high customisation clusters often require the direct delivery of products to customers, thus imposing the delivery costs on the end customer, which could, feasibly, reduce the overall cost associated with transportation.

For the analysis of the Marketing function, retailers' costs increased the most in the case of HVLC, followed by LVLC, HVHC, and LVHC. Inventory is considered to affect retailers' cost most severely in the case of HVLC. In addition, the inventory of the high customisation clusters associated with more upstream de-coupling points was less adversely affected than the low customisation clusters when variety was increased. Therefore, there is a minimal difference in retailers' cost between HVHC and LVHC. Also, demand forecast uncertainty does not increase much in high customisation clusters compared to low customisation clusters, while high variety clusters displayed a slightly higher increase in demand forecast uncertainty than the low variety clusters. The result implies that demand forecast complexity depends principally on the level of customisation. In addition, according to Lee (2002), low customisation clusters that typically provide functional products have a preference for efficient or risk-hedging supply chain strategies.

Overall, the research observed that the level of customisation is a more significant factor in determining the impact of product variety on business function performance than the level of existing product variety offered. However, the level of existing product variety also has considerable influence on certain aspects of business function performance particularly for an accompanying low level of customisation. HVLC is an important preliminary step to shift to a high level of customisation.

7.3. SUPPLY CHAIN DESIGN TO SUPPORT THE MANAGEMENT OF PRODUCT VARIETY INCREASES: THE RELATIVE RELATIONSHIP BETWEEN A VARIETY CONTROL STRATEGY AND SUPPLY CHAIN PERFORMANCE ACCORDING TO THE LEVEL OF CUSTOMISATION

High customisation has an earlier de-coupling point with more use of modularisation, postponement and cellular manufacturing systems compared to that of low customisation (see Tables 5-17 and 6-7). In addition, these variety control strategies typically improve supply chain flexibility and agility, which enhances cost efficiency and customer service for both low and high customisation (see Table 5-12). However, high customisation focuses more on customer service through supply chain flexibility and agility than low customisation. On the other hand, low customisation focuses more on cost efficiency through supply chain flexibility and agility, that allows economies of scale to be achieved. Thus, the relative impact of supply chain flexibility and agility on cost efficiency and customer service differ depending on the level of customisation.

In the overall dataset, VCS shows a statistically significant impact on both flexibility and agility. In addition, comparing path values among three constructs (i.e. from VCS to flexibility/agility and from flexibility to agility), supply chain flexibility mediates the impact between VCS and supply chain agility, in both the low and high customisation case. Furthermore, supply chain flexibility and agility have statistically significant impacts on both cost efficiency and customer service. Thus, one can conclude that VCS improves supply chain performance and manages the trade-off between product variety and supply chain performance in terms of cost reduction and improving customer service through supply chain flexibility and agility.

The results for low customisation indicate that supply chain flexibility and agility mediate VCS's impact on cost efficiency and customer service, while, relatively, customer service is not highly influenced by supply chain agility. Furthermore, in a low-customisation supply chain, agility does not guarantee better customer service ($p = 0.058$); instead, supply chain flexibility impacts cost efficiency and customer service directly. The results reveal that reaction capability (flexibility) rather than reaction time (agility) have a direct influence on customer service in the case of low customisation. In addition, supply chain agility resulting from supply chain flexibility also has a high impact on cost-efficiency performance, which is the target strategy in a low customisation, mass production scenario or with a low level of mass customisation (i.e. PS, SS and CS). This result reveals that supply chain agility is also an influential factor in enhancing cost efficiency in low-customisation scenarios. The reason for this can be found within the characteristics of low customisation. Low customisation focuses on price and reliability by employing MTS or ATO systems to enhance market competiveness via cost leadership. As a result, a lean (or leagility) supply chain strategy that focuses on cost efficiency weakens the effect of supply chain agility on customer service. Factors such as low product variety with low demand uncertainty, and long product life cycle in terms of product characteristics (i.e. functional products) also weaken supply chain agility.

In the case of high customisation, the value for the path coefficient of supply chain agility showed a higher impact on cost efficiency and customer service than the value for supply chain flexibility. Particularly concerning the link between supply chain agility and customer service, the research found a high coefficient value ($\beta = 0.346$) compared with the link between SC flexibility and customer service ($\beta = 0.188$). This result implies that supply chain agility resulting from supply chain flexibility is a crucial factor in enhancing customer service in high customisation situations. The results relating to the difference in the coefficients also highlight how reaction time (agility) influences customer service and cost efficiency more than reaction capability (flexibility) under a high customisation context. The reason for this can be found in the characteristics of high customisation. High customisation has an upstream de-coupling point that enables a rapid response to customer requirements and demand fluctuations. In addition, high customisation focuses on quality and service by using make-to-order (MTO) or design-to-order (DTO) to enhance competitive capability through product differentiation. Thus, high customisation utilises an agile (or leagile) supply chain strategy, which improves cost efficiency and customer service simultaneously. Moreover, high product variety – because of diverse customer requirements, competition with high demand uncertainty and short product lifecycles (innovative products) – generally strengthens supply chain agility in high customisation types such as TC and PC. Furthermore, it is notable that VCS showed no direct impact on supply chain agility in a high customisation situation. The result proves that an improvement in supply chain agility can be achieved through supply chain flexibility in high customisation environments.

This research confirms the fact that supply chain flexibility and agility resulting from a VCS have a positive impact on cost efficiency and customer service. Thus, though some firms with low customisation only focus on efficiency through a lean strategy in their manufacturing and logistics' functions, the results reveal that flexibility and agility through modularity, postponement and cellular manufacturing can also be key factors in managing the effects of increased product variety and in enhancing cost efficiency and customer service in the supply chain.

7.4. STRATEGY AND PERFORMANCE DIFFERENCES ACCORDING TO THE LEVEL OF CUSTOMISATION

Cost leadership and a high customer service (i.e. differentiation) are related to lean and agile supply chain strategies, respectively. The lean supply chain and agile supply chain are also related to low customisation focusing on efficiency and to high customisation focusing on flexibility/agility, respectively (Agarwal et al., 2006; Stavrulaki and Davis, 2010). This research expected to confirm that a high customisation context typically focuses on strategies associated with close customer relations, variety control and differentiation, and enhances supply chain flexibility, agility and customer service. In contrast, a low customisation context focusing on strategies of close partnership with suppliers and cost leadership enhances cost efficiency (see Table 3-3). This research also expected to find no difference in business performance according to the level of customisation and this too was proven (see Table 5-17).

Therefore, the results support the theory for high customisation in terms of customer relations, VCS, differentiation, supply chain flexibility and agility. In other words, high product customisation with a corresponding high product variety has a high level of customer relations, variety control and differentiation strategies supported by supply chain flexibility and agility. In particular, high customisation showed substantial differences in terms of the mean value of strategies for variety control (3.622>2.993), cost leadership (3.090<3.428) and differentiation (3.633>3.306), with low customisation at a significance level of 0.001. Customer service for high customisation scenarios (mean = 3.857) was higher than for low customisation scenarios (mean = 3.743); however, the result was not supported at the 0.05 significance level (p = 0.061).

In terms of low customisation contexts, the results support the theory that low customisation focuses on cost leadership. However, results for cost efficiency and partnerships with suppliers did not provide support to the theory. In respect of cost efficiency ($p = 0.612$), it can be seen that high customisation also has enough ability to minimise cost in terms of resources, manufacturing, distribution and inventory by employing various variety control strategies. Development of mass customisation is another reason for the results found for customer service and cost efficiency. Thus, the research suggests some reasons for this result.

The modularity enables companies to make changes in each element independently by varying only the corresponding component (part) without affecting other elements (parts) (Galvin and Morkel, 2001). In addition, a flexible manufacturing system such as cellular manufacturing or platform-based manufacturing promotes cost effective changeovers, and reduces material handling and inventory costs (Hyer and Wemmerlöv, 1984; Christopher, 2000). Postponement also improves inventory turns and asset productivity (Nair, 2005). In particular, the postponement approach has recently received considerable attention as one of the most beneficial methods to reduce costs and risks of product variety and improving the performance of supply chains (Davila and Wouters, 2007). Such a strategy may reduce supply chain cost and improve cost efficiency to a comparable level as that found in low customisation.

In the case of partnerships with suppliers, the results imply that high customisation usually involves a closer partnership with suppliers than for low customisation (close to a 0.05 significance level). This opposes the results of the standard, accepted theory. This research provides a number of possible explanations for this phenomenon.

Low customisation typically involves a collaborative supplier relationship with a long-term commitment, while high customisation involves opportunistic collaboration with low volume transactions (Stavrulaki and Davis, 2010). The joint product development/innovation and problem solving needed to respond to market orientation (e.g. co-creation) are, however, crucial for high-customisation environments. Sharing sensitive information such as financial, design or research information for product innovation with suppliers may strengthen trustful partnerships and allow rapid responses to customer needs when product variety is increased. For example, the integration of a cross-functional team with the supplier in high-customisation systems can enhance not only communication flow but also effective product development (Tummala et al., 2006). More companies are collaborating now with suppliers (e.g. supplier involvement) at the development stage and sharing resources such as development know-how (Monczka and Morgan, 1996). These can reduce variety cost and enhance supply chain flexibility. In addition, the early de-coupling point in high customisation systems enables a firm to focus on product development with the supplier by reducing operating costs. Thus, in spite of collaborative barriers, high customisation may give an incentive to closer supplier partnerships.

7.5. COMPARISON BETWEEN THE UK AND KOREA

7.5.1 Impact of product variety on business function performance

The results indicate that product variety has a significant positive impact on customer satisfaction, competitive advantage and market share in both the UK and Korea. On the other hand, product variety had a significant negative impact on engineering issues such as R&D costs and engineering design/change costs. Table 7-1 indicates for each country the business function performance most affected by increases in product variety.

In the UK, demand forecasting uncertainty is ranked second and scheduling complexity ranked third in terms of degree of impact by increased variety. This implies that the UK experiences difficulties in dealing with demand fluctuations and this may affect scheduling complexity in the Manufacturing function. In contrast, manufacturing cost is ranked second in Korea, which indicates that Korea may offer a relatively low level of customisation (i.e. more scale-efficient production) when compared to the UK; thus, manufacturing cost is highly affected by increased product variety. In addition, the results of the T-tests (Table 6-4) show that Korea had a higher degree of impact on key business function performances than the UK including the unit cost of products, manufacturing cost, material cost, market-mediation cost and labour cost. This result also supports the fact that the UK has a higher customisation structure with higher product variety than Korea.

Table 7-1 Impact of increased product variety on business function performance (Top 10 ranking)

	UK (n=163)			Korea (n=142)			
Rank	Code	Business function Performance	Mean	Code	Business function Performance	Mean
1	K4	**Competitive advantage**	5.33	K2	**Customer satisfaction**	5.24
2	K1	Demand forecast uncertainty	5.15	M2	Manufacturing cost	5.17
3	M12	Scheduling complexity	5.09	E2	**R&D cost**	5.04
4	K2	**Customer satisfaction**	4.94	K3	**Market share**	4.97
5	E1	Design complexity	4.88	M13	Material cost	4.95
6	K3	**Market share**	4.82	M16	Process technology investment cost	4.94
7	E2	**R&D cost**	4.77	P1	Purchasing cost	4.86
8	E4	**Engineering design and change cost**	4.70	K4	**Competitive advantage**	4.85
9	M10	Manufacturing complexity	4.64	E4	**Engineering design and change cost**	4.77
10	M6	Manufacturing flexibility	4.54	M9	Part variety	4.76

Note : Boldface indicates coincident performance by both the UK and Korea companies.

In addition, based on the theory by Randall and Ulrich (2001), both the UK and Korea supply production dominant variety since variety is production dominant if the increase in production costs associated with increased variety outweighs the increase in market-mediation costs. For example, variation in body styles of an automobile is production dominant because of the huge tooling investments associated with creating that variety. Conversely, variety is mediation dominant if the increase in mediation costs associated with increased variety outweighs the increase in production costs. For example, variation in trim colours of an automobile is mediation-dominant because the impact of additional colours on production costs is minimal, while the impact on inventory and stock-out costs is substantial. As a result, firms with scale-efficient production will offer types of variety associated with high production costs (e.g. fundamental and intermediate varieties), and firms with local production will offer types of variety associated with high market-mediation costs (e.g. peripheral varieties) (Randall and Ulrich, 2001). Therefore, Korea would be better off by attempting to aggregate the production volume of different geographic markets into one facility in order to achieve scale-efficient production, since manufacturing cost showed the highest impact on the cost due to increased product variety. Additionally, focusing on mediation-dominant variety (e.g. peripheral variety) could be one option to reduce manufacturing cost. In contrast, the UK shows a relatively low variety impact on both manufacturing and market-mediation costs. An improvement in logistics performance in the UK may mitigate the trade-off between aggregating production and the market-mediation cost.

7.5.2. A UK / Korea comparison according to customisation type

As expected, the UK had higher product variety (i.e. fundamental, intermediate and peripheral variety), longer lead time and a higher number of major competitors than Korea. In addition, higher customisation types (e.g. TC and PC) had a longer lead time than low customisation types (e.g. PS and SS) in both the UK and Korea. In Korea PS had the highest number of competitors from among the five customisation types.

In respect of variety-related strategies, VCSs and differentiation (D2) showed a higher mean value in high-customisation types (e.g. PC and TC), while cost leadership (CL1) was dominant in cases of low customisation (e.g. PS and SS) in both countries. However, partnerships with suppliers and customer relations showed no differences across the five types of customisation except for PAS2 (i.e. close relationships in product development) in Korea. Therefore, even though some items did not show significant differences, the results showing statistical significance from both countries support the findings that high customisation types focus on VCS (i.e. VCS1, VCS2 and VCS3) and differentiation (i.e. D2), while low-customisation types focus on cost leadership (i.e. CL1).

With regard to supply chain performance, supply chain flexibility is typically higher in high customisation types (e.g. PC and TC) in both countries. However, FL1 (ability to change quantity of supplier order) and FL3 (ability to change production volume) displayed the highest performance in the CS type in the UK. On the other hand, agility items showing statistical significance typically exhibited higher performance in high customisation types (e.g. PC and TC) in both countries. AG4 (ability to rapidly improve level of customer service) and AG5 (ability to rapidly improve delivery reliability) did not show significant differences according to customisation types in either country.

As expected from the results reported in Section 5.6.3 (see Table 5-17), there were no significant differences in cost efficiency across the different types of customisation except for CE3 (ability to minimise total cost of manufacturing) in the UK. Interestingly, for the UK, customer service items showing statistical significance (i.e. manufacturing lead time, customer complaint reduction and stock-out reduction) reached their highest levels under a CS regime. Business performance showed significant differences only with BP4 (sales growth) in the UK. Therefore, the results showing statistical significance from both countries support the findings that high customisation is typically associated with higher variety control strategy (i.e. VCS1, VCS2 and VCS3), differentiation (i.e. D2), supply chain flexibility (i.e. FL5) and agility (i.e. AG1, AG2, AG3, AG6 and AG7).

7.5.3. Overall Comparison between the UK and Korea

The results (Figure 6-2) illustrate the fact that the UK has a higher level of variety ($p < 0.001$), customisation ($p < 0.1$), customer relationships ($p < 0.001$), customer service ($p < 0.05$), differentiation ($p < 0.1$) and business performance ($p < 0.05$), while Korea exhibits higher performances in cost efficiency ($p < 0.01$), cost leadership ($p < 0.001$) and supply chain agility ($p < 0.001$). The results support the fact that high customisation context focuses more on differentiation, customer service, customer relationships and product variety (Stavrulaki and Davis, 2010). In addition, higher levels of production dominant variety (e.g. fundamental and intermediate variety) are positively related with high-volume production (Randall and Ulrich, 2001). Thus, this suggests that Korea focuses more on scale-efficient production (e.g. production-dominant variety) with a relatively lower level of customisation than the UK. The reasons for this include the following:

- The UK business function performance is affected less by increases in variety than Korea is (see Table 6-4).
- Increased product variety in Korea imposes a higher increase on manufacturing cost (mean =5.17) compared with the UK (mean =4.23).
- The UK has higher variety in terms of intermediate and peripheral variety (mean =3.83 and 3.69 respectively) than fundamental variety (3.67), while Korea has higher variety in its fundamental (mean =3.08) and intermediate variety (mean =3.08) than in its peripheral variety (mean=2.95).
- The UK has a higher performance than Korea in terms of differentiation (3.51 > 3.36), customer service (3.85 > 3.72), customer relationships (4.17 > 3.82), customisation (3.23 > 2.98), product variety (3.74 > 3.04) and order lead time (4.17 > 3.76), while Korea has a higher performance than the UK in terms of cost leadership (3.42 > 3.18) and cost efficiency (3.50 > 3.32) at an acceptable significance level (see Table 6-17).

- The UK had the largest number of competitors in the PC type (mean =3.22), while Korea had the largest number of competitors in the PS type (mean =3.38).

However, it is notable that Korea has higher agility performance than the UK, which runs counter to the expectation that the higher the level of customisation the higher level of agility. One explanation for this concerns trade competence and dependence in terms of a country's economic background. Supply chain activities developed for a quick response as a form of distinctive competence can enable firms to achieve cost and service-based competitive export advantages (Piercy et al., 1998). In short, supply chain agility is a critical factor affecting overall global competitiveness (Swafford et al., 2006). Christopher et al. (2006) also stressed that agility and responsiveness are increasingly fundamental to competitive success in global business activity such as global sourcing and offshore manufacturing. Thus, a global supply chain should develop an agile supply chain that allows firms to improve their trade performance and manage demand and supply uncertainty by being more responsive to unexpected change. Thus, a country focusing on export competitiveness may have a global supply chain network structure with a high level of agility. For example, total export volume in Korea (US$ 557 billion) is higher than for the UK (US$ 495 billion) and shows a high dependence, at nearly 48 per cent of GDP in 2011, while exports in the UK were 20 per cent of GDP in 2011.

Accordingly, the UK requires careful consideration in terms of local production, since the UK offers many types of variety associated with high market-mediation costs such as peripheral variety. Furthermore, the proximity of production facilities to the target market also enhances supply chain agility (Lee, 2004). In contrast, Korea needs to focus on centralised production to reduce high production costs resulting from high production-dominant varieties such as fundamental variety. Furthermore, Korea needs to undertake a structural shift to a high level of mass customisation (e.g. CS) in order to mitigate the negative impact of product variety on business function performance. In reality, the most dominant trend has not been towards PC, but towards the middle position of CS (Lampel and Mintzberg, 1996). Additionally, Korea should improve its logistics performance (currently ranked currently at 21st in the world) in order to mitigate market mediation costs including inventory holding cost, mark-down cost and lost sales as compared to the UK (ranked 10th in the world). It is notable that Korea had low business performance when compared to the UK, especially relating to sales growth.

Lastly, regarding the fundamental question as to the reason for the difference in the level of product variety, this research has considered the level of customisation and competition (Silveira, 1998) as factors that motivate variety increases. That is, a high level of product variety is closely related to the level of product customisation in terms of the product differentiation strategy, and number of major competitors in terms of the market environment:

- The UK employed product customisation above the CS level, while Korea employed product customisation below the CS level.
- The UK (mean =2.94, highest in PC) has more intense competition in the market than Korea (mean =2.72, highest in PS).

7.6. CHAPTER SUMMARY

The main purpose of this chapter was to discuss and compare the results stemming from the statistical analysis of the research data. The chapter began with the interpretation concerning the impact of product variety on business function performance according to the level of customisation, and the combination of the level of customisation and variety offered. Then, the chapter focused on a discussion of the association between VCS and supply chain performance depending on the level of customisation. After discussing the findings according to the level of customisation, finally, the chapter compared the difference in degree of variety impact, strategy and performance between the UK and Korea at both the item level and overall structural level, followed by suggestions on appropriate strategies for the UK and Korea to improve performance.

CHAPTER EIGHT

CONCLUSIONS

8.1. INTRODUCTION

This chapter draws overall conclusions by highlighting the findings and contributions of the research work carried out. It begins by addressing the research questions introduced in Chapter 1. Then, it illustrates the key findings and contributions of the research. Finally, it addresses some of the limitations this research is exposed to and provides some idea for future research.

8.2. RESEARCH FINDINGS FROM RESEARCH QUESTIONS

The main purpose of this research was to assess the impacts of product variety on business function performance and to test a model designed to support the management of impacts of variety on the supply chain qualified by the level of product customisation. Then, further investigation was undertaken to show differences in variety-related strategies and supply chain performance resulting from differences in the level of customisation. Finally, a comparative study of the UK and Korea was undertaken based on these findings. From the literature review carried out Chapter 2, there are numerous variety impacts and strategies available to manage the trade-off between product variety and supply chain performance. However, a variety-related strategy and supply chain performance should be considered alongside the level of product customisation. This relates to the de-coupling point where customer input takes place and approaches to variety-related strategy differ according to the level of customisation, which results in different outcomes in supply chain performance.

From this perspective, the research approach developed a research framework and associated hypotheses to be empirically tested (Chapter 3). The framework and hypotheses established tested the core research questions set out in Chapter 1:

Q1.1. How does an increase in product variety affect business function performance?

Q1.2. Does an increase in product variety impact on business function performance differently according to differences in the level of product customisation offered?

Q2.1. What is the association between a variety control strategy and supply chain performance?

Q2.2. Is the relationship between a variety control strategy and supply chain performance affected by differences in the level of product customisation?

Q3. What are the differences in variety-related strategy and supply chain performance according to differences in the level of product customisation?

Q4.1. What are the differences in variety, customisation, variety-related strategies and supply chain performance that exist between the UK and Korea?

Q4.2. Which factors are responsible for creating the differences in the level of product variety? and what are the appropriate policies for each country?

In elaborating on these key research questions, an empirical study employing a postal questionnaire survey method was carried out. Drawing on a sample of 364 manufacturing firms located in the UK and Korea, a number of statistical analyses were undertaken to find answers to the research questions and related hypotheses posed. The research explored answers to the questions with some significantly new and different results. An explicit explanation of the findings follows.

8.2.1. Impact of product variety on business function performance

In respect to Q1.1 and 1.2, the research examined the impact of product variety on the performance of five business functions: Engineering, Manufacturing, Purchasing, Logistics and Marketing across 162 manufacturing companies. Each company was classified as belonging to one of five customisation types: pure standardisation (PS), segmented standardisation (SS), customised standardisation (CS), tailored customisation (TC) or pure customisation (PC), which provided a continuum across which performance trends could be assessed. The research also investigated the relationships between business function performance, degree of customisation and the level of product variety offered. An increase in product variety was found to have a differential influence on business function performance depending on the combination of the degree of customisation and the level of product variety offered. Overall, the Marketing function was found to be impacted the most by an increase in product variety, followed by the Engineering, Manufacturing, Purchasing and Logistics function.

There were a number of additional key findings. The thesis found that TC environments displayed the highest level of product variety when compared against the fundamental, intermediate and peripheral dimensions of variety considered. A low degree of product customisation (in PS and SS environments) was found to have a more significant effect on business function performance than a high degree of customisation for a number of key functional attributes. These included the unit cost of the product, manufacturing cost, manufacturing lead time, manufacturing complexity and material cost. The research also revealed that an increase in product variety in low customisation types increases competitive capability in terms of customer satisfaction, market share and competitive advantage more than for high customisation types. However, product variety increases in low customisation types also impose higher costs than for high customisation types. Additionally, product variety increases in low customisation types were found to lead to a higher take-up of variety control strategies (e.g. the use of standardised parts, postponement, and manufacturing flexibility) than for high customisation types.

Furthermore, the prevailing degree of customisation was found to be a more significant factor than the existing level of product variety in determining the impact of an increase in variety on a number of key functional attributes including manufacturing cost, material cost, transportation cost, manufacturing complexity, manufacturing lead time and demand forecast uncertainty. HVLC demonstrated a consistently higher degree of negative impact on most aspects of business function performance than LVLC. Another apparent mismatch cluster, LVHC, also showed a higher negative impact than HVHC in some aspects of performance (for example, manufacturing and transportation costs). However, the degree of impact was lower than for low customisation clusters (HVLC, LVLC). The HVLC type needs to follow a seemingly contradictory path due to the mismatch between the level of variety and customisation; in short, reducing variety with a focused factory or increasing variety with flexible manufacturing by investing in process technology to shift to the higher level of customisation.

8.2.2. Supply chain design to support the management of product variety increases: the relative relationship between a variety control strategy and supply chain performance

With respect to the research questions Q2.1 and 2.2, the research tested the supply chain model designed to support the management of increases in variety. A focused factory rather than increased supply chain flexibility may reduce a company’s competiveness when considering long-term profit. Thus, the study developed the concept of a model in which the major activities that control product variety (such as modularisation, postponement and cellular manufacturing) are crucial requirements to achieve supply chain flexibility, agility, cost efficiency and customer service. First, this study investigated the general relationships between a variety control strategy and extended supply chain performance constructs. Three variety control strategies were considered, and four dimensions of supply chain performance were examined adding supply chain agility measures into supply chain performance metrics. Second, the research also examined the relative relationships among VCS and supply chain performance according to the level of customisation since their different de-coupling points may affect variety control strategies employed and also influence supply chain performance.

There were a number of key findings. First, this study provides insight by testing hypotheses that VCS positively impacts on supply chain flexibility and supply chain agility, which results in cost efficiency and improved customer service. Thus, the research supports the general belief that investment in three major VCSs improves final supply chain performance and manages the trade-off between them through supply chain flexibility and agility. Second, in terms of the relationship between different aspects of supply chain performance, supply chain agility resulting from supply chain flexibility had a positive impact on cost efficiency and customer service for both customisation levels. Therefore, the results generally show that a firm with a major VCS, supply chain flexibility (i.e. reaction capability) and supply chain agility (i.e. reaction time) has more potential to achieve cost efficiency and better customer service than a firm that only focuses on VCS in both high and low customisation environments. However, supply chain agility plays a crucial role in improving both cost efficiency and customer service in high customisation scenarios, while supply chain agility in low customisation types plays a relatively insignificant role, particularly in terms of customer service than for high customisation types.

Lastly, firms with high customisation utilising a VCS at the upstream de-coupling point in the supply chain, experienced higher levels of improvement in supply chain flexibility than those with low customisation that had a downstream de-coupling point in the supply chain. Thus, the earlier practice of a VCS in the supply chain structure can improve supply chain flexibility more, resulting in higher efficiency and better customer service. For example, an upstream de-coupling point in a high customisation system can focus on joint product development with the supplier by reducing operation costs.

8.2.3. Strategy and performance differences according to the level of customisation

Variety-related strategies (e.g. variety control strategy, partnership with suppliers, customer relationships, cost leadership and differentiation) and supply chain performance (e.g. supply chain flexibility, agility, cost efficiency, customer service) differ in their approaches according to the level of customisation. Therefore, the research consisted of theory testing (see Table 3-3), which is related to research question Q3.

There were three key findings. First, this research proved the theory through empirical survey research that firms with a high level of customisation focus more on customer relations, VCS and differentiation. These result in a high level of supply chain flexibility and agility when compared with firms having a low level of customisation. In contrast, firms with a low level of customisation were concerned with cost leadership.

Secondly, however, low customisation context does not result in a higher level of supply chain cost efficiency than a high customisation context. The results reveal that even a high customisation system (e.g. high level of mass customisation) also has enough ability to minimise costs in terms of resources, manufacturing, distribution and inventory by employing various strategies to manage variety, and increase supply chain flexibility and agility.

Lastly, in terms of partnership with suppliers, the results imply that high customisation environments have more close partnerships with suppliers than low customisation environments, which runs counter to results of the typically accepted theory. High customisation with a correspondingly high level of product variety involve more close relationships, particularly in joint product development (i.e. cross-functional teams), problem solving and performance evaluation with suppliers.

8.2.4. Comparison between the UK and Korea

Regarding research questions Q4.1 and 4.2, a comparison based on the research findings was conducted. Evidence was found that suggests that, typically, Korea is more focused on scale-efficient production with relatively lower product customisation than the UK.

Firstly, in the UK, product variety typically exerts a lower impact on business function performance than Korea including the unit cost of the product, manufacturing cost, material cost, market-mediation cost and labour cost. Particularly, an increase in product variety in Korea imposes a higher increase on manufacturing costs as compared with the UK. However, variety increases have a lower impact on both manufacturing and market-mediation costs in the UK.

Secondly, manufactured products in the UK have higher intermediate and peripheral forms of variety than fundamental variety; while Korea has higher fundamental and intermediate variety (i.e. higher production dominant variety) than peripheral variety. In addition, the UK had the largest number of competitors in PC, while Korea had the largest number of competitors in PS.

Finally, the overall comparison (see Table 6-17) between the two countries proved that the UK demonstrated higher levels of product variety, customisation, customer relationships, customer service, differentiation and business performance than Korea. On the other hand, Korea displayed higher cost leadership attributes and cost efficiency than the UK. These results indicate that Korea is more focused on scale-efficient production with lower product variety compared to the UK. However, that Korea has a more agile supply chain than the UK, probably due to its high dependence on trade, is seen as an interesting result.

In regard of the research question Q4.2 on the causes of product variety, the comparison considered differences in market and supply chain environments of the two countries. Two results mainly emerged. First, the UK displayed a higher level of product customisation than Korea. Second, firms in the UK face higher level of competition in the market than Korea. Additionally, the UK exhibits excellent logistic performance to support variety management compared to Korea.

8.3. CONTRIBUTIONS AND IMPLICATIONS OF THE STUDY

Several contributions and implications have been developed in this thesis concerning both theory and managerial practice as suggested below.

Regarding the survey that investigated the impact of product variety on business function performance, the research makes two significant contributions. Firstly, it establishes how business function performance is affected by an increase in product variety. A corollary, that is also provided for this contribution is the subsequent implications for business function design. Secondly, it explains how different levels of product variety and customisation impact on specific aspects of business function performance.

Therefore, the specific findings resulting from survey 1 have important managerial implications for the adoption of different approaches to variety under different customisation profiles. In addition, the results of this research support organisational decision-making by providing managers working in manufacturing environments with guidance on how to better manage heterogeneous market requirements and product variety ambitions. Specifically, the research provides managers working in different types of manufacturing plant, classified in the research using a five stage continuum from PS to PC, with evidence of how business functions are affected by an increase in product variety. Within the overall evidence set, managers are provided with the implications of variety increases on a comprehensive series of performance items typically required for the effective organisation and management of different business functions. Such insight is particularly valuable for manufacturing concerns that are considering changing the heterogeneity of their product base through product variety increases.

In addition, for academics, the thesis offers a significant contribution to the operations and supply chain literature. First, the findings reported in this research provide a better understanding of the potential impact of product variety on overall business function performance. Forty-seven business function performance that can be impacted by increases in product variety are identified. Second, the thesis determined the relative differences in the impact of product variety on business function performance according to five types of customisation. Investigation of this relationship by employing five types of customisation has rarely been carried out.

With regard to supply chain design to support the management of variety increases, the research reveals two significant contributions. Firstly, it establishes how major VCSs affect supply chain performance. As a corollary, this research provides a structural procedure to manage the trade-off between product variety and supply chain performance. In addition, VCS is developed based on three dimensions: product-based flexibility (i.e. modularity), process-based flexibility (i.e. cellular manufacturing) and structural-based flexibility (i.e.

postponement). Supply chain performance also comprised four dimensions: supply chain flexibility, agility, cost efficiency and customer service. This research then employed the supply chain flexibility and agility concepts to mediate the relationship between VCS and ultimate supply chain performance; that is, cost efficiency and customer service, based on links resulting from the literature review (see Beamon, 1999 and Scavarda et al., 2010). In particular, by adding supply chain agility as an external competence focusing on reaction time, the design model separated supply chain agility and supply chain flexibility that is a necessary internal capability needed to achieve agility. Therefore, this study was the first empirical attempt to examine the impact of VCS on different dimensions of supply chain performance, including supply chain agility using a large sample of 364 manufacturing industries. In other words, the thesis supports the general theories on relationships between fundamental variety control strategy and supply chain performance with a concept of the level of customisation. In particular, the fact that supply chain flexibility and agility positively improve the cost efficiency (i.e. the ability to minimise cost in the supply chain) has notable theoretical implications supported by Narasimhan and Jayaram (1998), Graves and Tomlin (2003) and Chan (2003). Secondly, it explains how different levels of customisation work differently on the relationship between VCS and supply chain performance. Although supply chain agility in low customisation environments plays a minor role particularly in terms of customer service, agility has a positive influence on cost efficiency and customer service in both the high and low levels of customisation. This result is supported by the theories of Hiroshi and David (1999), Agarwal et al. (2006) and Hallgren and Olhager (2009). Therefore, this research suggests that the procedure to manage variety impacts on the supply chain is through VCS, supply chain flexibility and agility.

The research findings from survey 2 also have important managerial implications for the adoption of different approaches to VCS, supply chain flexibility and agility under different levels of customisation. The findings provide guidance for manufacturers which have to manage the negative impacts of variety increases and the associated risks when product variety increased. Thus, it is necessary for a manufacturer to evaluate the strengths and weaknesses of their VCS, supply chain flexibility and agility needed to deploy those variety-related capabilities that gain competitive market position. In addition, it is also an important managerial recommendation that the earlier practice of VCS in the supply chain stream is better in terms of improving supply chain flexibility, which results in higher efficiency and better customer service.

Regarding strategy and performance differences according to the level of customisation, the research has one main contribution for academic. The findings prove the general theory relating to characteristics of high and low customisation (see Table 3-3) and the findings provide the basis of a more general theory in terms of customer relationships, variety control strategy, supply chain flexibility, supply chain agility, cost leadership and differentiation (see Agarwal et al., 2006; Stavrulaki and Davis, 2010). Most of the results supported the theoretical assumptions; however, partnership with suppliers displayed contradictory results and shows higher performance in a high customisation context rather than a low customisation context. Therefore, this result stresses the both theoretical and managerial implication that high customisation requires a strong partnership with the suppliers in such aspects as joint product development and problem solving with cross-functional teams.

Lastly, regarding the comparison between the UK and Korea, this research has contributed to several areas. For theoretical implications, the research findings were confirmed by comparing Korea and the UK. The comparison supports the theory that high customisation context focuses more on customer relationships and product variety while low customisation context focuses more on cost efficiency and cost leadership (Stavrulaki and Davis, 2010). In addition, the comparison supports the theory that higher levels of production dominant variety (e.g. fundamental and intermediate variety) are positively related with high-volume production and low customisation context (Randall and Ulrich, 2001). Secondly, the findings highlighted the fact that the fundamental reason for the difference in the level of product variety between the two countries was based on the market competitiveness (Silveira, 1998) and supply chain environment, including the level of customisation (Silveira, 1998) and supply chain/logistics performance.

For counties, the comparison – at both the specific item level and overall structural level – reveals the weaknesses and strengths of the countries under consideration. Furthermore, the research suggests appropriate strategies using this comparison. For Korea, the higher manufacturing cost due to increased product variety with a relatively low level of customisation is a major issue that needs to be overcome. On the other hand, the UK has a relatively lower supply chain agility compared to its level of customisation. Therefore, the findings will help international companies to set up specific strategies to enter both countries' markets.

More importantly, the research contributes to the current literature by arguing that the complex relationship between product variety and supply chain performance varies depending on the level of customisation. Each level of customisation has a different operational structure such as MTS, ATO, MTO and DTO due to the different de-coupling points (i.e. customer involvement points). Furthermore, different levels of customisation have different strategies and approaches to support effective purchasing, manufacturing, logistics, marketing and supply chain management. Therefore, this research firstly investigated the impact of product variety on business function performance depending on the five types of customisation including PS, SS, CS, TC and PC. Then, the model (i.e. supply chain design to support the management of variety increases) was also tested depending on the level of customisation (i.e. low and high customisation). Lastly, this research directly investigated the difference in variety-related strategies and supply chain performance according to the types of customisation, the level of customisation and for different countries. Such an approach can help managers to improve their understanding of the relationships that exist between product variety, customisation, variety-related strategies and performance, and identify how the VCS affects supply chain performance for different levels of customisation. Table 8-1 exhibits a summary of research contributions and implications.

Table 8-1 Summary of research contributions and implications

Research	***The impact of product variety on business function performance according to the level of customisation***
Contribution	➢ Establish how business function performance is affected by an increase in product variety. ➢ Explain how different levels of customisation and product variety impact differently on specific aspects of business function performance.
Implication	➢ Provide a better theoretical understanding of the potential impact of product variety on overall business function performance with a concept of customisation. ➢ Managerial implications for the adoption of different approaches to variety under different customisation profiles. ➢ Provide guidance on how to better manage heterogeneous market requirements and product variety ambitions according to levels of customisation.
Research	***Supply chain design to support the management of variety increases (The relative relationship between a variety control strategy and supply chain performance according to the level of customisation)***
Contribution	➢ Establish how major VCSs affect supply chain performance. ➢ Explain how different levels of customisation work differently on the relationship between a VCS and supply chain performance.
Implication	➢ Supports the general theories in relationships between fundamental variety control strategy and supply chain performance with a concept of level of customisation. ➢ Provide a structural procedure to support the management of the trade-off between product variety and supply chain performance through VCSs, supply chain flexibility and agility. ➢ Offer managerial suggestions for the adoption of different approaches to VCSs, supply chain flexibility and agility under different levels of customisation.
Research	***Variety-related strategies and SC performance differences according to the level of customisation***
Contribution	➢ Theory testing related to the characteristics of high and low customisation.
Implication	➢ Provide the basis of a more general theory ➢ Provide appropriate strategies under different levels of customisation. ➢ Improve managers' understandings of the relationships that exist between product variety, customisation, variety-related strategies, and supply chain performance.
Research	***Comparison between the UK and Korea***
Contribution	➢ Highlight the fundamental reasons for the difference in the level of product variety. ➢ Investigate the weaknesses and strengths of the countries for variety issues.
Implication	➢ Support the theory between product variety issues and customisation. ➢ Support decision making for both countries (and international companies) to set up specific strategies to achieve global competitiveness.

8.4. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

While this study contributes to the existing literature in various ways, similar to every contribution, the research and the chosen method have been subject to some limitations, which may have effects on the results.

Firstly, in the methodology, this study focused exclusively on manufacturing industries in the United Kingdom and Korea when examining the research hypotheses. This particularity may limit the ability to generalise the findings to other populations, considering competitive, environmental and cultural differences that exist between different countries and regions (Hughes and Morgan, 2008). In addition, the separated sample used to compare Korea and the UK does not show distinct differences due to minor differences in economic size, level of product variety and customisation. Thus, comparison with other developing countries could be one of the future areas of research. Furthermore, since data were collected from a single informant in each manufacturing company, a common method bias still exists, though some approaches were considered in this research to remedy matters.

Secondly, there are some limitations associated with survey 1. This research focused on a principal customisation type of each manufacturer in order to investigate differences according to type of customisation. However, mixed rather than single customisation types commonly occur, as shown in the descriptive results. The implications, trade-offs and synergies associated with such multiple scenarios have not been considered.

Thirdly, the single customisation type also had some limitations associated with survey 2. The research tested and compared data according to two levels of customisation (low and high) by employing cluster analysis based on a principal customisation type chosen from among five types of customisation. VCS with combinational customisation (e.g. SS+CS+TC) may have a different set of relationships with supply chain performance. An appropriate topic for future research concerns the examination of how manufacturers can optimise the provision of multiple products with actual mixed customisation. In addition, future research can investigate the relationship that exists between the variety-related strategy, performance and actual mixed-customisation environments.

Fourthly, to achieve the parsimony of the proposed model, the thesis did not investigate the relationship between VCS and business performance. Therefore, an appropriate topic for future research concerns the examination of how a company can optimise VCS and improves business performance, since a high level of business performance (e.g. ROA, ROI, market and sales growth) is required to keep a firm in business. In order to increase accuracy and reliability, those financial measures should be collected as a specific dataset through interview-based survey research or field-based case studies. In addition, other external variety-related strategies such as supplier involvement, customer involvement and communication technologies can be investigated alongside the general VCS employed in this research.

Lastly, the variety has been explored and examined in terms of three types (i.e. fundamental, intermediate and peripheral variety) from the perspective of the manufacturer. This may not be perfect when comparing actual variety among various industry types. Thus, further research is required considering market-based variety that has a more specific focus on customers as well. Furthermore, future research could conduct qualitative research such as field-based studies (i.e. action research), longitudinal case studies and case surveys to understand more fully the impact of product variety on the supply chain, strategy and performance by measuring actual product variety.

8.5. CHAPTER SUMMARY

The conclusion was devoted to explaining the key findings, main contributions and potential limitations associated with this study. This chapter first addressed the findings as they related to the research questions introduced in Chapter 1. Following this, the focal contributions and implications of this research were outlined. Finally, the major research limitations were elaborated and directions for future research were also discussed.

REFERENCE

Abdi, M.R. and Labib, A.W. (2004) 'Grouping and selecting products: The design key of Reconfigurable Manufacturing Systems (RMSs)', *International Journal of Production Research*, 42 (3), pp. 521-546.

Abegglen, J.C. and Stalk, G. (1985) *Kaisha, the Japanese Corporation*, New York, Basic Books.

Agarwal, A., Shankar, R. and Tiwari, M.K. (2006) 'Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach', *European Journal of Operational Research*, 173 (1), pp. 211-225.

Aitken, J., Christopher, M. and Towill, D. (2002) 'Understanding, implementing and exploiting agility and leanness', *International Journal of Logistics: Research & Applications*, 5 (1), pp. 59-74.

Alford, D., Sackett, P. and Nelder, G. (2000) 'Mass customisation: An automotive perspective', *International Journal of Production Economics*, 65 (1), pp. 99-110.

Amaro, G., Hendry, L. and Kingsman, B. (1999) 'Competitive advantage, customisation and a new taxonomy for non make-to-stock companies', *International Journal of Operations & Production Management*, 19 (3/4), pp. 349-371.

Anderson, C. (2006) *The Long Tail: Why the Future of Business is Selling Less of More*, New York, NY, Hyperion Press.

Anderson, D.M. (2004) *Build-to-Order and Mass Customization: The Ultimate Supply Chain Management and Lean Manufacturing Strategy for Low-Cost On-Demand Production without Forecasts or Inventory*, Cambria, CA, CIM Press.

Anderson, J.C. and Gerbing, D.W. (1988) 'Structural equation modeling in practice: A review and recommended two-step approach', *Psychological Bulletin*, 103 (3), pp. 411-423.

Anderson, S.W. (1995) 'Measuring the impact of product mix heterogeneity on manufacturing overhead cost', *Accounting Review*, 70 (3), pp. 363-387.

Armstrong, J.S. and Overton, T.S. (1977) 'Estimating nonresponse bias in mail surveys', *Journal of Marketing Research*, 14 (3), pp. 396-402.

Arntzen, B.C., Brown, G.G., Harrison, T.P. and Trafton, L.L. (1995) 'Global supply chain management at digital equipment corporation', *Interfaces,* 25 (1), pp. 69-93.

Arvis, J. F., Mustra, M. A., Ojala, L., Shepherd, B. and Saslavsky, D. (2012) *Connecting to Compete: Trade Logistics in the Global Economy*, Washington, D.C., World Bank.

Bagozzi, R.P., Yi, Y. and Phillips, L.W. (1991) 'Assessing construct validity in organizational research', *Administrative Science Quarterly,* 36 (3), pp. 421-458.

Banker, R.D., Datar, S.M., Kekre, S. and Mukbopadbyay, T. (1990) *Cost of product and process complexity, in R. S. Kaplan, Measures of Manufacturing Excellence*, Boston, MA, Harvard business school press, pp. 269-290.

Baraldi, A.N. and Enders, C.K. (2010) 'An introduction to modern missing data analyses', *Journal of School Psychology,* 48 (1), pp. 5-37.

Barnes, D. (2008) *Operations Management: An International Perspective,* London, Thomson.

Bayus, B.L., Erickson, G. and Jacobson, R. (2003) 'The financial rewards of new product introductions in the personal computer industry', *Management Science,* 49 (2), pp. 197-210.

Beamon, B.M. (1998) 'Supply chain design and analysis: Models and methods', *International Journal of Production Economics,* 55 (3), pp. 281-294.

Beamon, B.M. (1999) 'Measuring supply chain performance', *International Journal of Operations & Production Management,* 19 (3/4), pp. 275-292.

Benjaafar, S., Joon-Seok, K. and Vishwanadham, N. (2004) 'On the effect of product variety in production–inventory systems', *Annals of Operations Research,* 126 (1/4), pp. 71-101.

Bernardes, E.S. and Hanna, M.D. (2009) 'A theoretical review of flexibility, agility and responsiveness in the operations management literature toward a conceptual definition of customer responsiveness', *International Journal of Operations & Production Management*, 29 (2), pp. 30-53.

Berry, W.L. and Cooper, M.C. (1999) 'Manufacturing flexibility: Methods for measuring the impact of product variety on performance in process industries', *Journal of Operations Management*, 17 (2), pp. 163-178.

Bhandwale, A. and Kesavadas, T. (2008) 'A methodology to incorporate product mix variations in cellular manufacturing', *Journal of Intelligent Manufacturing,* 19 (1), pp. 71-85.

Blecker, T. and Abdelkafi, N. (2006) 'Complexity and variety in mass customization systems: Analysis and recommendations', *Management Decision,* 44 (7), pp. 908-929.

Bowersox, D.J. and Closs, D.J. (1996) *Logistical Management: The Integrated Supply Chain Process*, New York, McGraw-Hill.

Bozarth, C.C., Warsing, D.P., Flynn, B.B. and Flynn, E.J. (2009) 'The impact of supply chain complexity on manufacturing plant performance', *Journal of Operations Management*, 27 (1), pp. 78-93.

Bradley, N. (2007) *Marketing Research: Tools & Techniques*, Oxford, Oxford University Press.

Broekhuizen, T.L. and Alsem, K.J. (2002) 'Success factors for mass customization: A conceptual model', *Journal of Market Focused Management,* 5 (4), pp. 309-330.

Brynjolfsson, E., Hu, Y. and Smith, M.D. (2006) 'From niches to riches: Anatomy of the long tail', *Sloan Management Review*, 47 (4), pp. 67-73.

Brynjolfsson, E., Hu, Y. and Smith, M.D. (2010) 'Long Tails vs. Superstars: The effect of information technology on product variety and sales concentration patterns', *Information System Research*, 21 (4), pp. 736-747.

Carr, A.S. and Kaynak, H. (2007) 'Communication methods, information sharing, supplier development and performance - An empirical study of their relationships', *International Journal of Operations & Production Management*, 27 (3), pp. 346-370.

Carr, A.S. and Pearson, J.N. (2002) 'The impact of purchasing and supplier involvement on strategic purchasing and its impact on firm's performance', *International Journal of Operations and Production Management*, 22 (9/10), pp. 1032-1053.

Central Intelligence Agency (2012), The World Factbook, assessed on 15 July 2012, <https://www.cia.gov/library/publications/the-world-factbook/index.html>

Chan, F.T.S. (2003) ' Performance measurement in a supply chain', *International Journal of Advanced Manufacturing Technology*, 21 (7), pp. 534-548.

Chan, F.T.S. and Qi, H.J. (2003) 'An innovative performance measurement method for supply chain management', *Supply Chain Management - An International Journal*, 8 (3/4), pp. 209-223.

Chen, I.J. and Paulraj, A. (2004) 'Towards a theory of supply chain management: The constructs and measurements', *Journal of Operations Management*, 22 (2), pp. 119-150.

Chen, S., Wang, Y. and Tseng, M.M. (2009) 'Mass customisation as a collaborative engineering effort', *International Journal of Collaborative Engineering* 1(1/2), pp. 152-167.

Cheng, E.W.L. (2001) 'SEM being more effective than multiple regression in parsimonious model testing for management development research', *Journal of Management Development*, 20 (7), pp. 650-667.

Child, P., Diederichs, R., Sanders, F.-H. and Wisniowski, S. (1991) 'SMR Forum: The Management of Complexity', *Sloan Management Review*, 33 (1), pp. 73-80.

Choi, T.Y. and Wu, Z.H. (2009) 'Triads in supply networks: Theorizing buyer-supplier-supplier relationships’, *Journal of Supply Chain Management*, 45 (1), pp. 8-25.

Chopra, S. (2003) 'Designing the distribution network in a supply chain', *Transportation Research: Part E: Logistics and Transportation Review*, 39 (2), pp. 123-140.

Chopra, S. and Meindl, P. (2007) *Supply Chain Management: Strategy, Planning, and Operation,* 3rd ed., Upper Saddle River, N.J., Pearson Prentice Hall.

Christopher, M. (2000) 'The agile supply chain - Competing in volatile markets', *Industrial Marketing Management,* 29 (1), pp. 37-44.

Christopher, M., Peck, H. and Towill, D. (2006) 'A taxonomy for selecting global supply chain strategies', *International Journal of Logistics Management,* 17 (2), pp. 277-287.

Churchill, G.A. and Iacobucci, D. (2005) *Marketing Research : Methodological Foundations,* 9th ed., Mason, Ohio, South-Western.

Clark, K.B. and Fujimoto, T. (1991) *Product Development Performance: Strategy, Organization, and Management in the World Auto Industry*, Boston, Harvard business press.

Cooper, D.R. and Schindler, P.S. (2008) *Business Research Methods*, 10th ed., Boston. McGraw-Hill.

Corrocher, N. and Guerzoni, M. (2009) 'Product variety and price strategy in the ski manufacturing industry', *Journal of Evolutionary Economics,* 19 (4), pp. 471-486.

Council, S.C. (2012) *The supply chain operation reference (SCOR) model*, assessed on 30 July 2012, <http://www.supply-chain.org>

Cousins, P.D., Lawson, B., Petersen, K.J. and Handfield, R.B. (2011) 'Breakthrough scanning, supplier knowledge exchange, and new product development performance', *Journal of Product Innovation Management,* 28 (6), pp. 930-942.

Craig, C.S. and Douglas, S.P. (1999) *International Marketing Research*, 2nd ed, New York, Wiley.

Da Silveira, G., Borenstein, D. and Fogliatto, F., S. (2001) 'Mass customization: Literature review and research directions', *International Journal of Production Economics,* 72 (1), pp. 1-13.

Davila, T. and Wouters, M. (2007) 'An empirical test of inventory, service and cost benefits from a postponement strategy', *International Journal of Production Research,* 45 (10), pp. 2245-2267.

Davis, S.M. (1987). *Future Perfect,* Reading, MA, Addiseon-Wesley.

Davis, T. (1993) 'Effective supply chain management', *Sloan Management Review,* 34 (4), pp. 35-46.

De Groote, X. (1994) 'Flexibility and product variety in lot-sizing models', *European Journal of Operational Research,* 75 (2), pp. 264-274.

Derocher, R.P. and Kilpatrick, J. (2000) 'Six supply chain lessons for the millennium', *Supply Chain Management Review,* 3 (4), pp. 34-40.

Dillman, D.A. (2007) *Mail and Internet Surveys,* 2nd ed., Hoboken, New Jersey, John Wiley & Sons Ltd.

Droge, C., Jayaram, J. and Vickery, S.K. (2004) 'The effects of internal versus external integration practices on time-based performance and overall firm performance', *Journal of Operations and Management,* 22 (6), pp. 557-573.

Duclos, L.K., Vokurka, R.J. and Lummus, R.R. (2003) 'A conceptual model of supply chain flexibility', *Industrial Management & Data Systems,* 103 (5/6), pp. 446-456.

Duray, R. (2002) 'Mass customization origins: Mass or custom manufacturing?', *International Journal of Operations & Production Management,* 22 (3), pp. 314-328.

Duray, R., Ward, P.T., Milligan, G.W. and Berry, W.L. (2000) 'Approaches to mass customization: Configurations and empirical validation', *Journal of Operations Management,* 18 (6), pp. 605-625.

Easterby-Smith, M., Thorpe, R. and Lowe, A. (2001) *Management Research: An Introduction,* 2nd ed., London, SAGE.

ElMaraghy, H.A., Kuzgunkaya, O. and Urbanic, R.J. (2005) 'Manufacturing systems configuration complexity', *CIRP Annals - Manufacturing Technology,* 54 (1), pp. 445-450.

Er, M. and MacCarthry, B. (2003) 'Investigating the impact of product variety in international supply chains: A simulation study', *The 8th annual Cambridge international manufacturing symposium, September.*

Faems, D., Van Looy, B. and Debackere, K. (2005) 'Interorganizational collaboration and innovation: Toward a portfolio approach', *Journal of Product Innovation Management*, 22 (3), pp. 238-250.

Feitzinger, E. and Lee, H.L. (1997) 'Mass customization at Hewlett-Packard: The power of postponement', *Harvard Business Review,* 75 (1), pp. 116-121.

Fisher, M., Ramdas, K. and Ulrich, K. (1999) 'Component sharing in the management of product variety: A study of automotive braking systems', *Management Science,* 45 (3), pp. 297-315.

Fisher, M.L. (1997) 'What is the right supply chain for your product?', *Harvard Business Review,* 75 (2), pp. 105-116.

Fisher, M.L. and Ittner, C.D. (1999) 'The impact of product variety on automobile assembly operations: Empirical evidence and simulation analysis', *Management Science,* 45 (6), pp. 771-786.

Fisher, M.L., Jain, A. and MacDuffie, J.P. (1995) *Strategies for product variety: Lessons from the auto industry, in E. Bowman and B. Kogut (Eds.), Redesigning the Firm*, New York, Oxford University Press.

Flynn, B.B. and Flynn, E.J. (1999) 'Information-processing alternatives for coping with manufacturing environment complexity', *Decision Sciences,* 30 (4), pp. 1021-1052.

Fogliatto, F.S. and Silveira, G.J.C.d. (2011) *Mass Customization: Engineering and Managing Global Operations,* London, Springer.

Fornell, C. and Larcker, D.F. (1981) 'Evaluating structural equation models with unobservable variables and measurement error', *Journal of Marketing Research,* 18 (1), pp. 39-50.

Forza, C. (2002) 'Survey research in operations management: A process-based perspective', *International Journal of Operations & Production Management,* 22 (2), pp. 152-194.

Forza, C. and Salvador, F. (2001) 'Information flows for high-performance manufacturing', *International Journal of Production Economics,* 70 (1), pp. 21-36.

Forza, C. and Salvador, F. (2002) 'Managing for variety in the order acquisition and fulfilment process: The contribution of product configuration systems', *International Journal of Production Economics,* 76 (1), pp. 87-98.

Foster, G. and Gupta, M. (1990) 'Manufacturing overhead cost driver analysis', *Journal of Accounting and Economics,* 12 (1/3), pp. 309-337.

Frohlich, M.T. (2002) 'Methodological note: Techniques for improving response rates in OM survey research', *Journal of Operations Management,* 20 (1), pp. 53-62.

Fujita, K. (2002) 'Product variety optimization under modular architecture', *Computer-Aided Design,* 34 (12), pp. 953-965.

Galbreath, J. and Rogers, T. (1999) 'Customer relationship leadership: A leadership and motivation model for the twenty-first century business', *The TQM Magazine*, 11 (3), pp. 161-171.

Galvin, P. and Morkel, A. (2001) 'The effect of product modularity on industry structure: The case of the world bicycle industry’, *Industry & Innovation,* 8 (1), pp. 31-47.

Gartner Inc (AMR) (2011), *The Gartner Supply Chain Top 25 for 2011* by Hofman, D. and Aronow. S, assessed on 15 October, <http://www.gartner.com/technology/supply-chain/top25.jsp>

Garud, R. and Kumaraswamy, A. (1995) 'Technological and organisational designs for realizing economies of substitution’, *Strategic Management Journal,* 16 (1), pp. 93-109.

Gatignon, H. and Xuereb, J.M. (1997) 'Strategic orientation of the firm and new product performance', *Journal of Marketing Research,* 34 (1), pp. 77-90.

Gerbing, D.W. and Anderson, J.C. (1988) 'An updated paradigm for scale development incorporating unidimensionality and its assessment', *Journal of Marketing Research,* 25 (2), pp. 186-192.

Gerwin, D. (1987) 'An agenda for research on the flexibility of manufacturing processes', *International Journal of Operations & Production Management,* 7 (1), pp. 38-49.

Gerwin, D. (1993) 'Manufacturing flexibility: A strategic perspective', *Management Science,* 39 (4), pp. 395-410.

Gilmore, J.H. and Pine Ii, B.J. (1997) 'The four faces of mass customization', *Harvard Business Review,* 75 (1), pp. 91-101.

Goldman, S.L., Nagel, R.N. and Preiss, K. (1995) *Agile Competitors and Virtual Organizations: Strategies for Enriching the Customer*, New York, NY, Van Nostrand Reinhold.

Gosain, S., Malhotra, A. and El Sawy, O.A. (2004) 'Coordinating for flexibility in e-business supply chains', *Journal of Management Information Systems,* 21 (3), pp. 7-45.

Graves, S.C. and Brian, T.T. (2003) 'Process flexibility in supply chains', *Management Science,* 49 (7), pp. 907-919.

Groves, G. and Valsamakis, V. (1998) 'Supplier-customer relationships and company performance', *International Journal of Logistics Management,* 9 (2), pp. 51-64.

Groves, R.M., Floyd, J.F.J., Couper, M.P., Lepkowski, J.M., Singer, E. and Tourangeau, R. (2004) *Survey Methodology*, Hoboken, NJ, Wiley.

Gunasekaran, A., Patel, C. and McGaughey, R.E. (2004) 'A framework for supply chain performance measurement', *International Journal of Production Economics,* 87 (3), pp. 333-347.

Hair, F.J., Black, W.C., Babin, B.J. and Anderson, R.E. (2010) *Multivariate Data Analysis: A Global Perspective*. New Jersey, Pearson Education.

Hallgren, M. and Olhager, J. (2009) 'Lean and agile manufacturing: external and internal drivers and performance outcomes', *International Journal of Operations & Production Management*, 29 (10), pp. 976-999.

Hart, C.W.L. (1995) 'Mass customization: conceptual under pinnings, opportunities and limits', *International Journal of Service Industry Management*, 6 (2), pp. 36-45.

Hattie, J.A. (1985) 'Methodology review: Assessing unidimensionality of tests and items', *Applied Psychological Measurement,* 9 (2), pp. 139-164.

Hayes, R.H. (2002) 'Challenges posed to operations management by the 'new economy'', *Production and Operations Management,* 11 (1), pp. 21-32.

Hayes, R.H. and Wheelwright, S.C. (1984) *Restoring our Competitive Edge: Competing through Manufacturing*. New York, Wiley.

Heikkilä, J. (2002) 'From supply to demand chain management: Efficiency and customer satisfaction', *Journal of Operations Management,* 20 (6), pp. 747-767.

Heizer, J.H. and Render, B. (2011) *Operations Management*, 10th ed., Boston, MA, Pearson Education.

Hiroshi, K. and David, B. (1999) 'Agility, adaptability and leanness: A comparison of concepts and a study of practice', *International Journal of Production Economics,* 60 (3), pp. 43-51.

Holweg, M. and Pil, F.K. (2004) *The Second Century: Reconnecting Customer and Value Chain through Build-to-Order: Moving beyond Mass and Lean Production in the Auto Industry*. Cambridge and London, MIT Press.

Houlihan, J.B. (1987) 'International supply chain management', *International Journal of Physical Distribution & Logistics Management,* 17 (2), pp. 51-66.

Hu, L. and Bentler, P.M. (1999) 'Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives', *Structural Equation Modeling,* 6 (1), pp. 1-55.

Hu, S.J., Ko, J., Weyand, L., ElMaraghy, H.A., Lien, T.K., Koren, Y., Bley, H., Chryssolouris, G., Nasr, N. and Shpitalni, M. (2011) 'Assembly system design and operations for product variety', *CIRP Annals - Manufacturing Technology,* 60 (2), pp. 715-733.

Hu, S.J., Zhu, X., Wang, H. and Koren, Y. (2008) 'Product variety and manufacturing complexity in assembly systems and supply chains', *CIRP Annals - Manufacturing Technology,* 57 (1), pp. 45-48.

Hughes, P. and Morgan, R.E. (2008) 'Fitting strategic resources with product-market strategy: Performance implications', *Journal of Business Research Policy,* 61 (4), pp. 323-331.

Hurley, A.E., Scandura, T.A., Schriesheim, C.A., Brannick, M.T., Seers, A., Vandenberg, R.J. and Williams, L.J. (1997) 'Exploratory and confirmatory factor analysis: Guidelines, issues, and alternatives', *Journal of Organizational Behavior*, 18 (6), pp. 667-683.

Hyer, N.L. and Wemmerlöv, U. (1984) 'Group technology and productivity', *Harvard Business Review,* 62 (4), pp. 140-149.

International monetary fund (2012) Data and Statistics, assessed on 20 July 2012, <http://www.imf.org/external/data.htm>

Iyengar, S.S. and Lepper, M. R. (2000) 'When choice is demotivating: Can one desire too much of a good thing?', *Journal of Personality and Social Psychology*, 79 (6), pp. 995-1006.

Jacobs, F.R., Berry, W.L., Whybark, D.C. and Vollmann, T.E. (2011a) *Manufacturing Planning and Control for Supply Chain Management*, 6th ed., New York, McGraw-Hill.

Jacobs, M., Droge, C., Vickery, S.K. and Calantone, R. (2011b) 'Product and process modularity's effects on manufacturing agility and firm growth performance', *Journal of Product Innovation Management,* 28 (1), pp. 123-137.

Jeong, J.S. and Hong, P. (2007) 'Customer orientation and performance outcomes in supply chain management', *Journal of Enterprise Information Management,* 20 (5), pp. 578-594.

Jiao, J., Tseng, M.M., Ma, Q. and Zou, Y. (2000) 'Generic bill-of-materials-and-operations for high-variety production management', *Concurrent Engineering Research and Applications,* 8 (4), pp. 297-321.

Jiao, J.X. and Tseng, M.M. (1999) 'A methodology of developing product family architecture for mass customization', *Journal of Intelligent Manufacturing,* 10 (1), pp. 3-20.

Kaski, T. and Heikkila, J. (2002) 'Measuring product structures to improve demand-supply chain efficiency', *International Journal of Technology Management* 23 (6), pp. 578-598.

Kekre, S. and Srinivasan, K. (1990) 'Broader product line: A necessity to achieve success?', *Management Science,* 36 (10), pp. 1216-1231.

Kerlinger, F.N. (1986) *Foundations of Behavioral Research*, 3rd ed., New York, Harcourt Brace Jovanovich college publisher.

Khan, A.K., Bakkappa, B., Metri, B.A. and Sahay, B.S. (2009) 'Impact of agile supply chains' delivery practices on firms' performance: Cluster analysis and validation', *Supply Chain Management - An International Journal,* 14 (1), pp. 41-48.

Kim, J. O. and Mueller, C.W. (1978) *Introduction to Factor Analysis: What it is and How to do it*, London, Sage.

Kim, K. and Chhajed, D. (2000) 'Commonality in product design: Cost saving, valuation change and cannibalization', *European Journal of Operational Research,* 125 (3), pp. 602-621.

Kim, S.W. (2006a) 'The effect of supply chain integration on the alignment between corporate competitive capability and supply chain operational capability', *International Journal of Operations & Production Management,* 26 (9/10), pp. 1084-1107.

Kim, S.W. (2006b) 'Effects of supply chain management practices, integration and competition capability on performance', *Supply Chain Management,* 11 (3), pp. 241-248.

Kim, Y. (2005) 'The impact of product variety in the supply chain: an integrative review and future research direction', *Korea Marketing Journal*, 7 (1), pp. 67-89.

Kim, C., Son, B. G. and Bourlakis, M. (2012) 'Factors affecting successful adoption of ubiquitous computing technology in supply chain contexts' , *International Journal of Logistics Management,* 23 (2), pp. 280-306.

Kleijnen, J.P.C. and Smits, M.T. (2003) 'Performance metrics in supply chain management', *Journal of the Operational Research Society,* 54 (5), pp. 507-514.

Kline, R.B. (2011) *Principles and Practice of Structural Equation Modeling,* 3rd ed., New York, Guilford Press.

Ko, K.C. and Egbelu, P.J. (2003) 'Virtual cell formation', *International Journal of Production Research,* 41 (11), pp. 2365-2389.

Kotha, S. and Orne, D. (1989) 'Generic manufacturing strategies: A conceptual synthesis', *Strategic Management Journal,* 10 (3), pp. 211-231.

Kotteaku, A.G., Laios, L.G. and Moschuris, S.J. (1995) 'The influence of product complexity on the purchasing structure', *Omega-International Journal of Management Science,* 23 (1), pp. 27-39.

Krishnan, V. and Gupta, S. (2001) 'Appropriateness and impact of platform-based product development', *Management Science,* 47 (1), pp. 52-68.

Krishnan, V. and Ulrich, K.T. (2001) 'Product development decisions: A review of the literature', *Management Science,* 47 (1), pp. 1-21.

Kristensson, P., Gustafsson, A. and Archer, T. (2004) 'Harnessing the creative potential among users', *Journal of Product Innovation Management,* 21 (1), pp. 4-14.

Kristensson, P., Matthing, J. and Johansson, N. (2008) 'Key strategies for the successful involvement of customers in the co-creation of new technology-based services', *International Journal of Service Industry Management,* 19 (3), pp. 474-491.

Kumar, V., Aaker, D.A. and Day, G.S. (2002) *Essentials of Marketing Research,* 2nd ed., New York, Wiley.

Kumpe, T. and Bolwijn, P.T. (1988) 'Manufacturing: The new case for vertical integration', *Harvard Business Review,* 66 (2), pp. 75-81.

Lambert, D.M., Cooper, M.C. and Pagh, J.D. (1998) 'Supply chain management: Implementation issues and research opportunities', *International Journal of Logistics Management,* 9 (2), pp. 1-19.

Lampel, J. and Mintzberg, H. (1996) 'Customizing customization', *Sloan Management Review,* 38 (1), pp. 21-30.

Langlois, R.N. and Robertson, P.L. (1992) 'Networks and innonation in modular system - Lessons from the microcomputer and stereo component industries ', *Research Policy,* 21 (4), pp. 297-313.

Larson, P.D. and Rogers, D.S. (1998) 'Supply chain management: Definition, growth and approaches', *Journal of Marketing Theory and Practice,* 6 (4), pp. 1-5.

Lee, H.L. (2002) 'Aligning supply chain strategies with product uncertainties', *California Management Review,* 44 (3), pp. 105-119.

Lee, H.L. (2004) 'The triple – A supply chain', *Harvard Business Review,* 82 (10), pp. 102-112.

Lee, H.L. and Billington, C. (1993) 'Material management in decentralized supply chains', *Operations Research,* 41 (5), pp. 835-847.

Lee, K., Wei, J.C. and Ling-Lang, T. (2005) 'Responding to schedule changes in build-to-order supply chains', *Journal of Operations Management,* 23 (5), pp. 452-469.

Lieb, R. and Bentz, B.A. (2005) 'The use of third-party logistics services by large american manufacturers: the 2004 survey', *Transportation Journal*, 44 (2), pp. 5-15.

Lifang, W. (2007) 'Toward an Understanding of the product variety decision: An integrative model', *International Journal of Management*, 24 (3), pp. 499-504.

Lummus, R.R., Vokurka, R.J. and Duclos, L.K. (2005) 'Delphi study on supply chain flexibility', *International Journal of Production Research*, 43 (13), pp. 2687-2708.

Lusch, R.F., Vargo, S.L. and O'Brien, M. (2007) 'Competing through service: Insights from service-dominant logic', *Journal of Retailing*, 83 (1), pp. 5-18.

Lyons, A.C., Everington, L., Hernandez, J., Li, D., Michaelides, R. and Um, J. (2013), 'The application of a knowledge-based reference framework to support the provision of requisite variety and customization across collaborative networks, *International Journal of Production Research*, 51 (7), pp. 2019-2033.

MacDuffie, J.P., Sethuraman, K. and Fisher, M.L. (1996) 'Product variety and manufacturing performance: Evidence from the international automotive assembly plant study', *Management Science*, 42 (3), pp. 350-369.

Malhotra, N. and Birks, D. (2007) *Marketing Research: An Applied Approach*, 3rd European Edition ed., Harlow, UK, Pearson Education.

Martin, M.V. and Ishii, K. (1996) 'Design for variety: a methodoloty for understanding costs of product proliferation', *ASME Design engineering technical conferences*, Irvine, CA.

Martin, M.V. and Ishii, K. (1997) 'Design for variety: development of complexity indices and design charts', *ASME Design engineering technical conferences*, Sacramento, CA.

Martin, M.V. and Ishii, K. (2002) 'Design for variety: developing standardized and modularized product platform architectures', *Research in Engineering Design*, 13 (4), pp. 213-235.

Mason, J. R. and Towill, D.R. (1999) 'Using the information decoupling point to improve supply chain performance', *International Journal of Logistics Management*, 10 (2), pp. 13-26.

Mason, J. R., Naylor, B and Towill, D.R. (2000), "Lean, agile or leagile? Matching your supply chain to the marketplace", *International Journal of Production Research*, 38 (17), pp. 4061-4070.

Matell, M.S. and Jacoby, J. (1972) 'Is there an optimal number of alternatives for Likert-Scale items?', *Journal of Applied Psychology*, 56 (6), pp. 506-509.

McCutcheon, D.M. and Raturi, A.S. (1994) 'The customization-responsiveness squeeze', *Sloan Management Review,* 35 (2), pp. 89-99.

McDonald, R.P. (1981) 'The dimensionality of tests and items', *British Journal of Mathematical and Statistical Psychology,* 34 (1), pp. 100-117.

McKnight, P.E., McKnight, K.M., Sidani, S. and Figueredo, A.J. (2007) *Missing Data: A Gentle Introduction*, New York, Guilford Press.

Mendelson, H. and Pillai, R.R. (1999) 'Industry clockspeed: measurement and operational implications', *Manufacturing & Service Operations Management,* 1 (1), pp. 1-20.

Mentzer, J.T., DeWitt, W., Keebler, J.S., Min, S., Nix, N.W., Smith, C.D. and Zacharia, Z.G. (2001) 'Defining supply chain management', *Journal of Business Logistics,* 22 (2), pp. 1-26.

Meyr, H. (2004) 'Supply chain planning in the German automotive industry', *OR Spectrum,* 26 (4), pp. 447-470.

Michel, S., Brown, S.W. and Gallan, A.S. (2008) 'An expanded and strategic view of discontinuous innovations: Deploying a service-dominant logic', *Journal of the Academy of Marketing Science,* 36 (1), pp. 54-66.

Miles, R.E. and Snow, C.C. (1978) *Organizational strategy, structure, and process*, New York, McGraw-Hill.

Milgate, M. (2001) 'Supply chain complexity and delivery performance: An international exploratory study', *Supply Chain Management,* 6 (3), pp. 106-118.

Min, H. and Zhou, G. (2002) 'Supply chain modeling: past, present and future', *Computers & Industrial Engineering,* 43 (1), pp. 231-249.

Mintzberg, H. (1988) 'Generic Strategies: Toward a Comprehensive Framework', *in R. Lamb & P. Shrivastava (Eds.), Advances in strategic management*, Greenwich, JAI Press, pp. 1-67.

Monczka, R. and Morgan, J.P. (1996) 'Supplier integration a new level of supply chain management', *Purchasing*, 120 (1), pp. 110-113.

Montreuil, B. and Poulin, M. (2005) 'Demand and supply network design scope for personalized manufacturing', *Production Planning & Control*, 16 (5), pp. 454-469.

Nair, A. (2005) 'Linking manufacturing postponement, centralized distribution and value chain flexibility with performance', *International Journal of Production Research*, 43 (3), pp. 447-463.

Narasimhan, R. and Das, A. (1999) 'An empirical investigation of the contribution of strategic sourcing to manufacturing flexibilities and performance', *Decision Sciences*, 30 (3), pp. 683-718.

Narasimhan, R. and Jayaram, J. (1998) 'Causal linkages in supply chain management: An exploratory study of north american manufacturing firms', *Decision Sciences*, 29 (3), pp. 579-605.

Narasimhan, R. and Soo Wook, K. (2002) 'Effect of supply chain integration on the relationship between diversification and performance: Evidence from Japanese and Korean firms', *Journal of Operations Management*, 20 (3), pp. 303-323.

Naylor, J.B., Naim, M.M. and Berry, D. (1999) 'Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain', *International Journal of Production Economics*, 62 (1/2), pp. 107-118.

Ngai, E.W.T., Cheng, T.C.E. and Ho, S.S.M. (2004) 'Critical success factors of web-based supply-chain management systems: an exploratory study', *Production Planning & Control*, 15 (6), pp. 622-630.

Nieto, M.J. and Santamaria, L. (2007) 'The importance of diverse collaborative networks for the novelty of product innovation', *Technovation*, 27 (6), pp. 367-377.

Novak, S. and Eppinger, S.D. (2001) 'Sourcing by design: Product complexity and the supply chain', *Management Science*, 47 (1), pp. 189-204.

Nunnally, J.C. (1978) *Psychometric Theory,* 2nd ed., New York, McGraw-Hill.

OECD Factbook (2010), Economic, Environmental and Social Statistics, assessed on 20 July 2012, <http://www.oecd-ilibrary.org/sites/factbook-2010-en>

O'Leary-Kelly, S.W. and Vokurka, R.J. (1998) 'The empirical assessment of construct validity', *Journal of Operations Management*, 16 (4), pp. 387-405.

Otero-Neira, C., Varela, J. and Garcia, T. (2010) 'Competitive reaction to the introduction of a new product: An exploratory market signalling study', *Journal of Strategic Marketing*, 18 (5), pp. 379-394.

Otto, A. and Kotzab, H. (2003) 'Does supply chain management really pay? Six perspectives to measure the performance of managing a supply chain', *European Journal of Operational Research,* 144 (2), pp. 306-320.

Ozer, M. and Cebeci, U. (2010) 'The role of globalization in new product development', *IEEE Transactions on Engineering Management,* 57 (2), pp. 168-180.

Pallant, J. (2007) *SPSS, Survival Manual: A Step by Step Guide to Data Analysis using SPSS for Windows,* Berkshire, Open University Press.

Panayides, P.M. (2007) 'The impact of organizational learning on relationship orientation, logistics service effectiveness and performance', *Industrial Marketing Management,* 36 (1), pp. 68-80.

Parker, G.G. and Anderson, E.G. (2002) 'From buyer to integrator: The transformation of the supply-chain manager in the vertically disintegrating firm', *Production & Operations Management,* 11 (1), pp. 75-91.

Peter, T.W. and Rebecca, D. (2000) 'Manufacturing strategy in context: Environment, competitive strategy and manufacturing strategy', *Journal of Operations Management*, 18 (2), pp. 123-138.

Piercy, N.F., Kaleka, A. and Katsikeas, C.S. (1998) 'Sources of competitive advantage in high performing exporting companies', *Journal of World Business*, 33 (4), pp. 378-393.

Pine, B.J., Victor, B., Boynton, A.C. (1993). 'Making mass customization work', *Harvard Business Review*, 71 (5), pp.108–119.

Podsakoff, P.M., MacKenzie, S.B. and Lee, J.Y. (2003) 'Common method biases in behavioural research: A critical review of the literature and recommended remedies', *Journal of Applied Psychology* 88 (5), pp. 879-903.

Porter, M.E. (1980) *Competitive Strategy: Techniques for Analyzing Industries and Competitors*, New York, Free Press.

Porter, M.E. (2004) *Competitive Advantage : Creating and Sustaining Superior Performance*, New York, Free Press.

Poulin, M., Montreuil, B. and Martel, A. (2006) 'Implications of personalization offers on demand and supply network design: A case from the golf club industry', *European Journal of Operational Research*, 169 (3), pp. 996-1009.

Power, D.J., Sohal, A.S. and Rahman, S.U. (2001) 'Critical success factors in agile supply chain management: An empirical study', *International Journal of Physical Distribution and Logistic Management*, 31 (4), pp. 247-265.

Pyke, D.F. and Cohen, M.A. (1993) 'Performance-characteristics of stochastic integrated production distribution-systems', *European Journal of Operational Research*, 68 (1), pp. 23-48.

Qiang, T., Mark, A.V. and Ragu-Nathan, T.S. (2001) 'The impact of time-based manufacturing practices on mass customization and value to customer', *Journal of Operations Management*, 19 (2), pp. 201-217.

Ragatz, G.L., Handfield, R.B. and Scannell, T.V. (1997) 'Success factors for integrating supplier into new product development', *Journal of Product Innovation Management*, 14 (3), pp. 190-202.

Rajagopalan, S. and Swaminathan, J.M. (2001) 'A coordinated production planning model with capacity expansion and inventory management', *Management Science,* 47 (11), pp. 1562-1580.

Ramdas, K. (2003) 'Managing product variety: An integrative review and research directions', *Production & Operations Management*, 12 (1), pp. 79-101.

Ramdas, K., Fisher, M. and Ulrich, K. (2003) 'Managing variety for assembled products: modeling component systems sharing', *Manufacturing & Service Operations Management,* 5 (2), pp. 142-157.

Ramdas, K. and Randall, T. (2008) 'Does component sharing help or hurt reliability? An empirical study in the automotive industry', *Management Science,* 54 (5), pp. 922-938.

Ramdas, K. and Spekman, R. (2000) 'Chain or shackles: understanding what drives supply-chain performance', *Interfaces,* 30 (4), pp. 3-21.

Randall, T. and Ulrich, K. (2001) 'Product variety, supply chain structure, and firm performance: Analysis of the U. S. bicycle industry', *Management Science,* 47 (12), pp. 1588-1604.

Randall, T.R., Morgan, R.M. and Morton, A.R. (2003) 'Efficient versus responsive supply chain choice: An empirical examination of influential factors', *Journal of Product Innovation Management,* 20 (6), pp. 430-443.

R&D performance fair (2011), Korea evaluation institute of industrial technology, assessed on 21, 22 April, 2011, <http://edtmnt.windowstest.net/sub_01/sub_03.asp>

Ranganathan, C., Dhaliwal, J.S. and Teo, T.S.H. (2004) 'Assimilation and diffusion of web technologies in supply-chain management: an examination of key drivers and performance impacts', *International Journal of Electronic Commerce,* 9 (1), pp. 127-161.

Raykov, T. and Marcoulides, G.A. (2008) *An Introduction to Applied Multivariate Analysis*, Mahwah, Lawrence Erlbaum Associates Inc.

Remko, I.v.H., Alan, H. and Martin, C. (2001) 'Measuring agile capabilities in the supply chain', *International Journal of Operations & Production Management,* 21 (1/2), pp. 126-147.

Robinson, C.J. and Malhotra, M.K. (2005) 'Defining the concept of supply chain quality management and its relevance to academic and industrial practice', *International Journal of Production Economics*, 96 (3), pp. 315-337.

Rosenzweig, E.D., Roth, A.V. and Dean Jr, J.W. (2003) 'The influence of an integration strategy on competitive capabilities and business performance: An exploratory study of consumer products manufacturers', *Journal of Operations Management,* 21 (4), pp. 437-456.

Salvador, F., Forza, C. and Rungtusanatham, M. (2002) 'Modularity, product variety, production volume, and component sourcing: Theorizing beyond generic prescriptions', *Journal of Operations Management*, 20 (5), pp. 549-575.

Salvador, F., Rungtusanatham, M. and Forza, C. (2004) 'Supply-chain configurations for mass customization', *Production Planning & Control*, 15 (4), pp. 381-397.

Sánchez, A.M. and Pérez, M.P. (2005) 'Supply chain flexibility and firm performance: A conceptual model and empirical study in the automotive industry', *International Journal of Operations & Production Management*, 25 (7), pp. 681-700.

Santos, F.C.A. (2000) 'Integration of human resource management and competitive priorities of manufacturing strategy', *International Journal of Operations & Production Management,* 20 (5), pp. 610-628.

Saunders, M., Lewis, P. and Thornhill, A. (2009) *Research Methods for Business Students*, 5th ed., Harlow, Prentice Hall.

Scavarda, L.F., Reichhart, A., Hamacher, S. and Holweg, M. (2010) 'Managing product variety in emerging markets', *International Journal of Operations & Production Management*, 30 (2), pp. 205-224.

Schafer, J.L. and Olsen, M.K. (1998) 'Multiple imputation for multivariate missing-data problems: A data analyst's perspective', *Multivariate Behavioral Research,* 33 (4), pp. 545-571.

Schütz, P., Tomasgard, A., Ahmed, S. (2009) 'Supply chain design under uncertainty using sample average appoximation and dual decomposition', European Journal of Operational Research, 199 (2), pp, 409-419.

Segars, A.H. and Grover, V. (1993) 'Re-Examining perceived ease of use and usefulness: A confirmatory factor analysis', *MIS Quarterly,* 17 (4), pp. 517-525.

Sengupta, K., Heiser, D.R. and Cook, L.S. (2006) 'Manufacturing and service supply chain performance: A comparative analysis', *Journal of Supply Chain Management,* 42 (4), pp. 5-16.

Sethi, A.K. and Sethi, S.P. (1990) 'Flexibility in manufacturing: A survey', *International Journal of Flexible Manufacturing Systems,* 2 (4), pp. 289-328.

Sezen, B. (2008) 'Relative effects of design, integration and information sharing on supply chain performance', *Supply Chain Management - An International Journal,* 13 (3), pp. 233-240.

Sharifi, H. and Zhang, Z. (1999) 'A methodology for achieving agility in manufacturing organisations: An introduction', *International Journal of Production Economics,* 62 (2), pp. 7-22.

Silveira, G., Da (1998) 'A framework for the management of product variety', *International Journal of Operations & Production Management,* 18 (3), pp. 271-285.

Slack, N. (1983) 'Flexibility as a manufacturing objective', *International Journal of Operations & Production Management,* 3 (3), pp. 4-13.

Slack, N. (1987) 'The flexibility of manufacturing systems', *International Journal of Operations & Production Management,* 7 (4), pp. 35-45.

Slack, N. and Chambers, S. (2007) *Operations Management,* 5th ed., Harlow, Prentice Hall.

Slack, N. and Correa, H. (1992) 'The flexibilities of push and pull', *International Journal of Operations & Production Management*, 12 (4), pp. 82-92.

Sorensen, H.T., Sabroe, S. and Olsen, J. (1996) 'A framework for evaluation of secondary data sources for epidemiological research', *International Journal of Epidemiology*, 25 (2), pp. 435-442.

Squire, B., Readman, J., Brown, S. and Bessant, J. (2004) 'Mass customization: The key to customer value ?', *Production Planning & Control*, 15 (4), pp. 459–471.

Srinivasan, M.M. and Viswanathan, S. (2010) 'Optimal work-in-process inventory levels for high-variety, low-volume manufacturing systems', *IIE Transactions*, 42 (6), pp. 379-391.

Stablein, T., Holweg, M. and Miemczyk, J. (2011) 'Theoretical versus actual product variety: How much customisation do customers really demand?', *International Journal of Operations & Production Management*, 31 (3), pp. 350-370.

Stalk, G. (1988) 'Time - The next source of competitive advantage', *Harvard Business Review*, 66 (4), pp. 41-51.

Stalk, G. and Hout, T.M. (1990) *Competing against Time : How Time-based Competition is Reshaping Global Market*, New York, Free Press.

Stavrulaki, E. and Davis, M. (2010) 'Aligning products with supply chain processes and strategy', *International Journal of Logistics Management*, 21 (1), pp. 127-151.

Stevenson, M. and Spring, M. (2007) 'Flexibility from a supply chain perspective: Definition and review', *International Journal of Operations & Production Management*, 27 (7), pp. 685-713.

Stevenson, M. and Spring, M. (2009) 'Supply chain flexibility: An inter-firm empirical study', *International Journal of Operations & Production Management*, 29 (9), pp. 946-971.

Stock, J.R. and Boyer, S.L. (2009) 'Developing a consensus definition of supply chain management: A qualitative study', *International Journal of Physical Distribution & Logistics Management*, 39 (8), pp. 690-711.

Suarez, F.F., Cusumano, M.A. and Fine, C.H. (1996) 'An empirical study of manufacturing flexibility in printed circuit board assembly', *Operations Research*, 44 (1), pp. 223-240.

Sutton, J. (2001) *Technology and Market Structure : Theory and History*, Cambridge, MIT Press.

Swafford, P.M., Ghosh, S. and Murthy, N. (2006) 'The antecedents of supply chain agility of a firm: Scale development and model testing', *Journal of Operations Management*, 24 (2), pp. 170-188.

Swafford, P.M., Ghosh, S. and Murthy, N. (2008) 'Achieving Supply chain agility through it integration and flexibility', *International Journal of Production Economics,* 116 (2), pp. 288-297.

Tan, K.C. and Kannan, V.R. (1998) 'Supply chain management: Supplier performance and firm performance', *International Journal of Purchasing & Materials Management*, 34 (3), pp. 2-9.

Tan, K.C., Kannan, V.R., Handfield, R.B. and Ghosh, S. (1999) 'Supply chain management: An empirical study of its impact on performance', *International Journal of Operations & Production Management*, 19 (9-10), pp. 1034-1052.

Tang, E.P.Y. and Yam, R.C.M. (1996) 'Product variety strategy - An environmental perspective', *Integrated Manufacturing Systems*, 7 (6), pp. 24-29.

The top 1000: The largest corporation in South Korea (2010), Korea chamber of commerce & industry, assessed on 15 December, 2010, <http://www.korchambiz.net/company/ company_main.jsp>

Thomas, C. (2011) 'Too many products: Decentralized decision making in multinational firms', *American Economic Journal: Microeconomics*, 3 (1), pp. 280-306.

Thonemann, U.W. and Bradley, J.R. (2002) 'The effect of product variety on supply-chain performance', *European Journal of Operational Research*, 143 (3), pp. 548-569.

Tracey, M. and Tan, C.L. (2001) 'Empirical analysis of supplier selection and involvement, customer satisfaction, and firm performance', *Supply Chain Management - An International Journal*, 6 (4), pp. 174-188.

Treville, S.D., Shapiro, R.D. and Hameri, A.P. (2004) 'From supply chain to demand chain: the role of lead time reduction in improving demand chain performance', *Journal of Operations Management*, 21 (6), pp. 613-627.

Tseng, M.M., Jiao, J. and Merchant, M.E. (1996) 'Design for mass customization', *CIRP Annals - Manufacturing Technology,* 45 (1), pp. 153-156.

Tummala, V.M.R., Phillips, C.L.M. and Johnson, M. (2006) 'Assessing supply chain management success factors: A case study', *Supply Chain Management – An International Journal*, 11 (2), pp. 179-192.

Ulrich, K., Randall, T., Fisher, M. and Reibstein, D. (1998) 'Managing product variety', *in T. Ho, C. Tang (Eds.), Product variety management*, pp. 178-205.

Ulrich, K. and Tung, K. (1991) 'Fundamentals of product modularity', *in A. Sharon (Ed.), Issues in design / manufacturing integration*, New York, ASME, pp. 73-79.

Unnebrink, K. and Windeler, J. (2001) 'Intention-to-treat: Methods for dealing with missing values in clinical trials of progressively deteriorating diseases', *Statistics in Medicine,* 20 (24), pp. 3931-3946.

Upton, D.M. (1995) 'What really makes factories flexible?', *Harvard Business Review*, 73 (4), pp. 74-84.

Van Hoek, R.I. (1999) 'Postponement and the reconfiguration challenge for food supply chains', *Supply Chain Management - An International Journal*, 4 (1), pp. 18-34.

Van Hoek, R.I., Harrison, A. and Christopher, M. (2001) 'Measuring agile capabilities in the supply chain', *International Journal of Operations & Production Management*, 21 (2), pp. 126-147.

Van Hoek, R.I., Peelen, E. and Commandeur, H.R. (1999) 'Achieving mass customization through postponement: A study of international channel', *Journal of Market Focused Management*, 3 (3/4), pp. 353-368.

Verma, R. and Goodale, J.C. (1995) 'Statistical power in operations management research', *Journal of Operations Management*, 13 (2), pp. 139-152.

Vickery, S.K., Calantone, R. and Dröge, C. (1999) 'Supply chain flexibility: An empirical study', *Journal of Supply Chain Management*, 35 (3), pp. 16-24.

Vickery, S.K., Jayaram, J., Droge, C. and Calantone, R. (2003) 'The effects of an integrative supply chain strategy on customer service and financial performance: an analysis of direct versus indirect relationships', *Journal of Operations Management*, 21 (5), pp. 523-539.

Vinod, K., Kamel, A.F., Uma, K. and Todd, A.B. (2006) 'Implementation and management framework for supply chain flexibility', *Journal of Enterprise Information Management*, 19 (3), pp. 303-319.

Vollmann, T., Berry, W., Whybark, D. and Jacobs, F. (2005) *Manufacturing Planning and Control Systems for Supply Chain Management*, New York, NY, McGraw-Hill.

Voss, C., Tsikriktsis, N. and Frohlich, M. (2002) 'Case research in operations management', *International Journal of Operations & Production Management*, 22 (2), pp. 195-219.

Weisberg, H.F., Krosnick, J.A. and Bowen, B.D. (1996) *An Introduction to Survey Research, Polling, and Data Analysis*, 3rd ed., Thousand Oaks, CA US, Sage Publications, Inc.

Whang, S. and Lee, H. (1998) 'Value of Postponement', *in T.H. Ho and C.S. Tang (Eds.), Product Variety Management: Research Advances*, Boston, Kluwer Academic Publishers.

Yadav, S.R., Mishra, N., Kumar, V. and Tiwari, M.K. (2011) 'A framework for designing robust supply chains considering product development issues', *International Journal of Production Research*, 49 (20), pp. 6065-6088.

Yang, B. and Burns, N. (2003) 'Implications of postponement for the supply chain', *International Journal of Production Research*, 41 (9), pp. 2075-2090.

Yeh, K.-H. and Chu, C.-H. (1991) 'Adaptive Strategies for coping with product variety decisions', *International Journal of Operations & Production Management*, 11 (8), pp. 35-47.

Zelbst, P.J., Green, K.W., Sower, V.E. and Reyes, P. (2009) 'Impact of supply chain linkages on supply chain performance', *Industrial Management & Data Systems*, 109 (5), pp. 665-682.

Zhang, M., Chen, Y.J. and Tseng, M.M. (2005) 'Distributed knowledge management for product and process variety in mass customisation', *International Journal of Computer Applications in Technology*, 23 (1), pp. 13-30.

Zhang, X., Chen, R.Q. and Ma, Y.B. (2007) 'An empirical examination of response time, product variety and firm performance', *International Journal of Production Research,* 45 (14), pp. 3135-3150.

Zhang, Z. and Sharifi, H. (2000) 'A methodology for achieving agility in manufacturing organisations', *International Journal of Operations & Production Management,* 20 (3), pp. 496-512.

Zhang, Q., Vonderembse, M.A. and Lim, J.S. (2002), 'Value chain flexibility: A dichotomy of competence and capability', *International Journal of Production Research*, 40 (3), pp. 561-583.

Zhou, W. and Duan, W. (2012) 'Online user reviews, product variety, and the long tail: An empirical investigation on online software downloads', *Electronic Commerce Research and Applications*, 11 (3), pp. 275-289.

Appendix 1

Questionnaire

The University of Liverpool

University of Liverpool Management School, Liverpool, L69 7ZH, UK
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Dear Respondent,

I am a research student studying under the direction of Dr. Andrew Lyons at the University of Liverpool Management School. The research concerns the impact of variety and product customisation on supply chain performance. A key component of the research is to review existing supply chain practices through this survey questionnaire. Your experience of supply chain practices is very important for this study and your assistance is highly appreciated. This survey takes nearly 10 minutes to complete and all the responses will be kept confidential (Please use the enclosed free post envelope to return this questionnaire). The survey results will be used only for the academic work and will be published in the form of summaries in which individual responses cannot be identified. A copy of this summary will be provided to all respondents. If you are unsure of a survey question, please choose the response that you believe is most suitable.
Thank you once again for your kind assistance.

Sincerely yours.

Juneho Um, Doctoral Candidate

Part A. Business Background information

A1. What is the main product or service of your company?

- ☐ Food, beverage, tobacco
- ☐ Wood and furniture
- ☐ Chemical and petroleum materials and products
- ☐ Non-metal mineral products
- ☐ Fabricated metal products
- ☐ Computer and communication products
- ☐ Electronic parts and components
- ☐ Electrical machinery and equipment
- ☐ Transport equipment
- ☐ Textiles and leather
- ☐ Paper products
- ☐ Machinery and equipment
- ☐ Basic metal products
- ☐ Clothing and footwear
- ☐ Other

A2. What was the approximate total sales volume for your company in 2009? (Million £)

☐ Less than 0.25 (Million £) ☐ 0.25 to 0.5 (Million £) ☐ 0.5 to 1 (Million £) ☐ 1 to 2 (Million £)
☐ 2 to 10 (Million £) ☐ 10 to 50 (Million £) ☐ More than 50 (Million £)

A3. What was the Profit Margin in 2009? (Profit Margin = gross profit / revenue * 100)

☐ 0-5% ☐ 6-10% ☐ 11-15% ☐ 16-20% ☐ 21-25%
☐ Above 25% ☐ Don't know

A4. How many full-time employees work in your company?

☐ Less than 50 ☐ 51 to 150 ☐ 151 to 250 ☐ 251 to 1000 ☐ More than 1000

A5. How many major competitors does your company have?

☐ 1 ☐ 2 to 5 ☐ 6 to 10 ☐ 11 to 20 ☐ More than 20

A6. What form of service does your company provide?

☐ Domestic services ☐ International and domestic services ☐ International services

A7. What is your job title?

☐ Above Director/Deputy Director ☐ Director/Deputy Director ☐ Manager/Assistant Manager
☐ Sales Representative ☐ Clerk ☐ Other

Part B. Level of customisation and product variety

B1. Does your company provide single or various products and services? ☐ Various ☐ Single

B2. Has the general trend been for product variety to increase? ☐ Yes ☐ No

B3. Has consumer demand for product variety increased or decreased since 2005?

☐ -10% ☐ -5% ☐ same ☐ +5% ☐ +10%

B4. The current typical demand uncertainty for core products is

☐ -10% ➔ +10% ☐ -20% ➔ +20% ☐ -30% ➔ +30% ☐ -40% ➔ +40% ☐ -50% ➔ +50%

B5. Typical order lead time for core products is

☐ Within 1 day ☐ 2-3 days ☐ 4-6 days ☐ 7-14 days ☐ 15- 30 days ☐ Above 30 days

B6. Level of product variety

Please tick one of the following		1-5 1	6-10 2	11-15 3	16-20 4	Above 20 5
1	Number of different core designs for your products	☐	☐	☐	☐	☐
2	Number of different colours, sizes and technical options dependent on core design	☐	☐	☐	☐	☐
3	Number of particular options and accessories independent of core design	☐	☐	☐	☐	☐

B7. Type of customisation

Please indicate how product or service customisation is mainly achieved in your company. (Tick only one)		
1	We provide standard products that have pre-defined options and designs. Product customisation happens at the sales stage.	☐
2	We provide products in which customers may customise product packaging, delivery schedules, or delivery location. The actual product is standard with pre-defined options and designs. Customisation works at the sales and distribution stages.	☐
3	We provide various types of products in which customers are offered a number of pre-defined options. Products are assembled to customer order using standard components. Customisation is achieved at the assembly stage.	☐
4	We provide various types of products in which customers are offered a number of pre-defined designs. Products are manufactured to customer order. Customisation is achieved at the fabrication stage.	☐
5	We provide a unique product design in which customer input is at the start of the design process. Products are designed to order. Customisation is achieved at the design stage.	☐

B8. If the company provides more than one customisation type, please indicate the actual mixed customisation type.

☐ 2+3 ☐ 2+4 ☐ 3+4 ☐ 2+3+4
☐ Other

Part C. Supply chain factors for managing product variety

Please indicate your level of agreement with each of the following statement		Strongly disagree 1	2	Neutral 3	4	Strongly agree 5
Partnership with suppliers						
1	We develop trustworthy relationships with suppliers	☐	☐	☐	☐	☐
2	We have close relationships in product development with suppliers	☐	☐	☐	☐	☐
3	We undertake joint problem solving and performance evaluation with suppliers	☐	☐	☐	☐	☐
4	We share sensitive information (financial, production, design, research) with suppliers	☐	☐	☐	☐	☐
Advanced manufacturing (Variety control strategy)						
1	We use modular production at the assembly stage	☐	☐	☐	☐	☐
2	We delay the process that transforms the form and function of products until customer orders have been received (Postponement)	☐	☐	☐	☐	☐
3	We use cellular manufacturing which groups parts with similar design and processes	☐	☐	☐	☐	☐
Customer relationships						
1	We anticipate and respond to customers' evolving needs	☐	☐	☐	☐	☐
2	We emphasise the evaluation of formal and informal customer complaints	☐	☐	☐	☐	☐
3	We monitor and measure customer service levels	☐	☐	☐	☐	☐
4	We follow up with customers for quality/service feedback	☐	☐	☐	☐	☐

Part D. Agility, flexibility and Competitive strategy

Please indicate how well your company and/or its supply chain perform in each of the following		Poor 1	2	Neutral 3	4	Excellent 5
Supply chain flexibility						
1	Ability to change quantity of suppliers' orders	☐	☐	☐	☐	☐
2	Ability to change delivery times of orders placed with suppliers	☐	☐	☐	☐	☐
3	Ability to change production volume	☐	☐	☐	☐	☐
4	Ability to accommodate changes in production mix	☐	☐	☐	☐	☐
5	Ability to implement engineering change orders in production	☐	☐	☐	☐	☐
6	Ability to alter delivery schedules to meet changing customer requirements	☐	☐	☐	☐	☐
Supply chain agility						
1	Ability to rapidly reduce product development cycle time	☐	☐	☐	☐	☐
2	Ability to rapidly reduce manufacturing lead time	☐	☐	☐	☐	☐
3	Ability to rapidly increase the level of product customisation	☐	☐	☐	☐	☐
4	Ability to rapidly improve level of customer service	☐	☐	☐	☐	☐
5	Ability to rapidly improve delivery reliability	☐	☐	☐	☐	☐
6	Ability to rapidly improve responsiveness to changing market needs	☐	☐	☐	☐	☐
7	Ability to rapidly reduce delivery lead time	☐	☐	☐	☐	☐
Cost leadership (compared to competitors)						
1	The capability to reduce manufacturing unit cost	☐	☐	☐	☐	☐
2	The capability to supply low product price	☐	☐	☐	☐	☐
Differentiation(compared to competitors)						
1	The capability to deliver high quality product quickly with volume flexibility (Customer service differentiation)	☐	☐	☐	☐	☐
2	The capability to develop new product quickly with designing flexibility depending on customer demand (Technology differentiation)	☐	☐	☐	☐	☐
3	The capability to control sales/distribution network (Marketing differentiation)	☐	☐	☐	☐	☐

Part E. Supply chain management and business performance

Please indicate how well your company's supply chain performs		Poor 1	2	Neutral 3	4	Excellent 5
Resource performance (cost efficiency)						
1	Ability to minimise total cost of resources used	☐	☐	☐	☐	☐
2	Ability to minimise total cost of distribution (including transportation and handling costs)	☐	☐	☐	☐	☐
3	Ability to minimise total cost of manufacturing (including labour, maintenance, and re-work costs)	☐	☐	☐	☐	☐
4	Ability to minimise total cost related with held inventory	☐	☐	☐	☐	☐
Output performance (customer service)						
1	Order fill rate	☐	☐	☐	☐	☐
2	On-time delivery	☐	☐	☐	☐	☐
3	Customer response time	☐	☐	☐	☐	☐
4	Quality	☐	☐	☐	☐	☐
5	Manufacturing lead time	☐	☐	☐	☐	☐
6	Customer complaints reduction	☐	☐	☐	☐	☐
7	Customer satisfaction	☐	☐	☐	☐	☐
8	Stock-out reduction	☐	☐	☐	☐	☐
Firm performance						
1	Return on sales (ROS)	☐	☐	☐	☐	☐
2	Return on Assets (ROA)	☐	☐	☐	☐	☐
3	Market share growth	☐	☐	☐	☐	☐
4	Sales growth	☐	☐	☐	☐	☐

Part F. Impact of Product Variety on supply chain

If you have had recent increases in your product variety please indicate the impact of product variety on each of the following		Lowest Increase (%)									Highest Increase (%)
		1	2	3	4	5	6	7	8	9	10
		0-5 (%)	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-(%)
Engineering											
1	Design complexity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	R&D cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Unit cost of product	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Engineering / model design and change cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Manufacturing											
1	Total quality	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Manufacturing cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Utilisation of standardised parts	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Differentiation postponement (Differentiation point is placed later in the process)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Set-up cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Manufacturing flexibility	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Direct labour cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Process variety	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Part variety	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	Manufacturing complexity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	Supervision effort	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
12	Scheduling complexity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
13	Material cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
14	Overhead cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
15	Manufacturing lead time	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
16	Process technology investment cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Purchasing											
1	Purchasing costs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Order processing (ex. Adding supplier)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Purchased component / part variety	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Logistics											
1	Work in-process inventory	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Finished goods inventory	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Inventory cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Purchased parts inventory	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Delivery time	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	Material handling cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	Market mediation cost (Inventory holding, markdown cost and lost sale)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	Outsourcing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	Transportation cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Marketing											
1	Demand forecasting uncertainty	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Customer satisfaction	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Market share	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	Competitive advantage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	Product cost at retailer	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Thank you very much for your time

Korean version

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응답자 분들께,

저는 리버풀 대학교 경영학과에서 박사과정을 공부하고 있는 학생입니다. 이 연구는 제품의 다양성과 제품 고객화가 공급사슬망에 미치는 영향에 관한 것입니다. 이 설문을 통해 현 공급망 관리상황을 조사하려고 합니다. 응답자 분들의 경험은 이 연구에 중요하며 도움을 주심에 진심으로 감사 드립니다. 이 설문은 10분 정도가 소요되며 정보 보안이 보장되었음을 알려드립니다. 자료는 학문적 연구에만 사용될 것이고 개인의 자료는 노출되지 않고 종합적 통계자료로만 이용됩니다. 종합된 자료 결과는 응답자 분들에게 제공될 것입니다. 명확하게 이해되지 않는 질문에 관하여는 가장 적합하다고 생각되어지는 답을 선택해 주시기 바랍니다. 다시 한번 설문에 응해 주신 점에 대해 감사를 드립니다.

박사과정 엄준호 올림

Part A. 일반적 경영정보

A1. 회사의 주요 제품이나 서비스는 무엇입니까?

- ☐ 식품, 음료, 담배
- ☐ 화학, 석유제품
- ☐ 가공 금속
- ☐ 전자 부품
- ☐ 운송기기
- ☐ 제지
- ☐ 순수 금속
- ☐ 그외
- ☐ 가구, 목재
- ☐ 비금속 광물
- ☐ 컴퓨터, 통신 제품
- ☐ 전자기기
- ☐ 섬유, 가죽
- ☐ 산업기계
- ☐ 의류

A2. 당사의 2009 년도 총 매출액은 얼마입니까? (억원)

☐ 4.5 미만 (억) ☐ 4.5 to 9 (억) ☐ 9 to 18 (억) ☐ 18 to 36 (억)
☐ 36 to 180 (억) ☐ 180 to 900 (억) ☐ 900 이상 (억)

A3. 2009년도 마진율은 얼마입니까? (마진율= 총수익/ 총수입 * 100)

☐ 0-5% ☐ 6-10% ☐ 11-15% ☐ 16-20% ☐ 21-25%
☐ 25% 이상 ☐ 모름

A4. 회사의 종업원 수는 몇 명입니까? (명)

☐ 50 이하 ☐ 51 - 150 ☐ 151 - 250 ☐ 251 - 1000 ☐ 1000 이상

A5. 주 경쟁업체의 수는 몇 개입니까? (개)

☐ 1 ☐ 2 - 5 ☐ 6 - 10 ☐ 11 - 20 ☐ 20 이상

A6. 회사의 제품 서비스 형태는?

☐ 국내 서비스 ☐ 국내 및 국제 서비스 ☐ 국제 서비스

A7. 당신의 직급은?

☐ 이사급 이상 ☐ 이사/ 상무 ☐ 팀장/부장
☐ 영업사원/대리 ☐ 일반사원/대리 ☐ 그 외

Part B. 제품다양성과 고객화 정도

B1. 당신의 회사는 한가지 혹은 다양한 제품을 제공합니까? ☐ 다양함 ☐ 단품

B2. 제품의 다양성이 증가하는 추세입니까? ☐ 네 ☐ 아니요

B3. 제품 다양성에 대한 소비자의 수요가 2005 년부터 얼마나 증가 혹은 감소하였습니까?

☐ -10% ☐ -5% ☐ 동일 ☐ +5% ☐ +10%

B4. 주제품군에 대한 일반적인 수요의 불확실성은 어느 정도 입니까?

☐ -10%➔+10% ☐ -20%➔+20% ☐ -30%➔+30% ☐ -40%➔ +40% ☐ -50%➔+50%

B5. 평균적인 주문에서 배송까지 걸리는 시간은 몇 일 입니까?

☐ 1일 이내 ☐ 2-3일 ☐ 4-6일 ☐ 7-14일 ☐ 15- 30일 ☐ 30일 이상

B6. 주 제품군의 다양성 수준

다음 중 각각 하나씩 선택하시기 바랍니다		1-5	6-10	11-15	16-20	20 이상
		1	2	3	4	5
1	당사의 제품에 있어서 서로 다른 핵심 디자인의 다양성(개수)	☐	☐	☐	☐	☐
2	핵심 디자인에 영향을 미치는 서로 다른 색, 크기, 기술적 옵션의 다양성(개수)	☐	☐	☐	☐	☐
3	핵심 디자인에 영향을 미치지 않는 특별한 옵션과 액세서리의 다양성(개수)	☐	☐	☐	☐	☐

B7. 고객화 수준

제품 고객화가 어느 정도 이루어지고 있는지 선택하시기 바랍니다(적절한 한가지만)		
1	당사는 미리 정해진 옵션과 디자인을 가진 표준제품을 일방적으로 제공한다. 즉 제품 고객화는 판매단계에서 이루어진다	☐
2	당사는 고객이 포장, 배송계획, 배송지역을 선택할 수 있는 제품을 제공한다. 실 제품은 미리 정해진 옵션과 디자인으로 표준화 되어있다. 즉, 고객화는 판매와 유통단계에서 이루어진다	☐
3	당사는 고객이 정해진 옵션을 선택할 수 있는 다양한 제품을 제공한다. 제품주문이 들어온 후 표준화된 부품의 조립을 통해 제품이 완성된다. 즉, 고객화는 조립단계에서 이루어진다.	☐
4	당사는 고객이 정해진 디자인을 선택할 수 있는 다양한 제품을 제공한다. 제품 주문이 들어온 후 제품이 만들어진다. 즉, 고객화는 제조단계에서 이루어진다.	☐
5	당사는 고객이 원하는 고유한 제품 디자인을 제작하여 공급한다. 제품은 주문이 들어온 후 디자인에 들어가며 고객화는 다자인 단계에서 이루어진다	☐

B8. 만약 한가지 이상의 고객화가 이루어 진다면 명시하여 주시기 바랍니다

☐ 2+3　☐ 2+4　☐ 3+4　☐ 2+3+4
☐ 그 외

Part C. 제품다양성 통제를 위한 공급망 관리 요인

다음 질문에서 어느 정도 동의하는지에 관하여 명시해 주시기 바랍니다		매우 동의안함		보통		매우 동의
		1	2	3	4	5
공급업자와의 파트너쉽						
1	우리는 공급업체와 신뢰를 기반으로 한 관계를 발전시켜가고 있다	☐	☐	☐	☐	☐
2	우리는 공급업체와 제품 개발에 있어 밀접한 관계를 유지하고 있다	☐	☐	☐	☐	☐
3	우리는 공급업체와 공동의 문제해결과 성과 측정을 수행하고 있다	☐	☐	☐	☐	☐
4	우리는 민감한 정보(재정, 생산, 디자인, 연구)를 공유하고 있다	☐	☐	☐	☐	☐
제품 생산 전략 (다양성 관리전략)						
1	우리는 조립단계에서 모듈화된 생산기술을 사용한다.	☐	☐	☐	☐	☐
2	우리는 고객의 주문이 발생시까지 제품의 기능이나 형태를 제작하는 과정을 최대한 늦춘다(지연전략)	☐	☐	☐	☐	☐
3	우리는 비슷한 디자인과 제조과정을 가진 부품을 그룹화 하는 셀룰라 제조 과정을 사용하고 있다	☐	☐	☐	☐	☐
고객 관리						
1	우리는 고객의 다양한 니즈를 기대하고 반응한다	☐	☐	☐	☐	☐
2	우리는 공식, 비공식적인 고객불만에 대한 평가를 강조하고 있다	☐	☐	☐	☐	☐
3	우리는 고객서비스 수준을 모니터하고 측정하고 있다	☐	☐	☐	☐	☐
4	우리는 품질/서비스 피드백을 위해 고객과 함께 하고 있다	☐	☐	☐	☐	☐

Part D. 민첩성, 유연성, 경쟁전략

당신의 회사의 공급망이 얼마나 잘 시행되고 있는지 명시해 주시기 바랍니다		매우 나쁨 1	2	보통 3	4	매우 좋음 5
공급망 유연성						
1	공급업체 주문의 양을 변경, 조절할 수 있는 능력	☐	☐	☐	☐	☐
2	공급업체와 주문의 배송시간을 변경, 조절할 수 있는 능력	☐	☐	☐	☐	☐
3	생산량을 변경, 조절할 수 있는 능력	☐	☐	☐	☐	☐
4	제품 조합을 변경, 조절할 수 있는 능력	☐	☐	☐	☐	☐
5	생산에 있어 엔지니어링 단계(순서) 변경을 조절할 수 있는 능력	☐	☐	☐	☐	☐
6	고객의 조건 변경에 맞춰 배송스케줄을 조절할 수 있는 능력	☐	☐	☐	☐	☐
공급망 민첩성						
1	제품개발 주기를 신속하게 줄일 수 있는 능력	☐	☐	☐	☐	☐
2	제조 리드타임을 신속하게 줄일 수 있는 능력	☐	☐	☐	☐	☐
3	제품고객화의 수준을 신속하게 증가시킬 수 있는 능력	☐	☐	☐	☐	☐
4	고객서비스 수준을 신속하게 증가시킬 수 있는 능력	☐	☐	☐	☐	☐
5	배송 신뢰성을 신속하게 증진시킬 수 있는 능력	☐	☐	☐	☐	☐
6	변화된 마켓의 니즈에 대한 반응을 신속하게 증진시킬 수 있는 능력	☐	☐	☐	☐	☐
7	배송 리드타임을 신속하게 줄일 수 있는 능력	☐	☐	☐	☐	☐
가격우위(경쟁업체와 비교)						
1	제조단가를 줄이는 능력	☐	☐	☐	☐	☐
2	낮은 제품가격을 제공하는 능력	☐	☐	☐	☐	☐
차별화(경쟁업체와 비교)						
1	고품질을 제품을 생산량 유연성을 가지고 빠르게 배송할 수 있는 능력 (고객서비스차별화)	☐	☐	☐	☐	☐
2	신제품을 고객의 수요에 따라 디자인 유연성을 가지고 개발할 수 있는 능력 (기술차별화)	☐	☐	☐	☐	☐
3	판매/유통 네트워크를 조절 할 수 있는 능력 (마케팅 차별화)	☐	☐	☐	☐	☐

Part E. 공급망, 경영관리 성과

당신 회사의 공급망이 얼마나 잘 수행되고 있는지 명시해 주시기 바랍니다		매우 나쁨 1	2	보통 3	4	매우 좋음 5
비용절감						
1	총 자원 사용비용을 최소화 하는 능력	☐	☐	☐	☐	☐
2	총 유통비용을 최소화하는 능력 (운송과 취급비용 포함)	☐	☐	☐	☐	☐
3	총 제조비용을 최소화하는 능력 (인건비, 유지보수, 재작업비용 포함)	☐	☐	☐	☐	☐
4	재고유지와 관련된 총비용을 최소화하는 능력	☐	☐	☐	☐	☐
고객서비스						
1	주문 충족률	☐	☐	☐	☐	☐
2	정시 배송	☐	☐	☐	☐	☐
3	고객 대응 시간	☐	☐	☐	☐	☐
4	품질	☐	☐	☐	☐	☐
5	제조 리드타임	☐	☐	☐	☐	☐
6	고객불만 감소	☐	☐	☐	☐	☐
7	고객만족	☐	☐	☐	☐	☐
8	재고품절 감소	☐	☐	☐	☐	☐
경영성과						
1	Return on sale (ROS)	☐	☐	☐	☐	☐
2	Return on Asset (ROA)	☐	☐	☐	☐	☐
3	시장 점유율 증가	☐	☐	☐	☐	☐
4	판매 증가	☐	☐	☐	☐	☐

Part F. 공급망에 있어서 제품 다양성의 영향

최근에 제품의 다양성이 늘어났다면 각 항목에 제품의 다양성이 미치는 영향력을 명시하여 주시기 바랍니다		낮은 증가(%)									높은 증가(%)
		1	2	3	4	5	6	7	8	9	10
		0-5 (%)	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-(%)
엔지니어링											
1	디자인 복잡성	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	R&D 비용	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	생산 단가	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	엔지니어링 / 모델 디자인 비용 및 변경비용	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
제조											
1	총 품질(total quality)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	제조비용(manufacturing cost)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	표준화된 부품사용	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	차별화 지연(Postponement) (제품 차별화 시점을 제조단계에서 지연하여 늦춤)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	셋업(set up) 비용	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	제조 유연성	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	직접 인건비	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	프로세스의 다양성	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	부품의 다양성	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
10	제조의 복잡성	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11	감독관의 노력	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
12	작업 스케줄의 복잡성	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
13	원재료 비용	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
14	간접비 (예. 자재취급 비용, 품질유지 비용 등)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
15	제조 리드타임	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
16	프로세스 기술 투자비용	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
구매											
1	구매비용	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	주문 프로세스(예, 공급업체 추가)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	구매 부품 다양성	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
물류											
1	재공품(생산공정중) 재고	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	완성품 재고	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	재고비용	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	구매부품 재고	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	배송 시간	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	원자재 취급 비용	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7	시장 조정 비용(Market mediation cost) (재고유지비, 할인 비용, 판매 유실 비용)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8	아웃소싱	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9	운송 비용	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
마케팅											
1	수요예측의 불확실성	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	고객만족	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	시장점유율	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4	경쟁적 이점	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5	소매점에서의 제품 가격	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

설문에 응해 주셔서 감사합니다

Appendix 2

Variety impact on business function

Business function	Mean						F	Sig
	PS	SS	CS	TC	PC	Total		
Engineering	5.25	5.04	4.72	4.60	3.98	4.62	1.281	.280
Manufacturing	5.23	4.93	4.41	4.22	3.28	4.29	4.009**	.004
Purchasing	5.33	4.05	4.12	4.09	3.06	4.01	2.789*	.028
Logistics	5.18	4.09	4.01	3.70	3.13	3.86	2.856*	.025
Marketing	6.18	5.49	5.05	4.62	3.83	4.84	4.126**	.003

*represents significant level $p< 0.05$, ** $p<0.01$, *** $P<0.001$