IMPACT OF MANUFACTURING FLEXIBILITY ON MANUFACTURING PERFORMANCE AND BUSINESS PERFORMANCE AMONG MALAYSIAN MANUFACTURING FIRMS

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ABSTRAK

Sorotan kepustakaan terdahulu menunjukkan terdapatnya penjelasan yang kabur mengenai hubungan di antara keluwesan pembuatan, prestasi pembuatan dan prestasi perniagaan. Bagi memenuhi jurang ini, kajian tentang impak keluwesan pembuatan terhadap prestasi pembuatan dan prestasi perniagaan telah dijalankan. Dalam kajian ini, pengkaji telah mencadangkan satu kerangka kerja pengantara apabila prestasi pembuatan berfungsi sebagai pengantara dalam hubungan di antara keluwesan pembuatan dan prestasi perniagaan. Komponen keluwesan pembuatan meliputi keluwesan campuran, keluwesan produk baru, keluwesan pekerja, keluwesan mesin, keluwesan pengendalian bahan, keluwesan penyaluran, dan keluwesan volum. Ukuran bagi prestasi pembuatan meliputi kualiti produk, pengurangan kos, produktiviti, pengurangan tempoh masa pembuatan dan pengurangan inventori. Sementara itu, prestasi perniagaan diukur oleh prestasi pasaran bagi produk, kepuasan pelanggan dan keberuntungan. Empat hipotesis utama telah dibentuk untuk menguji perhubungan di antara keluwesan pembuatan, prestasi pembuatan dan prestasi perniagaan. Kajian ini bersifat keratan rentas yang menggunakan metodologi tinjauan dan dijalankan ke atas lima industri perkilangan di Malaysia. Data diperolehi daripada 137 borang soal selidik yang dikembalikan dan telah dianalisis menggunakan analisis korelasi dan regresi. Keputusan analisis korelasi Pearson menunjukkan korelasi yang positif dan tinggi wujud dalam kalangan komponen keluwesan pembuatan. Di samping itu, dicadangkan bahawa komponen keluwesan pembuatan adalah saling bergantungan. Analisis regresi pula menyokong dapatan kajian bahawa keluwesan pembuatan mempunyai impak positif yang signifikan terhadap kedua-dua prestasi pembuatan dan prestasi perniagaan. Selain itu, kepentingan prestasi pembuatan sebagai pengantara dalam perhubungan keluwesan pembuatan dengan prestas perniagaan juga ditemui. Oleh itu, keluwesan pembuatan meningkatkan prestasi perniagaan secara langsung dan tidak langsung menerusi prestasi pembuatan sebagai pemboleh ubah pengantara. Secara spesifiknya, keempat-empat hipotesis utama yang diuji dalam kajian ini disokong. Kesimpulannya, kajian empirikal ini menyumbang dalam peningkatan pengetahuan dan kefahaman berkenaan saling perhubungan di antara keluwesan pembuatan, prestasi pembuatan dan prestasi perniagaan. Justeru, kajian ini membolehkan pihak penyelidik dan pengamal memperoleh pengetahuan yang lebih mendalam tentang konsep keluwesan pembuatan dan impaknya.

Kata kunci: keluwesan pembuatan, prestasi pembuatan, prestasi perniagaan, Malaysia

ABSTRACT

The unclear relationships between manufacturing flexibility, manufacturing performance and business performance have been indicated in past literature. To seal the gap, this study aimed to investigate the impact of manufacturing flexibility on manufacturing performance and business performance. In this study, the researcher proposed a mediating framework where manufacturing performance serves as a mediator in the relationship between manufacturing flexibility and business performance. The components of manufacturing flexibility were mix flexibility, new product flexibility, labor flexibility, machine flexibility, material handling flexibility, routing flexibility and volume flexibility. The measures for manufacturing performance were product quality, cost reduction, lead time reduction, productivity and inventory minimization. Product market performance, customer satisfaction and profitability were used as the measures for business performance. Four main hypotheses were developed to test the interrelationships between manufacturing flexibility, manufacturing performance and business performance. The study was a cross-sectional study, employing the survey methodology, conducted in five manufacturing industries in Malaysia. The data obtained from 137 returned questionnaires were analysed using correlational and regression analyses. Results of the correlation analyses indicated that components of manufacturing flexibility were positively and highly correlated among themselves, thus suggesting that the components were interdependent. Meanwhile, findings of the regression analyses provided support that manufacturing flexibility has significant positive impacts on both manufacturing performance and business performance. In addition, the mediation role of manufacturing performance on the relationship between manufacturing flexibility and business performance was revealed. In other words, manufacturing flexibility improves business performance both directly and indirectly via manufacturing performance as the mediator. Specifically, all four main hypotheses tested in this study were supported. In conclusion, this empirical study provides insights about the interrelationships between manufacturing flexibility, manufacturing performance and business performance. Hence, this study allows researchers and practitioners to gain in-depth knowledge about the concept of manufacturing flexibility and its impacts.

Keywords: manufacturing flexibility, manufacturing performance, business performance, Malaysia

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LIST OF ABBREVIATIONS

BP	Business Performance
CMV	Common Method Variance
GDP	Gross Domestic Product
KMO	Kaiser-Meyer-Olkin Measure
MF	Manufacturing Flexibility
MP	Manufacturing Performance
PCA	Principal Component Analysis
RBV	Resource-based View Theory
VIF	Variance Inflation Factor

CHAPTER 1

INTRODUCTION

1.1 Background of the Research

In modern day, rapidly evolving business environments that are full with changes and uncertainty led to the need for flexibility. The increase of customers' expectation on the speed to fulfill their requirements have forced many organizations to act and respond faster, and to be more flexible to changes (Agus, 2011; Zhang, Vonderembse, & Lim, 2003). Traditional manufacturing approaches are no longer sufficient for a firm to secure competitive advantage in this drastically changing environment (Kaur, Kumar, & Kumar, 2016; Koste & Malhotra, 1999a).

Concurrently, rapid changes in world’s technology have shortened the life cycle of the product; with customer demand for more innovative products with higher value, creating a flexible organization becomes essential to cope for rapid changes (Judi & Beach, 2008; Russell & Taylor, 2014). Decreasing of profit margins, increasing of inventory levels to cope with uncertainty, increasing of global competition, and increasing speed of technological changes (Agus, 2011; Judi & Beach, 2008; Kaur et al., 2016; Kher, Malhotra, Philipoom, & Fry, 1999; Mishra, Pundir, & Ganapathy, 2014; Nayak & Ray, 2012) have further amplified the need for flexibility. As a result, organizations must find better ways to meet these challenges. Since manufacturing flexibility enhances the ability of a firm to respond to customer needs that are highly diversified, it is generally accepted that incorporating manufacturing flexibility within the manufacturing function will help the organization to respond to such changes and customer needs in a faster and better way (Mishra et al., 2014; Mishra, Pundir, & Ganapathy, 2016; Peláez-Ibarrondo & Ruiz-Mercader, 2001; Pérez Pérez, Serrano Bedia, & López Fernández, 2016; Rogers, 2008).

Many organizations tend to solve problems using conventional way, where internal factors that are within the organization are focused even though the problems may be caused by external factors. However, negligence of external factors such as suppliers, distributors, and customers did affect an organization's ability to fulfill customer expectations and their survivability in uncertainty (Kher et al., 1999; Slack, 2005). Various manufacturing practices such as lean manufacturing, world class manufacturing, knowledge management, organization learning, total quality management (TQM), quick response program (QRM), efficient consumer response (ECR), systems dynamics, business process re-engineering, mass customization, manufacturing flexibility, total productive maintenance and benchmarking of best practices are proposed to help the organizations in enhancing their performance especially the manufacturing functions (Agus, 2011; Najmaei & Sadeghinejad, 2009; Seng, Jantan, & Ramayah, 2005; Tuanmat & Smith, 2011). With respect to the production system, due to lacking of understanding of the synergy within the manufacturing system, many firms have implemented the manufacturing flexibility in an incomplete way. Loss of the synergistic benefits have made the implementation of manufacturing flexibility being considered as a fail subject, as performance does not improve as expected (Narasimhan & Das, 1999; Rogers, Ojha, & White, 2011).

Manufacturing flexibility can provide an organization the ability to handle the rapidly changing business conditions with more dynamic options and act more effective to dynamic competitive business environment (Jack & Raturi, 2009; Rogers, 2008). As flexibility becomes important and its potentials are recognized by managers around the world, it has been proclaimed as the "*next competitive battle*" to improve organizations survivability in this ever changing yet volatile business environment (Brettel, Klein, & Friederichsen, 2016; Cox, 1989; Jack, 2000; Jack & Raturi, 2009; Upton, 1995; Vokurka & O'Leary-Kelly, 2000).

Impacts of flexibility in the value chain are substantial in many areas including development of new products, manufacturing system, and logistics. For example, flexibility allowed a firm to improve performance by reducing manufacturing lead time, introduce new products in a timely manner and reduce manufacturing costs (Alamro, 2014; Zhang, 2001).

Last but not least, multidimensionality of manufacturing flexibility within the function of manufacturing is generally accepted by past researchers and its importance honoured (Mishra et al., 2014). The complexity of manufacturing flexibility has made this concept difficult to comprehend yet delimit (Baykasoğlu & Özbakır, 2008; De Toni & Tonchia, 1998; Pérez Pérez et al., 2016). To date, agreement on how to practice this concept has not yet been resolved.

1.2 Manufacturing in Malaysia

As a developing country, Malaysia relies heavily on the manufacturing sector. Manufacturing sector has provided gross output of RM 731.9 billion in 2013 and employed more than 1.1 million employees (Ministry of Finance, 2015). The manufacturing sector in Malaysia has contributed 24.5 percent of Malaysia total Gross Domestic Product (GDP) for year 2013 (Ministry of Finance, 2015). In 2012, the electronics and electrical sector has accounted for 18 percent of GDP and 22 percent of Malaysia's total exports (Economic Planning Unit, 2014).

However, the challenging external environments have slowed down the growth of the manufacturing sector (Wong, Wong, & Ali, 2009). Growth of manufacturing sector has been reduced from double digits growth (11.4 percent at 2010) to single digit growth (4.7 percent for 2011, 4.8 percent for 2012, 3.5 percent for 2013, and estimate as 6.4 percent for 2014) (Ministry of Finance, 2012, 2013, 2014, 2015). As the manufacturing sector (an important contributor of GDP) in Malaysia is highly dependent on export (Ministry of Finance, 2015; Sambasivan, Nandan, & Mohamed, 2009), the increasing challenging external environments have made the adoption of manufacturing flexibility crucial for survival (Adis & Razli, 2009; Wong et al., 2009). The manufacturing sector in Malaysia also has problems in maintaining its competitiveness, quality and on time delivery to gain market share, while rapid changes of trading policies and regulatory are also affecting the performance of the manufacturing sector (Musa, 2007).

In order to sustain competitiveness and to deal with these changes properly, firms in Malaysia have imposed several policies and strategies such as having loyal customers, strong brand name, better product quality, higher production efficiencies, introducing new products and adopting new technology (Adis & Razli, 2009; Jabar, Soosay, & Santa, 2011; Wong et al., 2009). However, in the present situation of evolving environment, these competencies are easily imitable by competitors (due to low barriers to entry) and obsolete over time. There are no guarantees of the success in the changing business environment by adopting these policies and strategies. Furthermore, in this highly uncertain market, firms do not have a luxurious time to wait and learn from emerging market conditions (Jantan, Ndubisi, & Hing, 2006; Wong et al., 2009). Indeed, they must learn to be adaptive as success relies on its adaptive capabilities (Jabar et al., 2011). Therefore, organizations must instil flexibility in its organization settings and strategies to become competitive (Brettel et al., 2016; Jantan et al., 2006; Nassirnia & Tap, 2010).

As what happened in other countries, a lot of remedies have been adopted by Malaysian manufacturers (Agus, 2011; Najmaei & Sadeghinejad, 2009; Tuanmat & Smith, 2011; Zainol, Al-Mamun, & Permarupan, 2013) to counter the rapid changing environment, one of them is manufacturing flexibility (Jantan et al., 2006; Judi & Beach, 2008). This concept has been seen as the most notable in counter the uncertainty in a dynamic environment as suggested by the definition of flexible which mean responsiveness to changing environment (Beach, Muhlemann, Price, Paterson, & Sharp, 2000; De Toni & Tonchia, 1998; Gerwin, 2005; Pérez Pérez et al., 2016; Upton, 1995).

Some studies have been carried out in Malaysia context to define, classify and measure manufacturing flexibility (for example Judi, Beach, and Muhlemann (2004) and Judi and Beach (2008)) and what affect manufacturing flexibility (such as Jantan et al. (2006)). However, extensive studies aiming to investigate the contribution of manufacturing flexibility to firms' performance in the context of Malaysia are still limited and further explorations are needed.

1.3 Problem Statement

Since 1980s, researchers have proposed that, flexibility can only be explained to practitioners only if both a generalizable definition of manufacturing flexibility, and standardized measurement instruments for the concept of manufacturing flexibility are developed (De Toni & Tonchia, 1998; Kumar, Fantazy, Kumar, & Boyle, 2006; Mishra et al., 2014; Pérez Pérez et al., 2016; Sethi & Sethi, 1990). Due to lack of clarity about the concept of flexibility in past literature and the multidimensional nature of the concept, flexibility has been claimed to be hard to conceptualize and understand by researchers and organizations that try to adopt it (Oke, 2005; Pérez Pérez et al., 2016).

Vokurka and O'Leary-Kelly (2000) have stated that manufacturing flexibility has gradually become one of the approaches to achieve competitive advantage. Although researchers agreed upon the importance of manufacturing flexibility, there is still no generally accepted definition (Bordoloi, Cooper, & Matsuo, 1999; Rogers, 2008). A numbers of studies have been done on manufacturing flexibility, yet the idea is still not fully understood (Cox, 1989; Koste, 1999; Pérez Pérez et al., 2016; Rogers, 2008). Kumar et al. (2006), Shi and Daniels (2003) and Upton (1995) have stated that flexibility is something that hard to understand, difficult to improve but important to competitiveness. The initial problems for organizations that try to increase manufacturing flexibility are the abundance lists (yet keep on increasing) of manufacturing flexibility components with overlapping of component definitions. A generalizable list of manufacturing flexibility components are urgently needed so that survey and measurements that enable comparisons can be carried out (Mishra et al., 2016; Pérez Pérez et al., 2016; Rogers, 2008; Upton, 1995).

Another problem arises when terminology like "*flexible manufacturing systems*" (FMS) that use fully automated machines that are highly specialized and consider inflexible by most researchers is used interchangeably with "*manufacturing flexibility*" (Rogers, 2008; Wadhwa, 2014). This causes misunderstanding within the manufacturing flexibility literature and practical applications.

Literature in manufacturing flexibility is highly fragmented, where according to Vokurka and O'Leary-Kelly (2000), most past researches adopted industry specific measure(s) that are hard to generalize to other industries and single facet of manufacturing flexibility is measured even though multidimensional of manufacturing flexibility was supported by many past studies (Anand & Ward, 2004; Boyle, 2006; Judi et al., 2004; Koste, 1999; Oke, 2005; Sawhney, 2013; Sethi & Sethi, 1990; Suarez, Cusumano, & Fine, 1996; Wilson & Ali, 2014). Unstandardized methods to measure manufacturing flexibility (Beach et al., 2000; De Toni & Tonchia, 1998; Judi & Beach, 2008; Pérez Pérez et al., 2016) are happening due to lack of understanding about the relationships between components of manufacturing flexibility (Chang, Yang, Cheng, & Sheu, 2003; Rogers, 2008; Rogers et al., 2011; Vokurka & O'Leary-Kelly, 2000). Complementary effects of components in manufacturing flexibility components create synergy (Camisón & López, 2010; Rogers et al., 2011), but study on the potential trade-off between them is still scarce (Camisón & López, 2010; Rogers, 2008; Vokurka & O'Leary-Kelly, 2000). This implicit that further research in synergy between manufacturing flexibility's components is required.

Manufacturing flexibility is perceived as a tool to improve manufacturing performance (Al-jawazneh, 2012; Camisón & López, 2010). However, some of the past researches have reported that manufacturing flexibility affects both manufacturing performance (Rogers, 2008; Rogers et al., 2011) and business performance (Anand & Ward, 2004; Chang, Lin, & Sheu, 2002; Gupta & Somers, 1996; Zhang, Vonderembse, & Cao, 2009) directly. The strong evidence of the impact of manufacturing flexibility on both manufacturing performance and business performance, couple with impact of manufacturing performance on business performance (Camisón & López, 2010; Combs, Crook, & Shook, 2005; Nawanir, 2011; Nawanir, Lim, & Othman, 2013; Vokurka & O'Leary-Kelly, 2000) did prospect that manufacturing performance (act as both predictor and criterion variable) is a potential mediator within the relationships of these three constructs (Baron & Kenny, 1986).

Meanwhile, a thorough literature review indicated that the number of studies investigating how manufacturing flexibility leads to business performance is still lacking (Al-jawazneh, 2012; Camisón & López, 2010; Vokurka & O'Leary-Kelly, 2000). In specific, very few studies investigated the interrelationships between manufacturing flexibility, manufacturing performance, and business performance (Camisón & López, 2010; Larso, Doolen, & Hacker, 2009). In addition, more studies are needed to test the extent to which manufacturing performance mediates the relationship between internal activities (such as manufacturing activities/manufacturing flexibility) and organization’s business performance (Combs et al., 2005). This indicated that the relationships between manufacturing flexibility, manufacturing performance, and business performance are unclear. In the same vein, Vokurka and O'Leary-Kelly (2000) and Camisón and López (2010) also highlighted that there is a clear need for more studies investigating the direct and indirect relationships involving manufacturing flexibility and organizational performance. As the pattern of interrelationships between manufacturing flexibility, manufacturing performance and business performance are important for researchers and practitioners to understand how manufacturing flexibility affects organization performance, further researches are required.

In short, several gaps have been had been identified. Specifically, numerous past studies have indicated that manufacturing flexibility has been commonly accepted as a powerful tool to enhance manufacturing and business performance. However, a generalizable definition of manufacturing flexibility, the common components of manufacturing flexibility and a standardized measurement instrument for the concept of manufacturing flexibility are still unavailable for this powerful tool to be measurable (Camisón & López, 2010; De Toni & Tonchia, 1998; Kumar et al., 2006; Pérez Pérez et al., 2016; Sethi & Sethi, 1990). Meanwhile, the contradiction of theoretical perspectives in the development of manufacturing flexibility components also served as a problem that indirectly related to the incapability to develop a parsimony set of manufacturing flexibility components. On the other hand, the chaotic relationships between manufacturing flexibility and firms' performance have protruded the needs to systematically investigate the interrelationships between manufacturing flexibility, manufacturing performance and business performance in order to fully understand how manufacturing flexibility lead to firms' performance.

Due to the previous obstacles and the lack of consensus within the existing manufacturing flexibility literature, the assessment of manufacturing flexibility is still "*an underdeveloped subject*" (Mishra et al., 2014), and hence more empirical studies are required to clarify the unknown and misconception about manufacturing flexibility.

This empirical study aims to identify the components of manufacturing flexibility while investigating the pattern of interrelationships between manufacturing flexibility, manufacturing performance and business performance in Malaysian manufacturing firms. This research was important to clarify “what is manufacturing flexibility” and “what is the impact of manufacturing flexibility towards manufacturing performance and business performance”. Besides, current research will also assess the potential mediator effect of manufacturing performance on the relationship between manufacturing flexibility and business performance, as this was a crucial point that can lay a foundation for future studies.

1.4 Research Questions

With reference to the research problems discussed in the preceding section, the following research questions were formulated:

1. What are the components of manufacturing flexibility?
2. Is there a relationship between manufacturing flexibility and manufacturing performance?
3. Is there a relationship between manufacturing flexibility and business performance?
4. Does manufacturing performance mediates the relationship between manufacturing flexibility and business performance?

1.5 Research Objectives

The purpose of the study is to investigate empirically and systematically the impact of manufacturing flexibility on firm performance with respect to manufacturing performance and business performance. This general objective was divided into the following four specific objectives:

1. To identify the components constituting manufacturing flexibility.
2. To examine the relationship between manufacturing flexibility and manufacturing performance.
3. To examine the relationship between manufacturing flexibility and business performance.
4. To examine the role of manufacturing performance in mediating the relationships between the manufacturing flexibility and business performance.

1.6 Significance of the Research

This research is important for several reasons:

1. Lack of concise list of manufacturing flexibility's components and inconsistent terminologies of manufacturing flexibility make the need to identify the components of manufacturing flexibility crucial.
2. The benefits of increasing manufacturing flexibility and how manufacturing flexibility contributes to business performance are yet to be determined; this becomes an obstacle for manufacturing organizations to implement the concept. Consistent with the recommendations from the past studies (such as Rogers

(2008), Vokurka and O'Leary-Kelly (2000) and Alamro (2014)), this study will examine manufacturing flexibility and firm performance systematically. Manufacturing flexibility is viewed intrinsically, and firm performance is measured at two levels in the hierarchy of objectives, where manufacturing performance is the lower in the hierarchy and business performance is the higher in the hierarchy.

3. In this study, a mediation model is proposed to investigate the relationship between the firm's manufacturing flexibility, the firm's manufacturing performance and the firm's business performance. Studies involving investigation about the nature of the relationship directly and indirectly is still lacking. This further suggested that the study considering impact of manufacturing flexibility on both types of firm performance is still necessary (Camisón & López, 2010; Vokurka & O'Leary-Kelly, 2000).
4. Published studies related to manufacturing flexibility and performances that have been conducted in a developing country are limited (Mishra et al., 2014). This research contributes to the literature on manufacturing flexibility by providing a Malaysian perspective on the subject.

In specific, this research investigates (i) the flexibility components that support the concept of manufacturing flexibility and (ii) whether manufacturing flexibility would increase the manufacturing performance and eventually business performance of manufacturing companies. Through this research, researcher hopes to link up manufacturing flexibility to manufacturing performance and ultimately, to business performance. The findings of this study will enhance the existing body of knowledge about manufacturing flexibility and also providing guidance for practitioners to implement this multidimensional concept.

1.7 Scope of the Research

This study investigated the interrelationships between three constructs i.e. manufacturing flexibility, manufacturing performance and business performance, in the context of Malaysia. The components of manufacturing flexibility are mix flexibility, new product flexibility, material handling flexibility, routing flexibility, volume flexibility, labor flexibility and machine flexibility. The measures of manufacturing performance include product quality, cost reduction, inventory minimization, productivity, and lead time reduction. Meanwhile, the measures of business performance include product market performance, customer satisfaction and profitability.

Consistence with the past studies (e.g. Rogers (2008) and Zhang et al. (2009)), the industries chosen in this study include the electrical and electronic related sector, machine and equipment fabricator, chemicals and chemical products producers, food products and beverages manufacturers, and also metal related products manufacturers. Manufacturing plant is the unit of analysis for this research. Production managers, director of production/manufacturing, the head of production/manufacturing department or equivalent position in the manufacturing function are the respondents of this research.

1.8 Definitions of Key Terms

Some of the important terms used in the context of this study were defined as below:

Manufacturing Flexibility

"*A multidimensional construct that represents the overall ability of the manufacturing system to adapt to both external changes and internal changes*" (Chauhan & Singh, 2014; D'Souza & Williams, 2000; De Toni & Tonchia, 1998; Koste & Malhotra, 1999b; Rogers, 2008).

Manufacturing System

A collection of integrated equipment (include manufacturing machines as well as material handling devices) and human resources, whose function is to perform multiple processing and/or assembly operations on a starting raw material, part, or set of parts to produce a desired set of finished and also semifinished goods (Groover, 2008; Shewchuk & Moodie, 1998).

Manufacturing Flexibility's Components

The characteristics of a manufacturing system that increase the system's ability to respond to changes whether internally or externally (Rogers, 2008). The components of manufacturing flexibility are machine flexibility, labor flexibility, material handling flexibility, volume flexibility, routing flexibility, new product flexibility, and mix flexibility.

Mix Flexibility

The ability of the manufacturing system to switch between different products in the product mix (Judi & Beach, 2008).

New Product Flexibility

The ability of the manufacturing system to incorporate new product(s) into the existing range of products (Alamro, 2014; Pérez Pérez et al., 2016).

Labor Flexibility

The ability of the production workers to perform more than one task in the manufacturing system (Rogers et al., 2011).

Machine Flexibility

The ability of the manufacturing machine to perform more than one operation to produce different parts or products (Al-jawazneh, 2012; Lucas & Kirillova, 2011; Rogers et al., 2011; Sethi & Sethi, 1990).

Material Handling Flexibility

The ability of the material handling system to handle various types of material (Helkiö, 2008; Sethi & Sethi, 1990).

Routing Flexibility

The ability of the manufacturing system to manufacture products through a variety of different routes (Koste, 1999; Nishith, Rishi, & Sharma, 2013; Rogers, 2008; Rogers et al., 2011; Sethi & Sethi, 1990).

Volume Flexibility

The ability of the manufacturing system to alter the output volume of a manufacturing process (Judi et al., 2004; Sethi & Sethi, 1990).

Business Performance

Business performance measures encompass profitability, customer satisfaction and product market performance; where its look at firm's performance as a whole rather than only at functional level (Nawanir et al., 2013; Nawanir, Lim, & Othman, 2016; Richard, Devinney, Yip, & Johnson, 2009).

Manufacturing Performance

The outcomes which are influenced by operating conditions, such as product quality, cost, lead time and productivity, and represent or reflects some internal properties of the manufacturing system (Nawanir et al., 2013).

1.9 Organization of Research Report

The research report is divided into the following chapters: The first chapter introduces the background of the study, couples with problem statement, research questions, research objectives, significance of the research, scope of the research and definition of key terms used in this study. Literature reviews on manufacturing flexibility, manufacturing performance and business performance are presented in the second chapter. Furthermore, the relationships between manufacturing flexibility, manufacturing performance and business performance are also explored in this section. The related theories, theoretical framework, hypotheses, and research methodologies used in this study are presented in Chapter 3. Chapter 4 provides the result of the study. Chapter 5, the final chapter of the research report, devotes to discussion and conclusion of the study, the implications and limitations of the study, as well as recommendation for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Flexibility has been recognized as an important manufacturing capability that has the potential to impact both the competitive position and the business positions of a firm (Brettel et al., 2016; Cox, 1989; Vokurka & O'Leary-Kelly, 2000). As mass customization has slowly become a substitution for mass production, the importance of flexibility has leverage to a degree that the understanding of how it affects manufacturing performance and business performance is crucial to ensure efficient management of manufacturing flexibility (Russell & Taylor, 2014). Furthermore, it also helps to explain the nature of flexibility in manufacturing, and proceed to foretell its behaviors.

This chapter reviews the existing research works pertaining to definitions of flexibility, benefits of flexibility, definitions of manufacturing flexibility and benefits of adopting them, the components constituted manufacturing flexibility and also the impacts of manufacturing flexibility towards firm’s performance. Meanwhile, the possible interrelationships between manufacturing flexibility, manufacturing performance and business performance are also discussed. In short, this chapter will help to identify the founding block of manufacturing flexibility. It also serves as the bridge to identify the operational measures of variables used in this research as well as the development of the research framework.

2.1.1 Definition of Flexibility

Manufacturing sector is a constantly changing and upgrading sector that needs reforms for its sustainability. The manufacturing sector needs to be flexible in dealing with increasing competition in the market and customer demands that are getting complex. Flexibility is now emerges as one of the key competitive priorities in manufacturing environment (Brettel et al., 2016; Russell & Taylor, 2014) that prioritized products variety, ability to varied production volumes, short product life cycle and time based competition. Thus, flexibility is seen as an important attribute of the manufacturing system that is capable of fulfilling the challenges posed by uncertain business environment (Al-jawazneh, 2012).

A great deal of researches in attempting to identify various types of flexibilities in manufacturing has been carried out over the past few decades. Nevertheless, there is no general agreement on how to define flexibility (Rogers, 2008). According to Beach et al. (2000), flexibility can be the capability to cope with environmental ambiguity and variation. Groote (1994) defined flexibility as a way to solve problems arising from assortments of situations. According to Nilsson and Nordahl (1995), flexibility is the capability to react effectively to frequent changing of state of affairs. Upton (1995) noted that flexibility is the capability to adjust with little drawback in performance, time, cost and effort. Flexibility's role is to serve as the response to different types and categories of problems, where numerous choices of responses are available.

For an organization, flexibility means generating choices at various stages in the firm, creating methods and also reasons of change across various choices and providing freedom of choice to numerous players in the organization for enabling this transformation to materialize with slightest effort and time (Sushil, 2001).

Bahrami (1992) stated that flexibility is a polymorphism that its definition may change from one state to another state of affair, *"implying stability, sustainable advantage, and capabilities that may evolve over time"*.

Meanwhile, Carlsson (1989) defined flexibility as an attribute that enables a production technology to accommodate greater variation in output. He also stated that flexibility is an attribute that enables firms to respond to uncertainty, in terms of fluctuations in demand and market imperfection. In the same vein, Schulz, Fricke, and Igenbergs (2000) defined flexibility in a similar way as "*property of the system to be changed easily*".

In addition, Saleh, Hastings, and Newman (2001) defined flexibility in manufacturing system as "*nature of change the production system can accommodate"*. While Araujo and Spring (2002) claimed flexibility as the absorber of environmental ambiguity and variability. Last but not least, Bernardes and Hanna (2009) described flexibility as "*ability of the system to change status within an existing configuration*".

Summary of definitions of flexibility is depicted in Table 2.1.

Table 2.1
Definitions of Flexibility

Authors	**Definitions of Flexibility**
Carlsson (1989)	An attribute that enables a production technology to accommodate greater variation in output.
Groote (1994)	A way to solve problems arising from assortments of situations.
Nilsson and Nordahl (1995)	The capability to react effectively to frequent changing of state of affairs.
Upton (1995)	The capability to adjust with little drawback in performance, time, cost and effort.
Beach et al. (2000)	The capability to cope with environmental ambiguity and variation.
Schulz et al. (2000)	"*Property of the system to be changed easily*".
Saleh et al. (2001)	"*Nature of change the production system can accommodate".*
Araujo and Spring (2002)	The absorber of environmental ambiguity and variability.
Bernardes and Hanna (2009)	"A*bility of the system to change status within an existing configuration*"
Al-jawazneh (2012)	An important attribute of the manufacturing system that is capable of fulfilling the challenges posed by uncertain business environment.
Russell and Taylor (2014)	One of the key competitive priorities in manufacturing environment that prioritized products variety, ability to varied production volumes, short product life cycle and time based competition.

With reference to the preceding definitions, it is reasonable to conclude that the concept of flexibility is a complex term. It carries different meanings in different contexts and implies adaption to environmental changes, sensitivity to changes, adaptability of actions and capability to tackle unforeseen event through non-rigid solution. Flexibility is a multidimensional construct and various responses exist to meet different flexibility challenges. Utmost importantly, flexibility is acting as the medium, which enables the existence of choices and options to handle unexpected circumstances.

2.1.2 Benefit of Flexibility

Many benefits of adopting flexibility have been reported in various case studies and empirical studies. Some of the benefits include reduction of time in new product design and new product introduction; improve performance of products without sacrificing key performance indicator such as product quality, time to delivery and manufacturing cost (Heizer, Render, & Munson, 2017; Russell & Taylor, 2014). On the other hand, better financial performance, bigger market share, reduction of rework cost, reduce of raw material cost and cost to manufacture, increase throughput, reduce machine setup time, increase efficiency, inventory reduction, increase productivity, better customer satisfaction are also part of the benefits reported by past studies (Al-jawazneh, 2012; Narasimhan & Das, 1999; Olhager & West, 2002; Powers & Jack, 2008; Roca-Puig, Beltrán-Martín, Escrig-Tena, & Bou-Llusar, 2005; Rogers, 2008; Zhang et al., 2003). Outcomes and benefits of flexibility to organization are uncountable and diverse in different situation (Jain, Jain, Chan, & Singh, 2013), as flexibility allowed delay of decision making or judgement to a later time, where information may be more accessible (Koste, 1999; Rogers, 2008).

According to Gerwin (1993), flexibility can be active or passive. Passive flexibility improves firm’s awareness and response to uncertainties (Jordan & Graves, 1995) while active flexibility allowed a firm to shape the market and control the uncertainties (Gerwin, 1993). As an example, passive flexibility enables a firm to defend against customer expectations that are increasingly demanding, which include but not limited to faster response time and frequent change of order quantities. Passive flexibility is reactive in nature and acts after customer demand. On the other hand, active flexibility is the ability to tap the opportunity exists whenever it happens and shapes the buying pattern of the customers, it also served as the capability to foresee and foretold what customer need and prepared against it. Typically firm with higher flexibility has higher chance of surviving through volatile market environment that are temperamental yet changing at fast pace (Camisón & López, 2010; Rogers, 2008). This is further support by the fact that competitors will keep on improving and those do not improve will find themselves unable to survive (Camisón & López, 2010).

As stated by Bahrami (1993), flexibility in management introduces a new way of competitiveness for an organization and creates organizational and managerial effectiveness; stimulate exceptional business performance, with enlightenment, freedom and inspiration. According to the author, flexibility is the blend of speed and versatility. Speed is the time-based ability to change course to obtain benefits when opportunity arrived or step a side when a threat present to mitigate the risk. Versatility is the ability to do things in different way and the ability to do many different things. In sum, flexibility enables an organization to embrace innovation, improve speed and reduce response time to market needs. As flexibility allowed an organization's products and services as well as the ways of doing business to evolve more rapidly than their contenders, it has becomes the cradle of competitive advantage (Brettel et al., 2016; Jack & Raturi, 2009).

On the other point of view, Bolwijn and Kumpe (1990) noted the needs of flexibility is aroused when price and quality are no longer the decisive authority in determining customer satisfaction, as customers nowadays not only demand product with cheap price and high quality, but also variety of products to choose from (Jain et al., 2013; Zhang et al., 2009; Zhang et al., 2003). Tastes of customers are unpredictable and keep on changing, which make the market is to be viewed as comprising of multiple niches. This promotes the needs to be flexible, to tackle the various niche markets exist in the global market.

In sum, flexibility has been seen as a source to promote competitive advantage by various researchers (Brettel et al., 2016; Camisón & López, 2010; Koste & Malhotra, 1999b; Rogers, 2008). Manufacturing flexibility, as an extension of flexibility is burden with the same expectations by various researchers and industry practitioners (Al-jawazneh, 2012).

2.2 Manufacturing Flexibility

This section will review the literature on the definitions of manufacturing flexibility, the components that form the building block of manufacturing flexibility as well as the benefits of manufacturing flexibility. Besides, it also investigates how well the concept of manufacturing flexibility is understood and used within manufacturing firms.

2.2.1 Definition of Manufacturing Flexibility

In general, researchers agreed on the importance of manufacturing flexibility. Although a significant number of studies have been done on manufacturing flexibility, the idea of the concept is still not fully understood (Cox, 1989; Jain et al., 2013; Pérez Pérez et al., 2016; Rogers, 2008). According to Jain et al. (2013), Kumar et al. (2006) and Upton (1995), flexibility is something that is difficult to understand, difficult to be enhanced but important for competitiveness. In addition, there is still no consensus among the academicians and industry practitioners on the definition of manufacturing flexibility (Bordoloi et al., 1999; Jain et al., 2013; Rogers, 2008; Upton, 1995). Below are examples of the meaning of manufacturing flexibility that can be identified in the literature:

Swamidass and Newell (1987) defined manufacturing flexibility as "*the capability of the manufacturing system to adapt effectively to changing environmental circumstances and process requirements*". It also can be referred as the ability of a manufacturing system to handle the volatility set off by the surroundings. Similarly, Sushil (1999) and Narasimhan and Das (1999) also have referred manufacturing flexibility as the overall capability of a firm's manufacturing system to respond to changes, either internally or externally without incurring unreasonable penalty of time, cost or effort.

According to D'Souza and Williams (2000), manufacturing flexibility is a multifaceted concept that denotes the proficiencies of a manufacturing function, to make the essential tunings as a respond to environmental changes without compromising the performance of the organization.

For Zhang et al. (2003), manufacturing flexibility is the ability of a firm to manage manufacturing resources and ambiguity to fulfill all the customer needs and expectations. Meanwhile, Slack (2005) described manufacturing flexibility as the true capability observed in the manufacturing system that enable it to make alterations to the environment either in short or long term.

In Malaysia context, Jantan et al. (2006) defined manufacturing flexibility as the swiftness and the ease with which firms can react to all type of changes in market conditions. On the other hand, Judi and Beach (2008) described manufacturing flexibility as the ability of organization to manage its resources in order to cope with unknown in surroundings while promoting the variety of products.

Summary of definitions of manufacturing flexibility is depicted in Table 2.2.

Table 2.2
Definitions of Manufacturing Flexibility

Authors	**Definitions of Manufacturing Flexibility**
Swamidass and Newell (1987)	“*The capability of the manufacturing system to adapt effectively to changing environmental circumstances and process requirements*”.
Sushil (1999)	The overall capability of a firm’s manufacturing system to respond to changes, either internally or externally without incurring unreasonable penalty of time, cost or effort.
Narasimhan and Das (1999)	
Swamidass (2000a)	“*The capacity of a manufacturing system to adapt successfully to changing environmental conditions as well as changing product and process requirements, where the flexibility provides the manufacturing plant the ability to maintain customer satisfaction and profitability under conditions of change and uncertainty.”*
D'Souza and Williams (2000)	A multifaceted concept that denotes the proficiencies of a manufacturing function, to make the essential tunings as a respond to environmental changes without compromising the performance of the organization.
Zhang et al. (2003)	The ability of a firm to manage manufacturing resources and ambiguity to fulfill all the customer needs and expectations.
Slack (2005)	The true capability observed in the manufacturing system that enable it to make alterations to the environment either in short or long term.
Jantan et al. (2006)	The swiftness and the ease with which firms can react to all type of changes in market conditions.
Judi and Beach (2008)	The ability of organization to manage its resources in order to cope with unknown in surroundings while promoting the variety of products.
Rogers (2008)	Characteristics of a manufacturing system that increase the system’s ability to respond to changes whether internal or external
Chauhan and Singh (2014)	A manufacturing system’s ability to respond to fluctuations in the production process and produce customer-oriented products at low cost and greater response sensitivity in dynamically changing manufacturing systems.

Based on the above definitions, manufacturing flexibility can be referred to either as the ability of a manufacturing firm or the ability of a manufacturing system. Manufacturing system is defined by Groover (2008) as "*a collection of integrated equipment and human resources, whose function is to perform one or more processing and/or assembly operations on a starting raw material, part, or set of parts*".

According to Shewchuk and Moodie (1998), the function of manufacturing system is to transform inputs (raw materials, purchased items, and others) into outputs (finished, semi-finished goods) that fulfill specified production requirement (products characteristic, production lead time, product mix, production volume, responsiveness to customer requirement and delivery need, quality, efficiency, and operating cost (raw material cost, processing cost, warehousing cost)). In other words, all the equipment and human resources used in the production system must have the abilities to perform the assigned operations converting the inputs to outputs of greater value that fulfilled specific requirements in terms of quality, time, cost and flexibility.

Misunderstanding and ignorance of the difference in the definition of the manufacturing flexibility and its concept, whether referring to the organization or manufacturing system, can cause confusion in the literature and practical applications. Difficulty in measurement arises when manufacturing flexibility is treated as ability of the whole manufacturing organization (i.e. the whole firm including marketing function, research and development function, human resource function and others). This is because the different functional areas of the organization will require different kind of flexibility and different levels of flexibility. Some of the functional areas require minimal flexibility while some of the other functional areas lead the implementation of manufacturing flexibility (Mishra et al., 2016; Pérez Pérez et al., 2016; Upton, 1995). As an example, mix flexibility may be more relevant to manufacturing system in the manufacturing function if compare to others business functions. In addition, organizational characteristics that enhance an organization's ability to respond to changes either internally or externally may differ with different characteristics of manufacturing systems (Shewchuk & Moodie, 1998).

In the meantime, manufacturing flexibility is a concept that grows and changes gradually as new elements or new methods developed. The number of definition for manufacturing flexibility’s components is increasing and are expected to continue to increase (Rogers, 2008; Rogers et al., 2011; Sethi & Sethi, 1990; Shewchuk & Moodie, 1998). There is no consensus on what constitutes manufacturing flexibility and various names have been given to a component of manufacturing flexibility (Pérez Pérez et al., 2016). The issue of duplication of manufacturing flexibility components’ definition and loose use of the term (i.e. the same component name with different definitions) are common in the literature related to manufacturing flexibility.

Concept of manufacturing flexibility is increasingly complicated and confusing when certain manufacturing system features that have nothing to do with manufacturing flexibility are associated with the concept. For example, the term “*manufacturing flexibility*” and “*flexible manufacturing system*” (FMS) are used interchangeably. FMS is a specialized manufacturing technology involving computer based control and the usage of fully automated machine that operates with minimal staffs and minimal supervision; in order to enable the organization to carry out fully automated production without the need for a more skilled workforce (Rogers et al., 2011). According to this definition, an organization will be considered to have a flexible manufacturing system, although it uses equipment that are very specific and inflexible (Gupta & Somers, 1992; Rogers, 2008). When FMS is used interchangeably with "*manufacturing flexibility*", such term usage may again result in confusion in the literature and practical applications.

The lack of consensus on the definition of manufacturing flexibility and its components have created problems for researchers to further investigate the link between manufacturing flexibility and firm's performance (Mishra et al., 2016). Confusion about what is manufacturing flexibility and what constitutes it has made the selection of instrument(s) to assess the concept become difficult. To mitigate the problem, a common definition of manufacturing flexibility and its components are indeed necessary.

For the purpose of this study, manufacturing flexibility is defined as a multidimensional construct that represents the overall ability of the manufacturing system to adapt to both external changes and internal change (Chauhan & Singh, 2014; D'Souza & Williams, 2000; De Toni & Tonchia, 1998; Koste & Malhotra, 1999b; Rogers, 2008; Upton, 1995). In other words, manufacturing flexibility is the specific characteristics of a manufacturing system.

2.2.2 Past Research on Manufacturing Flexibility

The concept of manufacturing flexibility has caught the attentions of many researchers and practitioners since 1980s. Since then, numerous studies have been carried out to define and clarify the concept of manufacturing flexibility and to investigate its impacts on organizational performance (De Toni & Tonchia, 1998;

Kumar et al., 2006; Rogers et al., 2011; Sethi & Sethi, 1990). Below are the various examples of past studies with respect to manufacturing flexibility.

Swamidass and Newell (1987) have studied the effects of manufacturing flexibility (in terms of new product, product mix and modification flexibilities) on business performance that focus on growth (a composite index that include growth in return on sale, return on assets, and growth in sales). The research used structured questionnaires that targeted top management and chief executive (general managers, plant managers, vice-president or equivalent) that take charge of the manufacturing function. Target industry was machinery and machine tools industry with employees more than 50 persons. 77 questionnaires were sent and 35 of the firms responded. The research provides statistical significant result which concluded that greater manufacturing flexibility bring forth better performance results. On the meantime, this study also proposed that manufacturing flexibility is one of the possible solutions to cope with environmental ambiguity. However, this study has limitation on generalizability as it only involved limited number of manufacturing flexibility components, yet conducted in a single industry with only 35 firms as the participants.

Sethi and Sethi (1990) have published a paper which provided background for manufacturing flexibility, where eleven dimensions of manufacturing flexibility (refer to Appendix A) have been defined. Purposes, ways to acquire them and suggested measurements have been provided. A number of empirical studies and various optimization models for decision making dealing with various flexibility alternatives have been reviewed and discussed with the aim to foster the taxonomy or standardization of the flexibility terminology. Operational measures are tabled with the purpose to help manufacturing practitioners to have a better understanding about the magnitude of flexibility embedded in their manufacturing processes, and provide financial justifications for investment of new equipment.

Research by Ramasesh and Jayakumar (1991) have shown that manufacturing flexibility can improve financial performance (net revenue measured using "*ratio of the mean to the standard deviation of the distribution of optimal net revenues*"). This research was done using stochastic mixed integer mathematical program (an optimizations technique) to facilitate the modelling of different manufacturing flexibility's dimensions and the determination of the optimum revenues in every possible state of operation. Synergy between components of manufacturing flexibility (which include product mix, material, machine, labor and volume flexibilities) is observed, where aggregate flexibility increased the net revenue (as measured by the proposed ratio) by 16 percent higher than the sum of individual flexibility dimension. This suggested that synergy between various components of manufacturing flexibility plays a critical role in the increment of net revenue.

Study by Gerwin (1993) has conceptually argued that manufacturing flexibility (operationalized by mix, changeover, modification, volume, rerouting, and material flexibilities as well as flexibility responsiveness) fulfilled a firm strategy needs to achieve the goals of product diversification, product innovation, fulfilling customer requirements and product specifications, and enabled market share dominance, reduction of delivery time and product quality improvement. Meanwhile, Benjaafar and Ramakrishnan (1996) have suggested that sequencing flexibility, i.e. "*possibility of interchanging the sequence in which required manufacturing operations are performed*", has a positive relationship with operating performance such as reduced waiting times, reduced inventory and system utilization. In addition, several models were simulated to quantify the effects of manufacturing flexibility towards operating performances.

Gupta and Somers (1996) have conducted a study to investigate the relationship between business strategy, manufacturing flexibility, and organization performance in terms of financial performance and growth performance. In this research, business strategies under investigation were aggressiveness, analysis, defensiveness, futurity, pro-activeness and riskiness; while manufacturing flexibility was operationalized by nine components of manufacturing flexibility (which include expansion, material handling, routing, machine, market, product/production, process, program, and volume flexibilities) and were measured using 21 items. Financial performance was measured using operating profit, cash flow from operations, return on investment, and profit to sales ratio; while the growth performance was measured by sales growth and market share.

In the study by Gupta and Somers (1996), 269 respondents from top management (chief executive officer, president, and vice president of manufacturing) of manufacturing companies in five industry categories (cars and parts, metal, electrical and electronics, machinery, and precision machinery) in the United States have been asked to respond to items measuring manufacturing flexibility components, financial performance and growth performance based on comparison with their competitors. The results of the path analysis showed that only process flexibility has a marginal significant direct effect on the firm’s financial performance (negative result (-0.111) at $\alpha = 0.10$), while only 5 of the 9 components of manufacturing flexibility (expansion, process, routing, products/production, and volume flexibilities) have direct impact on growth performance. When go into detail, expansion/market flexibility and volume flexibility exhibited positive and significant result towards growth performance at α = 0.01, routing flexibility at α = 0.05, while products/production flexibility and process flexibility exhibited negative result towards growth performance at α = 0.05 and α = 0.10 respectively. However, this study has limitations in terms of lack of items (for example, volume flexibility and programming flexibility were measured using only one item) constructed to measure certain component of manufacturing flexibility studied. This vulnerability can cause certain flexibility component cannot be measured properly. In addition, the findings of this study provide evidence of direct effects of business strategies on manufacturing flexibility, direct effects of manufacturing flexibility on organizational performance and also indirect effects of business strategies on organizational performance.

In the context of five industries with 68 usable responses have been obtained from 600 members of National Association of Purchasing Management (NAPM), Narasimhan and Das (1999) have provided empirical evident to support that new product flexibility has a positive relationship with customer satisfaction, while enabling customization of products. Meanwhile, modification flexibility helps an organization to achieve cost reduction. Besides, the authors also proposed that firms that focus on delivery performance should also focus on the development of volume flexibility.

A case study have been conducted by Olhager and West (2002) at The Linköping plant of Ericsson Mobile Communications using quality function deployment. The study reported that manufacturing flexibility dimensions (volume, mix and new product flexibility) could help to improve product quality, delivery speed, delivery reliability, and reduction of costs, while increase product variety and foster product innovations.

On the other hand, Slack (2005) has collected opinions from managers of 10 manufacturing firms about the relationship between manufacturing flexibility and company's performance. Findings of the study showed that most of the managers agreed that manufacturing flexibility can increase productivity and capable to help diversifying firm's products. Besides, there is a lack of comprehensive view about manufacturing flexibility amongst most of the managers, i.e. managers tend to understand flexibility as the individual structural and infrastructure resource of manufacture rather than flexibility of the total manufacturing system (individual level versus system level). In addition, different managers tend to understand flexibility and its components differently.

Using the sampling frame which listed all the winners of "*America's Best*" award organized by magazine *"Industry Week"* (from year 1990 to 1999 with 145 samples sent and 57 retuned as usable), study by Swink, Narasimhan, and Kim (2005) indicated that both process and new product flexibilities have a positive impact on market-based performance that was measured using operating profits, sales increment and market share for process industry, machines and computer industry, electronics industry, automotive industry, and miscellaneous industry.

Rogers (2008) has done a research involving varies manufacturing industry in United States of America to understand the relationship between manufacturing flexibility and organization performance. The industries involved in his study were metal fabrication, electronics, automotive, healthcare and medical devices, aerospace, food and beverage, plastics and rubber, electrical, pharmaceutical and chemical, transportation and software/hardware industry. 206 top management (chief executive officers, vice presidents of manufacturing, inventory managers, procurement managers, manufacturing managers, plant managers, production supervisors, and engineers) from various firms had taken part in the study. The components of manufacturing flexibility involved were labor, routing, volume, product mix and supply management flexibilities. Based on the regression analyses, Rogers (2008) reported that (at $\alpha = 0.05$):

i. Significant negative relationships (negative relationships here mean improvement of manufacturing flexibility improves the organization performance) have been observed: between product mix flexibility and various types of inventory (raw material, work-in-process, finished goods) as well as number of backorders; between routing flexibility and setup times, throughput time, scrap/rework cost, raw material inventory, and backorders; between volume flexibility and setup times, throughput time, scrap/rework cost, work in process and finished goods inventories, backorders as well as unit manufacturing cost; between labor flexibility and setup times, throughput time, scrap/rework cost, work in process inventory, finished goods inventory, backorders, unit manufacturing cost, and purchased material cost; between supply management flexibility and scrap/rework cost, raw material and work in process inventories, unit manufacturing cost, and purchased material cost.

ii. Significant positive relationships have been observed: between product mix flexibility and on-time delivery; between routing flexibility and utilization; between volume flexibility and utilization as well as worker productivity; between labor flexibility and worker productivity; between supply management flexibility and worker productivity;

iii. No relationship have been observed: between product mix flexibility and setup times, throughput time, scrap/rework cost, worker productivity, unit manufacturing cost, material cost and utilization; between routing flexibility and worker productivity, work in process inventory, finished goods inventory, on-time delivery, unit manufacturing cost and material cost; between volume flexibility and raw material inventory, on-time delivery and material cost; between labor flexibility and raw material inventory, on-time delivery and utilization; between supply management flexibility and setup times, throughput time, finished goods inventory, backorders, on-time delivery and utilization.

iv. As the summated scale of manufacturing flexibility (score of manufacturing flexibility for each organization was aggregated after averaging the score of five manufacturing flexibility components) increases, setup times, throughput time, scrap/rework cost, raw material, work in process and finished goods inventories, backorders, unit manufacturing cost, and purchased material cost decrease. Meanwhile as manufacturing flexibility increases, worker productivity and machine utilization are increasing. Aggregated manufacturing flexibility has no relationship with on-time delivery;

v. Summated scale of manufacturing flexibility has a positive and significant association with organization performance which encompasses reduction of scrap and rework cost, reduction of raw material cost, reduction of manufacturing cost per unit, reduction of throughput time, increased utilization of machines, reduced raw materials, finished goods and semi-finished goods inventory levels, machine setup time reduction, backorders reduction and increased employee productivity. In addition, the aggregated manufacturing flexibility tends to explain more of the variance in aggregated manufacturing performance than the individual manufacturing flexibility components.

The study conducted by Zhang et al. (2009) collected data from 273 manufacturing firms in USA using mailing list provided by The Society of Manufacturing Engineers (SME) which involved five Standard Industrial Classification (SIC) codes (electronic & electrical equipment, fabricated metal products, industrial & commercial machinery, instruments equipment as well as transportation equipment). Based on the result of multiple regression analysis, the researchers concluded that product concept flexibility and products prototype flexibility are the effective way to develop new products. These capabilities help meeting the challenges of competition and customer demand, which in turn increased customer satisfaction.

Research by Hallgren and Olhager (2009b) collected manufacturing practices in the plant and classified according to manufacturing flexibility's elements to find out the link between manufacturing flexibility and operational performance via structural equations modelling. The aims of the study is to differentiate the importance of the two dimensions of manufacturing flexibility, volume flexibility and product mix flexibility, towards the manufacturing value chain as well as to determine how different flexibility configurations are related to various manufacturing practices. The study was done with data from 211 plants across three industries (electronics, machinery and automotive supplier) and seven countries (Austria, Finland, Germany, Japan, South Korea, Sweden and USA). Based on the pair-wise *t*-tests for the mean differences between the a priori determined groups (low flexibility, mix flexibility, volume flexibility, and high flexibility), results of the research showed that focuses of manufacturing flexibility adoption (focus on mix flexibility, focus on volume flexibility or focus on both flexibilities) lead to different level of performance outcomes. Plants with higher levels of flexibility on both types of flexibilities generally perform better than those having lower levels of flexibility, in terms of operational performance (measured by delivery speed, quality conformance and on-time delivery).

In line with the opinion of Vokurka and O'Leary-Kelly (2000) that more research investigating the direct-indirect effect of manufacturing flexibility on performance are needed, Camisón and López (2010) have conducted a study to examine the interrelationships between manufacturing flexibility, organizational innovation and firm’s performance. Questionnaires have been sent out to Spanish industrial firms listed in the SABI database (Sistema de Analisis de Balances Ibericos) which involved 2145 industrial firms that encompasses 30 industries (except agricultural, energy, service sectors as well as microbusinesses (firms with less than ten workers)). With 159 samples returned in good condition (28.9 percent - small firms, 42.8 percent - medium sized firms and 28.3 percent - big firms) obtained from 19 industries, the result of the structural equations modelling using the partial least squares approach showed that the relationship between manufacturing flexibility and firm’s performance was mediated by organizational innovation. The study used “*multi-item Likert scale*” to measure manufacturing flexibility using managerial perceptions (items includes “*increase or decrease of aggregate production*”, “*wide variety of different products*”, “*handle additions and substrations of product mix*” and “*effectively implement changes in current products due to corrective actions or changing customer requirements*”). On the other hand, firm’s performance was operationalized using economic performance (profitability, sales growth and market share gain) and satisfaction performance (productivity, customer satisfaction, others stakeholders' satisfaction and strength of competitive position).

Another research work by Rogers et al. (2011) suggested "*a holistic perspective of manufacturing flexibility encompassed six complementary components"* (i.e. mix, routing, equipment, labor, volume and supply management flexibilities). The results of confirmatory factor analysis using structural equation modelling supported that manufacturing flexibility is a second order multidimensional factor. Criterion-related validity using speed of workflow (operationalized by number of back orders, setup time and throughput time) has reported that a positive and significant correlation (0.513 at $\alpha = 0.001$) existed between manufacturing flexibility and speed of workflow. According to the findings of the study, these researchers highlighted that when the manufacturing flexibility dimensions are not used concurrently, the potential benefits will reduce. In the other words, optimization of the system is not feasible when a subset of those dimensions is employed due to the complementary nature of the manufacturing flexibility components. The lower the number of manufacturing flexibility components that are practiced, the further the performance of the firm performance will be away from optimum.

Al-jawazneh (2012) has conducted a research towards six private pharmaceutical firms in Jordan to assess how manufacturing flexibility affecting manufacturing performance. Machine flexibility, volume flexibility, material handling flexibility, routing flexibility and product mix flexibility had been chosen to operationalize the constructs of manufacturing flexibility, while manufacturing performance was measured using product quality, manufacturing cost, speed (cycle time) and reliability of delivery. By using convenient sampling, questionnaires were delivered to 350 respondents comprised of the production manager, division manager, manufacturing supervisor, engineers, chemists and pharmacists. Altogether 295 questionnaires were collected and used for the subsequent data analysis. Results of regression analysis showed manufacturing flexibility has a positive and significant relationship ($r = 0.29$; $p = 0.0001$; $R^2 = 0.084$) with manufacturing performance. However, detail analysis to identify the impact of each of the manufacturing flexibility components towards manufacturing performance revealed that only machine and material handling flexibilities have significant impact on manufacturing performance (at $\alpha \leq 0.05$); where volume flexibility, routing flexibility and product mix flexibility exhibited no relationship with manufacturing performance. As a whole, the research findings may suggest that synergy between components of manufacturing flexibility created the improvement in manufacturing performance.

Recent research done by Chauhan and Singh (2014) has focused on resource flexibility (integration of machine and labor flexibility). The study collecting data from automobile, automotive parts, machinery and metal part industries based on Directory of Industries 2009, India. 52 returned questionnaires were used to analyze and result indicated that low practices of resource flexibility in India. Once again, single component of manufacturing flexibility is used and holistic effects of manufacturing flexibility components are ignored in this study.

According to Vokurka and O'Leary-Kelly (2000), several gaps exist within manufacturing flexibility literature. First, most of the past studies adopt industry specific measure(s), therefore there were difficulty to generalize to other industries. Second, manufacturing flexibility is a multidimensional construct as claimed by various researchers (Anand & Ward, 2004; Boyle, 2006; Judi et al., 2004; Koste, 1999; Oke, 2005; Rogers, 2008; Suarez et al., 1996); however, a number of the past studies still focused only on one component of manufacturing flexibility (example: Nassirnia and Tap (2010) in labor flexibility; Jack (2000), and Jack and Raturi (2009) in volume flexibility), which revealed that further exploration into the components of manufacturing flexibility and their interrelationships are needed; and third, investigation pertaining to the direct and indirect effect of manufacturing flexibility on companies' performance is still scarce, more rigorous research works in this area are indeed needed.

Similarly, Rogers (2008) has listed several unresolved issues in the literature related to manufacturing flexibility, which include improper terminology usage, no definitive component list, overlapping component definitions, a weak understanding of relationships among components, and a lack of empirical evidence supporting whether manufacturing flexibility improves performance. This implied that researchers have a big gap to fill in researches related to manufacturing flexibility.

In the same vein, recent study by Mishra et al. (2014) presented a systematic review on literature about manufacturing flexibility and its enablers (or constraints to apply it) with the aim to provide a guide for future study with respect to manufacturing flexibility. One hundred and one related research papers available in academic journal database published from 1992 to January 2013 have been reviewed. Several conclusions have been made:

1. Literature reviews indicated that most of the past studies in the area of manufacturing flexibility have been conducted in developed countries (such as USA, UK, and Germany). This indicates that there is a need for more empirical

studies to investigate the relationships between manufacturing flexibility and firm performance in the context of developing countries.

2. Most of the past studies focused on financial indicators and employed it as a proxy to measure firm performance. More studies using alternative indicators for firm performance was suggested to fill the missing link on the assessment of the relationship between manufacturing flexibility and firm performance.
3. The volatile and ever changing market, together with environmental uncertainty have become the major enablers of manufacturing flexibility, where the needs for manufacturing flexibility are magnified to some extent where management attentions are grabbed.
4. Not all past studies found that manufacturing flexibility improve firm performance, and it was a gap worth further exploring.
5. Very few studies have rigorously addressed the question of fit between appropriate manufacturing flexibility's dimensions and the environmental uncertainty. This kind of studies will help to identify the manufacturing flexibility dimensions required for firm performance enhancement.

In the Malaysia context, some studies have been conducted to assess the potential of manufacturing flexibility to enhance firms' performance. One of them is the work by Jantan et al. (2006), who investigated the relationship between supplier selection strategies (based on cost, quality or delivery performance as well as technology competency) and manufacturing flexibilities which include product (similar to mix flexibility), launch (similar to new product flexibility), and volume flexibilities. Postal surveys have been sent to 120 manufacturers, 92 usable responses (about 77 percent return rate) have been obtained. Sampling frame for this research was obtained from the factory directory provided by the Penang Development

Corporation. One of the results of the study disclosed that the selection of suppliers based on technological and quality performance significantly affected all the three manufacturing flexibility components. More importantly, the study by Jantan et al. (2006) have proposed the existence of correlation between launch flexibility, product flexibility and volume flexibility. As the study was conducted among the manufacturing companies in the northern region of West Malaysia, regional clustering bias maybe a concern for this study. Secondly, most of the responding firms are foreign-owned multinational firms; the result generalizability is questionable especially on local contexts. Third, manufacturers under survey are electronic, telecommunication and computer industry, which is technology intensive in nature. This further limits the generalizability of the findings.

Judi and Beach (2008) have proposed a basic structure of manufacturing flexibility comprises of volume, variety (also known as mix flexibility), process (similar to routing flexibility) and material handling flexibilities. The studies collected data from electronic and electrical industry from both United Kingdom and Malaysia. This exploratory study proposed that there were significant correlations between volume, variety, process, and materials handling flexibilities, especially in the Malaysia context.

A study by Agus (2011) has investigated relationship between supply chain management (SCM), supply chain flexibility and business performance (return on assets, return on sales, and financial performance). In the study, supply chain flexibility was defined "*as the degree to which the supply chain can respond to random fluctuations in the demand and supply changes*" and this construct was operationalized using new product, product and volume flexibilities. Data analysis performed on the data collected from 250 companies' managers through face to face interview advocated that significant correlations existed between supply chain management and supply chain flexibility as well as business performance. The findings of the study also imply that supply chain management can enhance the performance of Malaysian manufacturing organization, via supply chain flexibility as a partial mediator.

Effects of customer demand, manufacturing flexibility, cost, and supply chain integration on product modularity ("*continuum that describing separateness, specificity and transferability of product components in a product system*") have been studied by Zainol et al. (2013). Participants of the study are 150 manufacturers from *"Association of Proton vendors"*, where findings of this study indicated that cost, customer demand, manufacturing flexibility and supply chain integration have significant impact on product modularity, where cost reduced when product modularity improved while others registered positive association with product modularity.

In sum, the above past studies conducted in both national and international context have provided some insights about the development of manufacturing flexibility over years. However, from the above summary of past studies, several problems or research gaps can be identified and will be discussed as below.

Gap One: The Meaning of Manufacturing Flexibility

One of the major deficiency is the concept of manufacturing flexibility is not fully understood (Oke, 2005). Besides, the property of manufacturing flexibility that is multi-faceted has made manufacturing flexibility difficult to be applied and put to effect. Confusion also arises with respect to whether manufacturing flexibility is referred as the characteristics of the manufacturing system or organization. These limitations have made the benefits of manufacturing flexibility hard to embrace by practitioners. What further make the matter complicated is, although researchers agreed that flexibility is important, general definition that is widely accepted is in nonexistence (Bordoloi et al., 1999; Pérez Pérez et al., 2016; Rogers, 2008; Upton, 1995). In the same vein, flexibility has been attributed by Kumar et al. (2006), Shi and Daniels (2003) and Upton (1995) as something that is hard to apprehend, hard to improve but crucial to competitiveness.

Gap Two: The Distinct Components Supporting the Concept of Manufacturing Flexibility

Lists of manufacturing flexibility's components that are overwhelming have made troubles for organizations that try to adopt manufacturing flexibility and tap on its benefits. In the meantime, overlapping components' definitions have made the adoption of manufacturing flexibility more problematic. The number of studies on manufacturing flexibility is increasing. However, this also increased the number of definitions and components for manufacturing flexibility. The number of labels for manufacturing flexibility components has been increased, from 20 in 1987, 50 in 1990 to 70 in 1998 and are still increasing as noted by a few researchers (Pérez Pérez et al., 2016; Rogers, 2008; Rogers et al., 2011; Sethi & Sethi, 1990; Shewchuk & Moodie, 1998; Swamidass & Newell, 1987). Many of the components have similar statement of meaning, whereas some studies used the same component label but carried an entirely different meaning.

Appendix A provided examples of flexibility components focus by past researchers. As shown in Appendix A, different authors have suggested different set of manufacturing flexibility components; it is evidence that there is no consensus on manufacturing flexibility components amongst the past researchers. Thus, a list of manufacturing flexibility components that are widely accepted is critically needed so that survey and measurements that enable contrasts and benchmarking can be carried out (Pérez Pérez et al., 2016; Rogers, 2008; Rogers et al., 2011; Upton, 1995).

Gap Three: Lacking of Good Measuring Instrument

A standard instrument or scale to measure manufacturing flexibility has not yet available (Koste, 1999; Rogers, 2008). While the lack of generalizable measures of manufacturing flexibility is also stated by Cox (1989), De Toni and Tonchia (1998), Koste (1999), Rogers (2008) and Sethi and Sethi (1990). Flexibility measures need to be easy for managers/practitioners to calculate using accessible data; or else they are impractical to be used. Although Koste (1999) has developed a scale to measure manufacturing flexibility and tested the instrument in electrical and electronic related sector, machine and equipment fabricators, and also metal related products, it has interpretation difficulty. Therefore, more systematic and rigorous studies to develop a standard measuring instrument that is easy to use for measuring the concept of manufacturing flexibility are indispensable (Mishra et al., 2014).

Gap Four: Contradiction of Theoretical Perspectives in the Development of Manufacturing Flexibility Components

Theoretical perspectives such as theory perspective, hierarchy perspective and strategic perspective (Oke, 2005; Pérez Pérez et al., 2016) have made the efforts to understand "the relationship(s) within manufacturing flexibility components" problematic.

Hierarchical perspective, embraced by Browne, Dubois, Rathmill, Sethi, and Stecke (1984), Sethi and Sethi (1990) and Chang et al. (2003); stated that manufacturing flexibility derived from components that are organized in a hierarchical structure that represents the different layers of a production system (Pérez Pérez et al., 2016). This hierarchy is developed bottom-up. Lower level of manufacturing flexibility components served as the building blocks for higher hierarchy. The components of lower level (such as labor flexibility, machine flexibility, routing flexibility and material handling flexibility) tend to be more tactical, while those at higher ranks of the hierarchy (such as mix flexibility, new product flexibility and volume flexibility) tend to be more strategical related. However, there is no consensus regarding the components within each layer from past literature (Pérez Pérez et al., 2016).

Strategic perspective proposed by Slack (1983) and Gerwin (1989) claimed that the existence of different components of manufacturing flexibility is a natural response to specific uncertainty. Under the strategic perspective, the components of manufacturing flexibility are divided into two stages: internal flexibility and external flexibility. External flexibility components (such as mix flexibility, volume flexibility, new products flexibility, delivery flexibility) are components that directly influence the firm’s ability to cope with the rapid changing market environments and influenced the competitive position of the firm in the market. While the internal flexibility components (such as process flexibility, machine flexibility, routing flexibility, material handling flexibility, materials flexibility and components flexibility) are related with the ability to deal with existing manufacturing resources (Mendes & Machado, 2014; Pérez Pérez et al., 2016). Internal flexibility components of a manufacturing system act as supports for external flexibility components. Similarly, the strategic perspective also has difficulty on getting the consensus of manufacturing flexibility components between and within the two stages.

The third perspective, the Theory perspective tried to synthesize the components of manufacturing flexibility to generate a parsimony set of manufacturing flexibility components, based on specific underpinning theory such as Resource Based View (RBV) and complementarity theory (Lucas & Kirillova, 2011; Rogers et al., 2011). Resource Based View (RBV) stressed that the sustainability of a firm's competitive advantage depends on the unique resources possessed that meet four essential characteristics (RVIN): Rare; Valuable; Inimitable; and non-substitutable (Barney, 1991; Makadok, 2001). Per this theory, external resources did not allow a firm to gain competitive advantage as these resources are shared by competitors. Therefore, internal resources that are developed internally within the organization should be given emphasis.

Multidimensionality of manufacturing flexibility has made it difficult to be implemented even though its importance to the performance of a firm is highly recognized (Jain et al., 2013). Therefore, manufacturing flexibility fulfilled the prophecy of RBV as it was rare, valuable, inimitable and non-substitutable.

Furthermore, the configuration of manufacturing flexibility components (based on the combination of high, moderate or low) within each organization is unique and cannot be easily substituted because it depends on the strategic objectives of the business/industry and almost most of the time they are firm-specific-features (such as culture, processes, management supports and infrastructure within a firm) (Rogers, 2008). As a consequence, manufacturing flexibility is seen as a unique resource embedded within a firm that is non-transferable and has the potential to influence the firm’s competitive position and performance (Lucas & Kirillova, 2011). However, different combinations of manufacturing flexibility components affect performance differently (Larso, Doolen, & Hacker, 2009), the need for a unified set of manufacturing flexibility components is vital to the existence of the firm. This is further supported by complementarity theory, which emphasized the complementarity between the components of manufacturing flexibility and their synergy effects as critical aspects for the effective implementation of manufacturing flexibility. However, the theory perspective is considered as a newer perspective of manufacturing flexibility that is not fully established and hence further researches on it is still needed. In addition, studies on the possible trade-off or combined effects that may occur among components of manufacturing flexibility to date is still lacking (O'Leary-Kelly, 1998; Rogers, 2008; Rogers et al., 2011).

In sum, the three different perspectives affect the “choice of manufacturing flexibility components” and create differences in manufacturing flexibility outcomes.

Gap Five: Lack of Understanding About the Types of Uncertainty That Specific Manufacturing Flexibility Component Can Tackle

Confusion arises when past researchers adopted the proposed manufacturing flexibility components and applied them to tackle different manufacturing system outcomes without considering whether the components are valid. The lack of understanding about the effect of individual manufacturing flexibility components maybe the reason that leads to the inconsistent (significant and non-significant) findings, as different manufacturing flexibility types affect performance in dissimilar ways (Ramasesh & Jayakumar, 1991). In addition, different types of manufacturing dimensions are to solve different types of problems occurs in the manufacturing system (Mishra et al., 2014; Sawhney, 2013).

Gap Six: The Chaotic Relationships between Manufacturing Flexibility and Firm's Performance

Previous studies suggested that manufacturing flexibility affects firm's business performance directly (in terms of market share and sales growth (Anand & Ward, 2004); profits, cash flow, sales and market share (Gupta & Somers, 1996)), while other studies suggested that manufacturing flexibility affects manufacturing performance (e.g. quality, speed (lead time and cycle time) and cost (Al-jawazneh, 2012)). On the meantime, some of the other studies tend to suggest manufacturing flexibility affects organizational performance (combination of manufacturing performance and business performance measures, e.g. combination of profit margin, quality, cost, delivery time, sales, market share, sales growth, return on investment

(Larso et al., 2009); and organizational performance that including productivity and customer satisfaction (Camisón & López, 2010)).

However, very few studies investigated the interrelationships between manufacturing flexibility, manufacturing performance, and business performance, therefore the relationships between them are unclear. As the pattern of interrelationship between manufacturing flexibility, manufacturing performance, and business performance is important for researchers to understand how manufacturing flexibility affects organization performance, further researches are required (Camisón & López, 2010; Vokurka & O'Leary-Kelly, 2000).

Specifically, the above discussions revealed that (i) the components constituting the concept of manufacturing flexibility is still not clear; and (ii) how manufacturing flexibility lead to a better firm performance is still unknown. Current research has responded to those six gaps by proper defining what is manufacturing flexibility, provided parsimony set of components that best represent manufacturing flexibility, generated instruments to measure manufacturing flexibility components and explored the relationships between manufacturing flexibility and firm's performance to solve the potential confusion created by past studies (where chaotic relationships and inconsistent evidence existed).

2.2.3 Flexibility Components and Types of Uncertainty

As proposed by various past researches, manufacturing flexibility can foster various competitive advantages that enable a firm to gain and consolidate market share. As highlighted by Al-jawazneh (2012), Beach et al. (2000), Gerwin (1993), Judi et al. (2004), Sawhney (2013) and Sethi and Sethi (1990), existence of different types of manufacturing flexibility dimensions are to solve various dilemma and uncertainty that existed around the manufacturing system. For example, Table 2.3 summarized some of the uncertainty that specific manufacturing flexibility components can help to overcome (Al-jawazneh, 2012; Beach et al., 2000; Gerwin, 1993; Judi et al., 2004; Mishra et al., 2014; Sawhney, 2013; Sethi & Sethi, 1990).

Table 2.3
Flexibility Tackling What Uncertainty?

Flexibility	Tackle which uncertainty
Mix Flexibility	Customers request for product variety.
New Product Flexibility	Customers request for product modifications and improvements.
Labor Flexibility	Increase labor utilization, reduce down time due to lack of workers.
Machine Flexibility	Bottleneck/machine breakdown.
Material Handling Flexibility	Increase resistant to new material’s shape or size when new product are introduced.
Routing Flexibility	Bottleneck/machine breakdown.
Volume Flexibility	Fluctuation in demand.

Specifically, mix flexibility can increase the product variety thus improve customer satisfaction by fulfilling customer demands for more choices. On the other hand, new product flexibility can tackle the customer needs for better products, with more features and higher reliability. Labor flexibility and machine flexibility reduced the likelihood of production delay due to insufficient workers or breakdown of machines; volume flexibility provides resistance to volatile in customer demands, and allowed a plant to alter production upwards or downwards within broad limits.

Material handling flexibility helped to increase productivity and reduce lead time, as change of shape and size of raw materials or finish goods may cause delay and inefficient in the manufacturing system. Finally yet importantly, routing flexibility enables the production to change route to another machines/stations to ease the burden of bottleneck. It allowed the manufacturing system to continue the production, maybe at a reduced rate, when unexpected incidents (example: machine breakdowns, detection of a faulty part or late receipt of tools) occurred.

This section generally provides some insight into the practitioners' views point, and explained why manufacturing flexibility being important to an organization, practically. Next section will discuss about the components of manufacturing flexibility.

2.2.4 Components of Manufacturing Flexibility

Table 2.4 is the summary of dimensions of manufacturing flexibility explored in the past empirically researches, while Table 2.5 is the summary of dimensions of manufacturing flexibility explored in the past conceptual researches. When sorted in Pareto form, researchers can easily identify which components of manufacturing flexibility is most used by past researchers in research and provides an insight on potential consensus of manufacturing flexibility's components. Further analysis of both tables indicates that components suggested by conceptual research did not differ much from components suggested by empirical study.

Based on Table 2.4 and Table 2.5, 15 components of manufacturing flexibility emerged within the literature (i.e. mix flexibility, volume flexibility, new product flexibility, machine flexibility, material handling flexibility, labor flexibility, modification flexibility, routing flexibility, delivery flexibility, supply management flexibility, expansion flexibility, program flexibility, production flexibility, market flexibility, operations flexibility). Definitions for each of the manufacturing flexibility's components as suggested by various researchers are summarized in Appendix B. Obviously, there is no consensus about the definitions of manufacturing flexibility's components amongst the researchers.

Based on the popularity of dimensions showed by Table 2.4 and Table 2.5, the top 10 components of the manufacturing flexibility of both table based on popularity have been compared, 8 components of manufacturing flexibility (mix flexibility, volume flexibility, new product flexibility, machine flexibility, material handling flexibility, labor flexibility, routing flexibility, and modifications flexibility) have been identified as having consensus on both empirical and conceptual study. Seven of the other components of manufacturing flexibility (i.e. delivery flexibility, supply management flexibility, expansion flexibility, program flexibility, production flexibility, market flexibility and operations flexibility) have minima agreement.

Table 2.4
Dimensions of Manufacturing Flexibility Explored in Various Empirical Researches Sorted Descending Based on Popularity in the Past Study

No	**Manufacturing Flexibility Components**	**Author(s)**
1	Mix Flexibility	1;2;4;5;6;7;8;11;12;14;15;16;20;21;25;26
2	Volume Flexibility	2;3;5;6;8;11;12;13;14;15;19;21;22;26
3	New Product Flexibility	1;4;5;7;8;9;11;14;16;19;22
4	Machine Flexibility	5;11;12;14;15;16;21;22;25;26
5	Material handling Flexibility	5;11;12;15;16;21;22;24;25;26
6	Labor Flexibility	11;15;16;17;21;22;23
7	Modification Flexibility	1;4;7;11;12;16;22;25
8	Routing Flexibility	5;12;21;22;24;25;26
9	Delivery Flexibility	7;8;18;19
10	Supply Management Flexibility	6;18;21
11	Expansion Flexibility	5;12;14
12	Program Flexibility	5;12
13	Production Flexibility	10
14	Market Flexibility	5
15	Operations Flexibility	25

Authors: 1 = Swamidass and Newell (1987); 2 = Cox (1989); 3 = Fiegenbaum and Karnani (1991); 4 = Dixon (1992); 5 = Gupta and Somers (1992, 1996); 6 = Olhager (1993); 7 = Upton (1995, 1997); 8 = Suarez et al. (1996); 9 = Thomke (1997); 10 = Vickery, Dröge, and Markland (1997); 11 = Koste (1999); 12 = Narasimhan and Das (1999); 13 = Jack (2000); 14 = Petroni and Bevilacqua (2002); 15 = Zhang et al. (2003); 16 = Koste, Malhotra, and Sharma (2004); 17 = Karuppan (2004); 18= Martínez Sánchez and Pérez Pérez (2005); 19 = Jantan et al. (2006); 20 = Karuppan and Kepes (2006); 21 = Rogers (2008); 22 = Larso et al. (2009); 23 = Nassirnia and Tap (2010); 24 = Torres, Jose Benitez-Amado, Perez-Arostegui, and Barrales-Molina (2011); 25 = Tamayo-Torres, Ruiz-Moreno, and Lloréns-Montes (2011); 26= Al-jawazneh (2012)

Table 2.5
Dimensions of Manufacturing Flexibility Defined in Various Conceptual Researches Sorted Descending Based on Popularity in the Past Study

No	**Manufacturing Flexibility Components**	**Author(s)**
1	Volume Flexibility	1;2;3;4;6;7;8;9;10;12;13;14;15;16;17;18;20
2	Mix Flexibility	1;2;3;4;6;7;8;9;10;12;14;15;16;17;18;20
3	Material handling Flexibility	1;2;6;7;8;9;12;14;15;17;18;19;20
4	Operations Flexibility	1;2;5;6;7;9;12;15;17;18;20
5	New Product Flexibility	1;2;3;7;8;9;14;15;16;20
6	Machine Flexibility	1;2;3;4;6;7;9;15;16;20
7	Expansion Flexibility	1;2;3;6;7;9;15;18;20
8	Labor Flexibility	3;4;6;7;9;15;18;20
9	Routing Flexibility	1;2;3;9;17;20
10	Modification Flexibility	3;7;12;14;17;20
11	Delivery Flexibility	3;4;9;15;16;20
12	Production Flexibility	1;2;9;17;20
13	Market Flexibility	2;9;11;20
14	Program Flexibility	2;9;20
15	Supply Management Flexibility	11;20

Authors: 1 = Jim Browne (1984); 2 = Sethi and Sethi (1990); 3 = Watts, Hahn, and Sohn (1993); 4 = Nilsson and Nordahl (1995); 5= Benjaafar and Ramakrishnan (1996); 6 = Tsourveloudis and Phillis (1998); 7 = Koste and Malhotra (1999a); 8 = D'Souza and Williams (2000); 9 = Vokurka and O'Leary-Kelly (2000); 10 = Peláez-Ibarrondo and Ruiz-Mercader (2001); 11 = Duclos, Vokurka, and Lummus (2003); 12 = Zhang et al. (2003); 13 = Raturi and Jack (2004); 14 = Judi et al. (2004); 15 = Kara and Kayis (2004); 16 = Slack (2005); 17 = Gerwin (2005); 18 = Héctor and Bernal (2006); 19 = D'Souza (2006); 20 = Pérez Pérez et al. (2016)

After assessment of definition overlapping, modification flexibility is dropped to prevent confusion between the two distinct types of flexibility dimensions - new product flexibility and mix flexibility. In the current setting, mix flexibility focused on existing product range changeovers and new product focus on changeovers involving new products only. In other words, new product flexibility is the ability to introduce new products into the existing range of products and mix flexibility is the ability to manufacture existing product range. While modifications flexibility overlapped with mix flexibility and new product flexibility as it is related to the ability to manufacture a variety of both new and existing products (refer Appendix B).

Hence, seven components of manufacturing flexibility have been shortlisted for this research, they are mix flexibility, volume flexibility, new product flexibility, machine flexibility, material handling flexibility, labor flexibility and routing flexibility. As with the definition of manufacturing flexibility proposed in Chapter 1, manufacturing flexibility components related to manufacturing system is the primary focus of this research. Specifically in this study, manufacturing system is referred as a collection of human resources and integrated equipment that include material handling devices and also manufacturing machines, whose functions are to execute assembly/processing operations on a starting raw materials or parts to produce a desired set of finished and also semifinished goods (Groover, 2008). Therefore, these seven components identified are consistent with this intention.

Definitions of the seven components of manufacturing flexibility for this study and the sources from which they are adopted/adapted are as shown below in Table 2.6.

Table 2.6
Definition of Manufacturing Flexibility's Components for This Study

Manufacturing Flexibility Components	**Definition**
Mix Flexibility	The ability of the manufacturing system to switch between different products in the product mix (Judi & Beach, 2008).
Volume Flexibility	The ability of the manufacturing system to alter the output volume of a manufacturing process (Judi et al., 2004; Sethi & Sethi, 1990).
New Product Flexibility	The ability of the manufacturing system to incorporate new product(s) into the existing range of products (Dixon, 1992; Gupta & Somers, 1992, 1996; Judi & Beach, 2008; Koste, 1999; Sethi & Sethi, 1990).
Machine Flexibility	The ability of the manufacturing machine to perform more than one operation to produce different parts or products (Al-jawazneh, 2012; Lucas & Kirillova, 2011; Rogers, Ojha & White, 2011; Sethi & Sethi, 1990).
Material handling Flexibility	The ability of the material handling system to handle various types of material, where dissimilar part are handle well without affecting the performance of the existing system (Helkiö, 2008; Sethi & Sethi, 1990).
Labor Flexibility	The ability of production workers to perform more than one task in the manufacturing system (Rogers et al., 2011).
Routing Flexibility	The ability of the manufacturing system to manufacture products through a variety of different routes (Das & Nagendra, 1993; Koste, 1999; Nishith et al., 2013; Rogers, 2008; Rogers et al., 2011; Sethi & Sethi, 1990; Zhang et al., 2003).

In the same vein, Rogers et al. (2011) shortlisted 10 manufacturing flexibility's components from 17 dimensions mentioned in previous 52 research papers published within year 1982 to year 2006; with consensus among previous researches which take into accounts of (i) descriptive and field type of study; (ii) survey type of research and (iii) others relevant type of study. The consensus manufacturing flexibility's components are material handling flexibility, new product flexibility, modification flexibility, machine flexibility, routing flexibility, mix flexibility, volume flexibility, labor flexibility, infrastructure flexibility and supplier management flexibility. After that, Rogers et al. (2011) further synthesize the manufacturing flexibility components to 6 dimensions i.e. machine, routing, mix, volume, labor and supplier management flexibilities. New product flexibility, modification flexibility and material handling flexibility are dropped due to overlapping of definitions and redundant on dimensions of manufacturing flexibility.

When compared with current study, researcher found that there is some agreement between the set of manufacturing flexibility dimensions identified by Rogers et al. (2011) with the set of the manufacturing flexibility's components shortlisted in this study. Specifically, the main different between the set of manufacturing flexibility's components identified in the current study and the set of manufacturing flexibility's components shortlisted by Rogers et al. (2011) are as shown in Table 2.7:

Table 2.7
Comparison between Current Research and Rogers et al. (2011) – Manufacturing Flexibility Components

Current Research	**Rogers et al. (2011)**
Mix Flexibility	Mix Flexibility
New Product Flexibility	-
Volume Flexibility	Volume Flexibility
Machine Flexibility	Machine Flexibility
Labor Flexibility	Labor Flexibility
Material handling Flexibility	-
Routing Flexibility	Routing Flexibility
-	Supplier Management Flexibility

Based on Table 2.7, 5 dimensions of current research are in agreement with Rogers's dimensions of manufacturing flexibility, and the discussion of three dimensions that deviate is presented below:

Current research involving new product flexibility yet Rogers et al. (2011) ignore it due to overlapping of definition within mix flexibility, modification flexibility and new product flexibility. This dilemma can be solved with removing of modification flexibility that caused the confusion, and redefine definitions for new product flexibility and mix flexibility to set solid boundary between them. Where in this research, mix flexibility is defined to identify changeovers on existing product range, while new product flexibility is to identify changeovers on new product range.

The same problems occur between material handling flexibility and routing flexibility, where past literature have difficulty to define them to be exclusive from each other's. In this research, material handling flexibility gives focus to the tools to move the different type of parts or materials around, while routing flexibility is pertaining to the route taken to move the parts or products around; in a layman term, material handling flexibility represents the "car" to move along the route, whereas routing flexibility denotes the "road" to move the parts/products, with both flexibility trying to achieve the smooth transition of manufacturing process, the input transfer to output process. Obviously, material handling flexibility and routing flexibility are distinct dimensions of manufacturing flexibility. Both dimensions are considered important by Larso (2004) as these dimensions have significant effects on firms' business performance.

In addition, supply management flexibility is discarded from the list of manufacturing flexibility components used in this study as the scope of this research is confined to manufacturing system of the organization. Supplier management that focuses on supplier-buyer relationship goes beyond the scope of this study. The following subsections provide the definitions and description of the seven chosen manufacturing flexibility dimensions.

2.2.4.1 Mix Flexibility

Mix flexibility always received much attention in the past manufacturing flexibility literature because it was intuitive in nature and perceived to has direct market implications (Suarez et al., 1996). The main objective of adopting mix flexibility is to minimize inventory costs and batch sizes (Browne et al., 1984), with the ultimate goal of enabling the firm to offer to customers a wider range of product lines in a strategic way (Gerwin, 1989). In this study, "*the ability of the manufacturing system to switch between different products in the product mix*" is used as the definition for mix flexibility (Judi & Beach, 2008). High product mix often mean high numbers of products which can be produced at the same time in the same plant (Al-jawazneh, 2012; Judi & Beach, 2008; Rogers, 2008; Suarez et al., 1996).

This flexibility component enables the manufacturing systems to customized products with different variety, with numerous features, options, sizes, and colors to meet customer demand. In the other words, the higher the number of product variance a firm can cope with, the higher the mix flexibility. This also indicated that the value of mix flexibility dimensions is increased as the complexity of range of products increased (Rogers, 2008; Sethi & Sethi, 1990; Slack, 2005). With reference to Sethi and Sethi (1990), this component of manufacturing flexibility allowed a firm to enter niche markets with specific customer requirement, thus allowing the expansion of market share and increment of sales (Gupta & Somers, 1996; Larso, 2004).

Product variety is regularly anticipated to foster competitive advantage by offering products or services personalized to specific customer needs; which will result in increment of more total sales volume, which indirectly increases the profit, as value is added by fulfilling specialized demands (Berry & Cooper, 1999).

A manufacturing system with high mix flexibility often has a large number of product categories that are manufactured in the plant (Al-jawazneh, 2012; Browne et al., 1984; Dixon, 1992; Gerwin, 1993; Judi & Beach, 2008; Rogers, 2008; Suarez et al., 1996). In a manufacturing system that has high mix flexibility, products combination is so flexible that it can be vary from time to time depending on the customer demand changes (Al-jawazneh, 2012; Rogers, 2008).

Other attributes of high mix flexibility include (i) no major changeovers required to changing from producing one product to another products, and the changeovers can be done easily, quickly or economically (Al-jawazneh, 2012; Judi & Beach, 2008; Rogers, 2008); (ii) mix of products manufactured by the plant can be changed easily and quickly (Judi & Beach, 2008; Rogers, 2008); (iii) enable the organization to offer customer a wide product range through the capability to alter the product mix regularly (Rogers, 2008).

Benefits of mix flexibility often link to broader range of products, thus enable greater market prospect, and indirectly increase market share, revenue and profit margin (Hallgren & Olhager, 2009a; Wilson & Ali, 2014). When range of products can satisfied ever changing and demanding customer needs, customer satisfaction is increased (Hallgren & Olhager, 2009a; Olhager & West, 2002; Rogers, 2008; Wilson & Ali, 2014; Zhang et al., 2003).

2.2.4.2 New Product Flexibility

Developing products that are economic in cost and high in quality are no longer sufficient to ensure success in today's business environment (Upton, 1995). Successful manufacturing firms must offer new products to fulfill the expectation of customers for an increasing number of new products introduction (Cousens, Szwejczewski, & Sweeney, 2009). Griffin (1997) found that sales revenue for new products was significantly lower for service firms than for manufacturing firms. This means that ability to offer new products in responding to changes associated with customers' expectation is vital to the manufacturing firms' financial well-being.

New product flexibility is referred as the ability of the firm's manufacturing system to incorporate new product into the current range of products (Dixon, 1992; Gupta & Somers, 1992, 1996; Judi & Beach, 2008; Koste, 1999; Sethi & Sethi, 1990). This element of manufacturing flexibility is important as a corner stone to fulfill the demand for new product at the market place. Indirectly, new product flexibility can foster and increase customer satisfaction (Alamro, 2014; Narasimhan & Das, 1999). According to Slack (2005), new product flexibility is an important capability that most of the firms would like to develop nowadays as current market is highly competitive and innovation has become the key to succeed. In other words, new product flexibility is needed so that manufacturing firms can respond to the changes attributed to rapid technology advances, short product life cycles, demand for product customization, dramatic changes in customer expectations and preferences, and business competition (Alamro, 2014; Suarez, Cusumano, & Fine, 1991; Suarez et al., 1996).

Firms that have high new product flexibility often have the following attributes: (i) low cycle time to develop a new product, and that reflect in manufacturing system as high frequency of new products introduction into the production line; (ii) a significant number of new products are introduced into production every year (Dixon, 1992; Gupta & Somers, 1992, 1996; Judi & Beach, 2008; Koste, 1999; Sethi & Sethi, 1990); (iii) new product can be added into existing range of products easily and quickly without involving major changeovers (Judi & Beach, 2008; Koste, 1999; Rogers, 2008); (iv) scheduling effort to introduce new products into the production scheduled is easy and quickly (Das, 2001; Dixon, 1992; Gupta & Somers, 1992, 1996; Koste, 1999; Rogers, 2008; Sethi & Sethi, 1990); (v) customer request for design change is well take care of (Chang et al., 2002; Das, 2001; Dixon, 1992; Gupta & Somers, 1992, 1996; Judi & Beach, 2008; Koste, 1999; Rogers, 2008; Rogers et al., 2011; Sethi & Sethi, 1990).

It is expected that new product flexibility contributes to cost efficiency, productivity, quality, cycle time reduction, customer satisfaction, market success and sales growth (Alamro, 2014; Chang et al., 2002; Larso, 2004; Narasimhan & Das, 1999).

2.2.4.3 Labor Flexibility

Within the components of manufacturing flexibility, labor flexibility is seen as the most challenging flexibility type because of the diverse aspects of human behaviors which make labor as one of the most valuable resources and also most flexible component of the manufacturing system (Nassirnia & Tap, 2010). Many researchers (such as Chang (2004) and Cox (1989)) have highlighted the significant contribution of labor flexibility to a flexible manufacturing system (Chauhan & Singh, 2014). However, according to Rogers (2008), labor flexibility is a relatively new dimension proposed in the manufacturing flexibility literature. Therefore, more attention should be given to labor flexibility compare to other manufacturing flexibility components in the context of manufacturing system.

Based on the review of literature, it has been found that most of the definitions of labor flexibility tend to relate to functional flexibility. For instance, Jensen, Malhotra, and Philipoom (1996) referred labor flexibility as the number of operations a typical worker can perform. Similarly, Rogers et al. (2011) defined labor flexibility as the ability of workers to perform several jobs effectively. Meanwhile, Koste and Malhotra (1999b) proposed a definition for labor flexibility as the number and heterogeneity of tasks or operations a worker can performs with least possible transition penalties or performance outcomes changes. Specifically, the workforce with multiple skills is considered as highly flexible workforce, with the assumption that the multiple skills did not deteriorate the quality of their outputs (Héctor & Bernal, 2006; Koste, 1999).

Workforce with high labor flexibility tend to cross-trained to perform many different tasks and often responsible for more than one task. (Cox, 1989; Kher et al., 1999; Koste, 1999; Rogers, 2008). To achieve that, workers are trained to possess many types of skill and learn new skills as needed (Kher et al., 1999; Koste, 1999; Rogers, 2008), and the trainings about works related skills are giving out regularly and frequently to make sure no one miss it (Cox, 1989; Kher et al., 1999; Koste & Malhotra, 1999b; Ramasesh & Jayakumar, 1991; Rogers, 2008). As a result of that, workers are used interchangeably between different task and different production line to maximize the potential of labor flexibility (Kher et al., 1999; Koste, 1999; Rogers, 2008). A firm with multi-skilled workforce can operate with minimum number of workers necessary to run the business’s operations. Workers with limited skills may sit idle during the time waiting for job to come to them. A multi-skilled workforce moves with the workload rather than waiting for the job to become available. As a result, there will be less idle work hours, which will help to reduce the operating cost of the firm.

Attributes of high labor flexibility also include but not limited to: (i) impact of workers rotation is low in terms of time and easiness (time delay incurred is negligible), which enables the transfers of production workers to another task or another line with ease (Chauhan & Singh, 2014; Kher et al., 1999; Koste, 1999; Ramasesh & Jayakumar, 1991); (ii) workers are able to use various type of tools and machines effectively after proper training (Chang, 2004; Chauhan & Singh, 2014; Kher et al., 1999; Ramasesh & Jayakumar, 1991; Rogers, 2008); (iii) workers are able to execute a variety of manufacturing operations economically and easily (Chang, 2004); (iv) workers are able to carry out task that differ greatly from one another (Chauhan & Singh, 2014; Cox, 1989; Koste, 1999; Ramasesh & Jayakumar, 1991).

Labor flexibility should (i) reduce inventory levels and cost, material costs, scrap/rework cost, labor costs, setup times and throughput time (Chauhan & Singh, 2014; Karuppan, 2004; Rogers, 2008); (ii) increase or improve worker productivity, labor utilization, profit margin and customer services (Chauhan & Singh, 2014; Koste, 1999; Rogers, 2008; Russell & Taylor, 2014); (iii) better response to design changes and new product introduction and superiority in capability to reallocate tasks in case of labor force incapability/absence (Chauhan & Singh, 2014). Moreover, firm that the workforce is highly flexible increases the options for transferring workers between tasks, which enable the firm to increase output of higher demand products because multi-skilled workers adapt faster to product changes (Olhager, 1993; Russell & Taylor, 2014).

2.2.4.4 Machine Flexibility

In a modern manufacturing system, most of the actual operations or assembly works are performed by machines or with the assistance of specific tools. In general, manufacturing machines can be classified into (Groover, 2008):

1. Manually operated machines that are controlled or monitored by production workers;
2. Semi-automated machines which perform a part of the entire job through certain form of program control; and
3. Fully automated machines run for prolonged periods without production workers interference.

Therefore, manufacturing machines are one of the critical resources in a manufacturing firm, and machine flexibility forms the foundations blocks of manufacturing flexibility (Chauhan & Singh, 2014). Machine flexibility is defined as the ability of the manufacturing machine to perform more than one operation to produce different parts or products (Al-jawazneh, 2012; Lucas & Kirillova, 2011; Rogers et al., 2011; Sethi & Sethi, 1990). Manufacturing system with high machine flexibility often has machines that are able to perform various operations in a flexible way without incurring high penalties in time; which lead to improvement on production lead time (Chauhan & Singh, 2014; Koste & Malhotra, 1999b; Rogers, 2008).

Typically machine that has high machine flexibility will has characteristics like: (i) able to perform a large number of operations (Al-jawazneh, 2012; Benjaafar, 1994; Gupta & Somers, 1992, 1996; Rogers, 2008; Sethi & Sethi, 1990); (ii) can be used interchangeably by different product line, to do different operations (Ramasesh & Jayakumar, 1991); (iii) machines changeovers time and the changeovers costs are inexpensive (Al-jawazneh, 2012; Chauhan & Singh, 2014; Koste, 1999; Rogers, 2008); and (iv) machines are equally effective, with respect to reliability, for all jobs (Benjaafar, 1994; Koste, 1999; Russell & Taylor, 2014). Specifically, efficiency and versatility are two aspects that should be considered for the measurement of machine flexibility (Chang, Whitehouse, Chang, & Hsieh, 2001; Chauhan & Singh, 2014).

Examples of technological sources of machine flexibility in a manufacturing system include but not limited to: machines that are controlled by software code to execute various operations with the aid of automated tool changers (computer numerically control), machines with rapid changing of die and machines with the ability to suit different circumstances (accepting inputs with a deviation of specification) in high reliability, integration with CAD/CAM and flexible manufacturing system (Chauhan & Singh, 2014; Rogers, 2008). In addition, most general purpose machines are machines with high machine flexibility (Hirano, 1989; Russell & Taylor, 2014; Wahab, Wu, & Lee, 2008).

Machine flexibility should (i) reduce batch sizes, setup times, throughput time, worker productivity, inventory quantity and costs, and manufacturing costs; and (ii) increase/improve machine utilization, products quality, customer service, and ability to produce complex parts and a variety of products (Chauhan & Singh, 2014; Gupta & Somers, 1996; Rogers, 2008; Sethi & Sethi, 1990).

2.2.4.5 Material Handling Flexibility

Material handling is defined as an integrated system which involved activities such as moving, handling, storing and controlling of materials (include but not limited to raw materials, scrap, semi-finished goods, and finished goods) by way of manual effort or power activated machinery (Aized, 2010). In many manufacturing systems that assemble or make discrete parts or products, material handling functions such as loading, positioning and unloading at each of the workstation as well as transporting work units between workstations and temporary storage of work units must be provided (Groover, 2008). Safe material handling is needed because it helps to minimizes breakage, scrapes, loss and also wastage. Likewise, efficient material handling is important for timely delivery and avoids congestion, as well as to reduce the event of machines waiting for jobs due to non-availability or accumulation of materials at certain workstations. Thus, material handling flexibility is considered as a critical element of manufacturing flexibility.

Material handling flexibility is the capability of the system of material handling to handle various forms of material, where dissimilar part are handle well without affecting the performance of the manufacturing system (Gupta & Somers, 1996; Sethi & Sethi, 1990). This encompasses the capability of the manufacturing function to handle unexpected deviations in inputs; involved the acceptance of machine and equipment on inputs with specification deviation without incurring quality problems (Gerwin, 1993; Narasimhan & Das, 1999).

Specifically, flexible material handling system means that: (i) the system can handle a wide variety of parts (Al-jawazneh, 2012; Judi & Beach, 2008; Koste, 1999; Rogers, 2008); (ii) material handling changeovers is easy, require very little time and economically viable (Judi & Beach, 2008; Koste, 1999); (iii) the system can handle different types of parts and material handling system can be reconfigure quickly and easily if needed to overcome material deviation circumstance (Al-jawazneh, 2012; Judi & Beach, 2008; Koste, 1999; Rogers, 2008); (iv) tools using for material handling can be changed easily and quickly (Al-jawazneh, 2012; Judi & Beach, 2008; Koste, 1999; Mohsen, 2010; Rogers, 2008).

Stecke and Browne (1984) have studied the impact of several kinds of material handling equipment have on several types of flexibility proposed by Browne et al. (1984), i.e. machine, routing, product, process, operation, volume, and expansion flexibilities, as well as the overall production flexibility, and ranked the equipment in order of increasing flexibility, the order is as follows: belt conveyors, powered roller conveyors, power-and-free conveyors, monorails or monotractors, towline carts, and automated guided vehicle systems. Meanwhile, Sethi and Sethi (1990) noted that using several general purpose fixtures, automatic tool changers, and automatic guided vehicle systems will enhance material handling flexibility (Sethi & Sethi, 1990).

Higher material handling flexibility should (i) reduce throughput times; (ii) increase machines availabilities, machines utilization (Gupta & Somers, 1996; Sethi & Sethi, 1990). Moreover, flexible material handling are able to support routing flexibility (Narasimhan & Das, 1999).

2.2.4.6 Routing Flexibility

Routing flexibility is the ability of the manufacturing system to manufacture products through a variety of different routes (Das & Nagendra, 1993; Koste, 1999; Nishith et al., 2013; Rogers, 2008; Rogers et al., 2011; Zhang et al., 2003). Processing a given set of part types using more than one route (alternative routing) may involve the use of different machines, operations, or sequences of operations (Sethi & Sethi, 1990). Hence, routing flexibility can be improved by having general purpose machines, identical machines, multi-skilled workforce and a versatile material handling system (Sethi & Sethi, 1990; Swamidass, 2000b; Tsubone & Horikawa, 1999).

Specifically, routing flexibility measures the capability to transfer parts between equipment, machines, production lines or workstations via multiple routes planned in the organization, thus allowed production to continue in case of disruption of system occurs due to multiple unforeseen reasons (Browne et al., 1984; D'Souza & Williams, 2000; Koste & Malhotra, 1999b; Narasimhan & Das, 1999; Watts et al., 1993; Zhang et al., 2003). Routing flexibility allowed the input or work in progress on the manufacturing floor using multiple paths, and reroute them using an alternative process plan, changing the sequence of process to reduce impact of machines breakdown and ease the burden of bottleneck processes (Gerwin, 1993, 2005; Koste, Malhotra, & Sharma, 2004; Slack, 2005; Swamidass & Newell, 1987). With the ability to modify the available paths to follow, alternate answer to the flow of manufacturing process can be produced, levelling on machines load and better machines utilization can be achieved (Gupta, 2004; Gupta & Somers, 1992).

Routing flexibility allowed the production process sequence to be restructured quickly and economically, thus enables the changing of machine visitation sequence (Al-jawazneh, 2012; Rogers, 2008). This enables a part to be routed to another machine quickly. Efficient scheduling due to alternative routing capability can help the manufacturing system to handle contingencies such as machine breakdown and rush orders, and continue to operate with least hassle (Sethi & Sethi, 1990; Swamidass, 2000b; Tsubone & Horikawa, 1999).

Past studies indicated that routing flexibility can improve throughput, reducing rework cost, reducing inventory levels and backorders, foster on-time delivery, and better equipment utilization (Gupta & Somers, 1996; Rogers, 2008; Sethi & Sethi, 1990). One thing worth mentioning is routing flexibility may require change in production floor layout for manufacturing organizations that want to adopt this component of manufacturing flexibility (Koste et al., 2004).

2.2.4.7 Volume Flexibility

Volume flexibility is often adopted as a meaningful way to gain competitive advantage in market place (Jack, 2000); where the need to serve different customers segments, high unpredictability in demands and supplies, pressure of customer requirement on lead time and responsiveness have leverage the importance of volume flexibility (Jack, 2000; Suarez et al., 1991). In order to achieve superiority in volume flexibility, practices like usage of overtime, part-time workers, training, better forecasting and planning systems and improving the capability to negotiate with suppliers and customers are used as the strategies to increase volume flexibility (Jack, 2000).

In this study, volume flexibility is defined as *"the ability of the manufacturing system to alter the output volume of a manufacturing process"* (Judi et al., 2004; Sethi & Sethi, 1990). It is closely related to how well firms cope with change of batch sizes and also unstandardized order quantities, where the ability to alter the level of aggregate output through capacity adjustment is the key to achieve high volume flexibility (Agus, 2011; Slack, 2005).

High volume flexibility often means that manufacturing system can: (i) run at lower volumes without eliminating workers (Sethi & Sethi, 1990); (ii) handle a large amount of change (increase or decrease) in aggregate production volume (Slack, 2005); (iii) produce a broad range of production volumes, with a wide range between the highest and the lowest possible production volumes (Al-jawazneh, 2012; Gupta & Somers, 1992, 1996; Judi & Beach, 2008; Koste, 1999; Sethi & Sethi, 1990); (iv) varied output rates for all products and aggregate production volume changes (increase or decrease of production volume) can be done easily and quickly

(Al-jawazneh, 2012; Gerwin, 1993; Judi & Beach, 2008; Koste, 1999; Rogers, 2008); (v) change the level of production volume quickly, regardless of what batch sizes is running; (vi) vary the total quantities of output from time to time easily (Al-jawazneh, 2012; Judi & Beach, 2008; Koste, 1999; Rogers, 2008).

High volume flexibility is often link with profit margin in terms of firm’s performance as volume flexibility allowed the manufacturing system to operate profitably at varying production volumes (Al-jawazneh, 2012; Browne et al., 1984; Gupta & Somers, 1992, 1996; Sethi & Sethi, 1990; Suarez et al., 1991). The important of volume flexibility arises when high unpredictability and seasonality in market demand compromised the ability to utilize level production, where production’s ability to alter production volumes rapidly is crucial and urgently required. On the other hand, ability to react quickly established by volume flexibility can enable an organizations to fill the demands gaps left out by competitors due to irresponsiveness (Suarez et al., 1991).

In short, higher volume flexibility should leads to shorter lead time, lower production cost, higher productivity, higher profitability and market share.

As a summary of Section 2.2, past researches provide numerous evidence that manufacturing flexibility can provide or generate competitive advantage over competitors. With proper definition and components of manufacturing flexibility defined, the influences of manufacturing flexibility towards firm performance can be further leveraged.

2.3 Firm Performance

In general, firm performance is a measure of the accomplishment of the firm goals (Richard et al., 2009). Firm performance is widely recognized as one of the critical constructs employed by previous researchers in the context of management research. However, there is no consensus about its definition, dimensionality and measurement (Santos & Brito, 2012). Overall, researchers admit that firm performance is a multidimensional construct (Combs et al., 2005; Richard et al., 2009). However, a number of studies represent this construct as unidimensional, even while agreeing it is multidimensional (Santos & Brito, 2012).

According to Richard et al. (2009), the construct of firm performance includes the following firm outcomes: (i) financial performance (such as profit margin, return on investment); (ii) product market performance (market share and its growth); and (iii) shareholder return (such as dividends, return on equity, cash value added). Meanwhile, proposed framework of balanced scorecard draws together a set of measures including financial performance, internal business processes performance, customer related performance, employee innovation and learning performance that allowed a firms to develop a balance and comprehensive system for performance measurement (Kaplan & Norton, 2005).

Likewise, Mann and Kehoe (1994) proposed the use of the business performance measurement system to measure firm’s business performance. This system categorized firm’s business performance into two broad categories: (i) Strategic business performance, which include performance measures that are measuring a firm’s achievement in terms of its major company goals and usually addressed by the company management board (e.g., profitability, market share, sales revenue, growth); and (ii) Operational business performance, which include performance measures that are addressed by both management and employees throughout the firm, and concerned with outcomes related to daily activities involved in running of the firm (e.g. delivery performance, rework and scrap, machine breakdowns, setup time reduction, throughput time, output per employee, skill level of employees, departmental performance, operating expense). In other words, business performance may be viewed as a higher level in the hierarchy of firm objectives, which looked at the business as a whole instead of operations level, while manufacturing (operations) performance representing the lower level (Bartezzaghi, Turco, & Spina, 1992; Nawanir, 2011).

In addition, Combs et al. (2005) reviewed previous attempts to describe the indicators of organizational performance, and noted that the indicators of performance identified appear to depend on the method of data analysis (qualitative or quantitative), source of data, and measures examined. Combs et al. (2005) also asserted that firm performance measures should be justified based on the appropriateness of the measures for the research setting and the validity of the measures as established in the literature.

Therefore, operationalization of firm performance should take into account of the research objectives and characteristics, and researchers should select the indicators closely related to their research with proper judgement (Richard et al., 2009; Santos & Brito, 2012).

Based on the above discussions and the examination of prior studies of manufacturing flexibility-performance relationship, this study conceptualized firm performance as having two facets: manufacturing performance (operational performance) and business performance (strategic business performance). Measuring firm's performance using this two indicators is also consistent with the notion that operational performance corresponds to firms' different operational activities (marketing, production/manufacturing, human resources, finance, and others), and operational performance is different from business performance (Combs et al., 2005; Mann & Kehoe, 1994).

The following sections (Section 2.3.1 & Section 2.3.2) will discuss the two-facet of firm performance, i.e. manufacturing performance and business performance.

2.3.1 Manufacturing Performance

Manufacturing performance is a critical performance measure of the outcome of flexibility, as this indicator denotes how well the manufacturing system transformed inputs to outputs with respect to quality, cost, speed, and others related parameters (Al-jawazneh, 2012). Acknowledging the fact that manufacturing performance is a multifaceted construct (Combs et al., 2005; Das, 2001; Ketokivi & Schroeder, 2004; Mann & Kehoe, 1994; Nawanir, 2011), empirical research should operationalize manufacturing performance taking into account of the research objectives and characteristics (Santos & Brito, 2012). In this study, based on the positions of many authors such as Combs et al. (2005), Das (2001), Nawanir et al. (2013), Ketokivi and Schroeder (2004) and Khanchanapong et al. (2014), manufacturing performance is referred as the outcomes which are influenced by operating conditions, such as quality, cost, lead time and productivity, that represents or reflects some internal properties of the manufacturing system.

Table 2.8 shows some of the typical manufacturing performance indicators used in the previous manufacturing flexibility related studies. The manufacturing performance indicators include quality, cost, lead time, productivity and inventory. However, different authors are using different set of manufacturing flexibility components (as noted in Section 2.2.2 and Appendix A) and different indicators for manufacturing performance measures (as shown in Table 2.8).

Table 2.8
Measures of Manufacturing Performance in Past Manufacturing Flexibility Related Studies

	Manufacturing Performance Measures				
Author	**Quality**	**Lead time**	**Cost**	**Inventory**	**Productivity**
Thomke (1997)		✓	✓		
Jack (2000)			✓		
Das (2001)		✓	✓		
Olhager and West (2002)			✓		
Pinilla and Prinz (2003)		✓			
Karuppan (2004)		✓	✓		
Slack and Lewis (2005)	✓	✓	✓		✓
Rogers (2008)	✓	✓	✓	✓	✓
Al-jawazneh (2012)	✓	✓	✓		
Nayak and Ray (2012)	✓				
Sawhney (2013)			✓	✓	
Alamro (2014)	✓	✓	✓		✓

While objective performance measures are preferable to subjective or perceived measures of performance, the latter has been recommended by a number of researchers as a substitute if objective measures are difficult to obtain or unavailable (Swamidass & Newell, 1987; Venkatraman & Ramanujam, 1986). Depending on the context, objective performance measures sometimes are improper for non-financial performance measurement and for comparison between firms particularly when firms have dissimilar ways of information record-keeping (Ketokivi & Schroeder, 2004). The critique over subjective performance indicators is that they are affected by human cognition and knowledge. The data obtained may be over or underestimated, as well as suffer from halo effects or may just be a guess (Ketokivi & Schroeder, 2004; Richard et al., 2009).

However, the study conducted by Venkatraman (1987) using 86 senior-level managers as the respondents indicated that managers tend to be less biased in their assessments of their organizational performance than researchers have tended to give them credit for. The study also showed strong convergence between the two types of measures using a confirmatory factor analysis. Based on the findings, the authors argued that the perceptual data could be employed as acceptable operationalization of organizational performance. Additionally, correlations between objective and perceptual performance measures were found to be positive and significant ($p < 0.05$) ranging from 0.44 to 0.69 in past studies (Forker, Vickery, & Droge, 1996; Venkatraman, 1987; Wall et al., 2004); indicating that the two types of measures point in the same direction. As evidenced by Wall et al. (2004), when this two types of performance measures (objective and subjective) were correlated to other variables, similar results in terms of significance and magnitude were obtained.

Accordingly, this study examines manufacturing performance from the perception of senior-level managers in the dimensions of product quality, cost reduction, lead time reduction, productivity and inventory minimization.

1. Product Quality: According to Koste and Malhotra (2000), product quality can generate competitive advantage to firms if managed well. As noted by

Sambasivan et al. (2009) and Al-jawazneh (2012), products with low defect rate and high quality are the key to competitive advantage and quality is a key indicator of manufacturing performance. Quality products also lead to low scrap and rework cost (Al-jawazneh, 2012; Narasimhan & Das, 1999; Rogers, 2008; Sambasivan et al., 2009).

2. Cost Reduction: It is a key indicator of manufacturing performance, and include raw material cost, overhead cost, failure cost, manufacturing cost and others (Al-jawazneh, 2012; Koste & Malhotra, 2000; Narasimhan & Das, 1999; Rogers, 2008; Sambasivan et al., 2009). Striving to be a low-cost manufacturer is a powerful competitive approach as majority of the buyers are price sensitive.
3. Productivity: It is referred as the ratio of output to its input. Higher output means higher productivity (Al-jawazneh, 2012; Kokic, Chambers, Breckling, & Beare, 1997; Rogers, 2008). Improving productivity required efficiency improvement, which can be realized through: (i) reducing inputs while increasing/maintaining outputs; (ii) increasing outputs while maintaining/reducing inputs (Heizer & Render, 2013).
4. Lead Time Reduction: It is the total length of time needed to manufacture a product, and sometimes lead time is also referred as throughput time (Russell & Taylor, 2014). The lower the lead time, the higher the manufacturing performance (Al-jawazneh, 2012). Reducing lead time can generate many benefits, as better availability of product(s) improving customer satisfaction.
5. Inventory Minimization: This refer to the minimization of levels of work-in-process (WIP) inventory, raw material inventory and finished goods inventory (Rogers, 2008). Excessive inventory hides problems on the production floor (Krajewski, Malhotra, & Ritzman, 2015), and therefore must be eliminated.

The advantages of reducing inventory include more competitive pricing and increment of profitability due to lower expenses on warehousing.

Specifically, product quality, cost reduction, lead time reduction, productivity and inventory minimization are the critical areas at which manufacturing function must be excel at (Russell & Taylor, 2014). These manufacturing performance measures are important for operations managers to create unique advantage over competitors.

2.3.2 Business Performance

Table 2.9 highlights a number of common business performance indicators employed in the past manufacturing flexibility studies. The business performance indicators include product market performance (sales/market share), profits, and customer satisfaction (Richard et al., 2009).

Table 2.9
Measures of Business Performance in Past Manufacturing Flexibility Studies

	Business Performance Measures			
Author	**Product market performance**	**Profits**	**Customer Satisfaction**	**On-time Delivery**
Gupta and Somers (1996)	✓	✓		
Jack (2000)	✓	✓	✓	
Das (2001)				✓
Chang et al. (2002)	✓	✓		
Olhager and West (2002)				✓
Zhang et al. (2003)			✓	
Larso (2004)	✓	✓		
Anand and Ward (2004)	✓			
Powers and Jack (2008)			✓	
Zhang et al. (2009)			✓	
Larso et al. (2009)	✓	✓		

According to various past researches (Combs et al., 2005; Mann & Kehoe, 1994; Nawanir, 2011; Nawanir et al., 2013), business performance is referred as "*the outcomes which are due to the interaction among all value creation activities and the firm's environment*". In this study, business performance is conceptualized to include the following facets: profitability, product market performance (that includes sales growth and market share) and customer satisfaction; in order to satisfy the desires of the firm's major stakeholders (Santos & Brito, 2012).

Freeman (2010) defined stakeholder(s) "*as any group or individual who can affect or is affected by the achievement of the organization's objectives*". While according to Clarkson (1995), shareholders and customers are two of the primary stakeholder groups, and there is a high level of interdependence between the firm and them. Superior business performance is a mean to satisfy shareholders and can be measured in terms of profitability and product market performance (sales/market share growth) (Santos & Brito, 2012).

Customer satisfaction translates into willingness-to-repurchase and therefore contributes to long-term profitability through the creation of a base of steady and loyal clients (Zhang et al., 2003). Furthermore, the fact that profit, growth and pleasing the customers are the three main reasons for the existence of a business firm is indisputable. It is therefore, in any attempt to measure a firm's business performance, the three indicators, i.e. profitability, product market performance and customer satisfaction must be included. Literature in manufacturing flexibility (Chang et al., 2002; Gupta & Somers, 1996; Zhang et al., 2003) also suggested that manufacturing flexibility contributes to business performance that comprises financial and non-financial performance (e.g., net profit, customer satisfaction, market share, sales growth).

As widely reported in the literature that managers are reluctant to share objective performance data with researchers due to their sensitive nature and concerns about revealing confidential information (Anand & Ward, 2004; Carr & Kaynak, 2007; Santos & Brito, 2012), therefore, in this study perceptual measures are used rather than objective measures. In other words, this study examines business performance from the perception of executive management in the dimensions of profitability, product market performance and customer satisfaction.

1. Profitability

The ability to consistently generating profits is critical to the survival of a firm. Profitability, a financial indicator, measures a firm's ability to generate returns or earn profits (Miller, Washburn, & Glick, 2013; Santos & Brito, 2012). It is one of the most commonly used indicators to represent firm performance (Carton & Hofer, 2006). Profitability measures encompass values and ratios which incorporate net income or one of its components such as operating income (Santos & Brito, 2012). For example:

- Return on Investment (ROI) - an indication of profit per dollar of investments, which indicates how good a firm use their investments to generate incomes (Finch, 2008). Return on investment is calculated by dividing net income (after interests and taxes) with total investments.

- Profits Margin, also called return on sales (ROS) - it is the ratio of income before interests and taxes to total sales (Agus, 2011; Anand & Ward, 2004; Camisón & López, 2010; Gupta & Somers, 1996; Jack, 2000; Nawanir et al., 2013; Sambasivan et al., 2009).

High revenue and return on investment often link to better profitability as the ability of the firm to generate income and efficiency of assets usage are ensured (Carton & Hofer, 2006; Finch, 2008). In addition to profitability, the next indicator is product market performance.

2. Product Market Performance

Product market performance is referred to the firm's major product line performance in terms of achieving sales and market share growth objective (Richard et al., 2009).

The benefit of flexibility to hedge against uncertainty are well-known as it promotes higher capacity utilization (Bish & Muriel, 2000; Jordan & Graves, 1995). Market share (defined as the percentage of a market in terms of either units or revenue accounted for by a product) and market share growth (referred as increment of market share over a specific period of time) are known as important indicators for market competitiveness, and are often used to gauge how well a firm is doing relative to its competitors (Wikipedia, 2015).

The important of market share towards profitability is observed as market share did affect the price-cost relationship in the manufacturing systems, both directly and indirectly (Venkatraman & Prescott, 1990). Manufacturing flexibility enables the growth of market share through greater responsiveness to changes of customer needs, demands uncertainty; better variation of product and delivery services provided (Jack, 2000; Swink et al., 2005).

In short, literature reviews (such as Anand and Ward (2004), Combs et al. (2005), Green and Inman (2007), Larso et al. (2009), Nawanir (2011), Nawanir et al. (2013) and Santos and Brito (2012)) indicated that sales growth, market share and its growth are the important measures of product market performance.

The last indicator of business performance is customer satisfaction, which is discussed in the next paragraph.

3. Customer Satisfaction

Customer satisfaction is a key indicator of how good a product or service provided by a firm. In real life, customer satisfaction is not only achieving by providing tangible products that fulfilling customer needs but also depends upon the superior services/after-sales-services provided. This superiority in products and services can foster customer loyalty, and through word-of-mouth, can subsequently improve business performance (Al-jawazneh, 2012; Anderson, Fornell, & Lehmann, 1994; Jack, 2000; Rogers, 2008; Stevenson, 2015).

Tangible products and intangible services often occurs jointly, where most business transactions are a combination of both providing services and selling products (as depicted in Figure 2.1). As an example, having the engine oil changed in your car is a service, but the oil that is delivered is a good. Similarly, house painting is a service, but the paint is a good. This creates a continuum of goods-services combination. The continuum can range from primarily goods, with little service, to primarily service, with few goods. Because there are relatively few pure goods or pure services, firms usually sell product-packages, which are a combination of goods and services. There are elements of both goods production and service delivery in these product-packages (Stevenson, 2015).

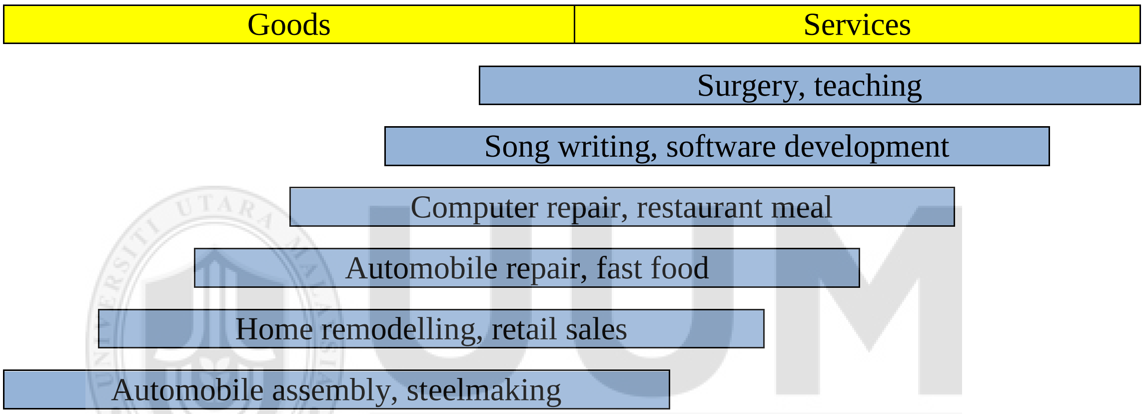

Figure 2.1
The Goods–Service Continuum
Source: Adopted from Stevenson (2015)

As a consequent, customer satisfaction means conforming to or surpassing customer requirements/expectation in terms of quality, delivery performance (for both products and services) and also after-sales-services such as customer changing needs and responses to customer complaints (Al-jawazneh, 2012; Anderson et al., 1994; Jack, 2000; Rogers, 2008; Stevenson, 2015). It was the best indicators of customer purchase intentions and loyalty (Farris, Bendle, Pfeifer, & Reibstein, 2010; Gabisch & Gwebu, 2011).

In a competitive market place, firms are competing for customers. Hence, customer satisfaction is seen as a key differentiator and it has become an important element of firm's business strategy (Gitman & McDaniel, 2008). Therefore, managing customer satisfactions in the open market place is crucial as word-of-mouth recommendations help to attract new customers in competitive business environments.

Current study employed profitability, product market performance and customer satisfaction as the keys to represent business performance. These business performance measures are important for managers to understand their real advantages over their competitors.

2.4 The Impact of Manufacturing Flexibility on Manufacturing Performance

Various past researches about manufacturing flexibility that shown positive and significant effects (at $\alpha = 0.05$) on manufacturing performance are depicted in Table 2.10. Based on the table, specific manufacturing flexibility component has significant influence on certain manufacturing performance measures. Manufacturing flexibility at aggregated level also showed similar results. Nevertheless, further examination revealed that the number of studies at the aggregated level is relatively scarce.

Impacts of manufacturing flexibility on product quality have been stressed by a number of past studies. For instance, research by Alamro (2014) showed that new product flexibility has positive and significant impact on quality of the product. Another study related to product quality was conducted by Rogers (2008) and found that labor, routing and volume flexibility have positive and significant impact on scrap and rework cost, which is highly correlates with product quality.

Cost reduction is another influential manufacturing performance indicator. Alamro (2014) has studied upon the impact of new product flexibility towards manufacturing cost efficiency in his research. Respondents were required to rate on a 5 point scale, ranging from (1) = *“strongly disagree”* to (5) = *“strongly agree”* on how their business had performed over the last 3 years relative to their major competitors. The study provided supportive evidence for a positive and significant relationship.

Table 2.10
Past Researches of Manufacturing Flexibility on Manufacturing Performance

Manufacturing Flexibility Components	**Manufacturing Performance Measures**					**General Manufacturing Performance**
	Product Quality	**Cost Reduction**	**Lead time reduction**	**Productivity**	**Inventory Minimization**	
Mix Flexibility		[4] [6] [7]	[4]		[11]	
New Product Flexibility	[2]	[2] [6]	[2]	[2]		
Labor Flexibility		[10] [11]	[11]	[11]	[10] [11]	
Machine Flexibility						[3]
Material Handling Flexibility						[3]
Routing Flexibility		[11]	[9] [11]	[11]	[11]	
Volume Flexibility		[6] [11]	[11]	[11]	[11]	
Aggregate Manufacturing flexibility	[8]	[11]	[1] [11]	[11]	[11]	[3] [5]

[1]=Rogers et al. (2011); [2]=Alamro (2014); [3]=Al-jawazneh (2012) [4]=Das (2001); [5]= Mendes and Machado (2014); [6]=Olhager and West (2002); [7]=Narasimhan and Das (1999); [8]=Nayak and Ray (2012); [9]=Pinilla and Prinz (2003); [10]= Sawhney (2013); [11]=Rogers (2008)
*significant at α = 0.10; Others are significant at α = 0.05

The effect of mix flexibility on manufacturing cost reduction was empirically proven by research done by Das (2001). In the same vein, mix flexibility has positive impact towards cost reduction and this has been supported by Narasimhan and Das (1999). Meanwhile, Sawhney (2013) has concluded that labor flexibility has positive and significant impact on cost reduction. Furthermore, research done by Olhager and West (2002) have link three flexibility types (i.e. mix, new product and volume flexibilities) to the success of cost reduction in manufacturing systems. On the other hand, Nawanir (2011)'s study has confirmed that resource flexibility (the mixture of machine and labor flexibility) has a positive impact on manufacturing performance (cost reduction) with α at 0.067.

In the term of lead time reduction, impact on mix flexibility towards lead time reduction has been studied by Das (2001) and positive relationships have been observed. Alamro (2014) also has touched upon the impact of new product flexibility towards lead time reduction in his research and the outcome is positive and significant. Rogers (2008) has link three flexibility dimensions (labor, routing and volume flexibility) on lead time reduction with positive and significant effect on it. Meanwhile, lead time reduction has positive relationship with routing flexibility, according to Pinilla and Prinz (2003).

Rogers (2008) has discussed about how labor flexibility, routing flexibility and volume flexibility impacted productivity. Besides that, research done by Alamro (2014) on new product flexibility also stated that new product flexibility can help to increase productivity. On the other hand, study by Sawhney (2013) on 74 PCB plant has concluded that labor flexibility (measure using (i) usage of multi skills workers; (ii) workers used for multiple jobs; (iii) workers used to increase profits) has significant effect on plant performance (in terms of cost and work-in-process inventory).

Effect of manufacturing flexibility on inventory minimization has been discussed by Rogers (2008), especially on mix flexibility, labor flexibility, routing flexibility, and volume flexibility. According to Rogers (2008), these four flexibility dimensions have positive and significant impact on inventory minimization effort, that mean the higher the capability of these flexibilities, the higher the effectiveness of inventory minimization can be achieved.

In the sense of aggregate manufacturing flexibility, its impact on elements of manufacturing performance is supported by various past study, e.g. Mendes and Machado (2014); Nayak and Ray (2012); Rogers (2008), Rogers et al. (2011) and Al-jawazneh (2012). Specifically, according to Rogers (2008), aggregate manufacturing flexibility affecting four elements of manufacturing performance (refer to Table 2.10) with R^2 ranging between 0.035 to 0.087.

In brief, there are evidences to support the existence of significant relationships between manufacturing flexibility and manufacturing performance.

2.5 The Impact of Manufacturing Flexibility on Business Performance

Table 2.11 presented the past researches on manufacturing flexibility that investigated the effect of specific manufacturing flexibility components on business performance measures. In general, past studies tend to suggest that positive and significant effects (at $\alpha = 0.05$) of manufacturing flexibility components on business performance measures. However, the number of studies for impact on specific manufacturing flexibility components towards business performance measures is still limited, for example labor flexibility and material handling flexibility. Similarly, more studies at the aggregated level for manufacturing flexibility and business performance are required.

Past researches tend to propose that manufacturing flexibility is able to contribute to business performance, both financially (e.g. return on investment, revenue) and non-financially (e.g. market share, sales growth, customer satisfaction).

Table 2.11
Past Researches on Manufacturing Flexibility that Shown Positive and Significant Effects on Business Performance

Manufacturing Flexibility Componenets	**Business Performance Measures**				**General Business Performance**
	Profitability	**Product Market Performance**	**Customer Satisfaction**	**Delivery Performance**	
Mix Flexibility	[3]	[3]	[1]	[11] [13]	[4]
New Product Flexibility		[3]			[4] [7] [8]
Labor Flexibility			[15]^{1}		
Machine Flexibility			[15]^{1}		[7]
Material Handling Flexibility					[7]
Routing Flexibility		[2]	[15]		[7] [8] [15]
Volume Flexibility		[2] [3]*[6]	[1][5][6]	[6][13]	[4] [6]
Aggregate Manufacturing flexibility			[4] [15]		[4] [9] [10] [12] [14]

[1]=Zhang et al. (2003); [2]=Gupta and Somers (1996); [3]=Chang et al. (2002) [4]=Mendes and Machado (2014); [5]=Powers and Jack (2008); [6]=Jack (2000); [7]=Larso (2004); [8]= Larso et al. (2009); [9]= Camisón and López (2010); [10]=Patel, Terjesen, and Li (2012); [11]=Rogers (2008); [12]= Lee, Chen, and Lee (2013); [13]=Olhager and West (2002); [14]=Swamidass and Newell (1987); [15] = Aranda (2003)
*significant at α = 0.10; Others are significant at α = 0.05; ^{1} = Personnel and equipment flexibility

According to Chang et al. (2002), when a firm can offer various choices of product to customer (mix flexibility), customer demands are better fulfilled and net profit rate will increase. In addition, new product flexibility and volume flexibility also have positive and significant impacts on sales growth rate (Chang et al., 2002).

Meanwhile, the findings of Gupta and Somers (1996) reported that routing flexibility and volume flexibility have positive and significant direct effects on firm's growth performance (sales growth rate and market share).

Manufacturing flexibility can promote customer satisfaction; this statement is supported by a few past researches. Specifically, Zhang et al. (2003) found that mix flexibility affects customer satisfaction, while Powers and Jack (2008) revealed that volume flexibility contributes to customer satisfaction and research done by Mendes and Machado (2014) indicated that aggregate manufacturing flexibility affects customer satisfaction in a positive way (total effects of 0.886).

Mix flexibility has positive and significant impacts on delivery performance (using on-time delivery), as supported by Rogers (2008)'s empirical research. In addition, effect of volume flexibility and mix flexibility on delivery performance (in terms of delivery speed and depandability) is supported by Olhager and West (2002), where author is using quality function deployment (QFD) to deploy manufacturing flexibility at Ericsson's Linkoping plant.

Positive and significant influence of manufacturing flexibility towards general business performance measured by total sales, market share, sales growth, profit margin and return on investment is supported by Larso (2004) that focused on machine, new product, material handling and routing flexibilities; where the study collected data from 273 U.S. electronics manufacturers and focused on how manufacturing flexibility influence new products development and new products performance.

Research done by Larso et al. (2009) further solidify the claim on impact of new product flexibility and routing flexibility towards general business performance (i.e. total sales, market share, sales growth, profit margin and return on investment). Besides that, Jack (2000) who studied on influence of firm size towards volume flexibility has collected data from 120 firms that are members of Greater Cincinnati Chapter of APICS in Ohio, U.S.; and concluded that volume flexibility has positive effect on firm performance indicators that involve “customer satisfaction on delivery performance”, “financial performance”, “sales growth performance”, and “market share growth performance”.

A study on the impact of aggregate manufacturing flexibility towards aggregate organizational performance have been done by Camisón and López (2010), Lee et al. (2013) and Mendes and Machado (2014); and the result is positive and significant ($R^2 = 0.251$ for Camisón and López (2010); $R^2 = 0.241$ for Lee et al. (2013) and Mendes and Machado (2014) with total effects of 0.886). Similarly, the study by Patel et al. (2012) also showed that aggregate manufacturing flexibility has positive and significant correlation (at $\alpha = 0.01$) with firm performances (measure using sales growth, employees growth, and operating profits growth), where correlation = 0.21 was recorded. On the meantime, parameter estimation method used in that research also supports the same findings (aggregate manufacturing flexibility has influence on performances, in a positive way). This research employed 852 samples gathered from 7500 small U.S. manufacturing companies listed in the Dun and Bradstreet (D&B)’s

Million Dollar database directed to Vice President of Manufacturing or CEO as they were knowledgeable about manufacturing routines and processes (Sharfman, 1998).

Meanwhile, research conducted by Swamidass and Newell (1987) involving 35 firms from machinery and machine tools industry have found that aggregate manufacturing flexibility (combination of mix flexibility and new product flexibility) has positive and significant direct impact on firm performances (aggregated by growth in return on assets, sales and return on sales for year 1977 to 1981), where $R^2 = 0.11$ was reported.

Study by Aranda (2003) on services sector (engineering consultant firms in Spain) through questionnaires, proposed that manufacturing flexibility components have significant direct effect on financial performance (example of measures include using firm profit on net income, set up times, return on investment, cost reduction due to quality increments). Positive relationships for flexibility on distribution of information and routing flexibility are observed, while equipment and personal flexibility, market flexibility, products and services flexibility, process, programming and volume flexibility, and expansion flexibility observed negative relationships towards financial performances. On the viewpoint of non-financial performance (measure using customer satisfaction related measures that include number of customer claims, level of workers efficiency, number of errors in the system of service delivery, new service(s) development, number of services not finally delivered because of customer request, time between service order and delivery, capability of service customisation, level of customer satisfaction, level of interdepartmental workers cooperation) indicated that all manufacturing flexibility dimensions excluding flexibility on distribution of information (including expansion flexibility, routing flexibility, personnel and equipment flexibility, market flexibility, services and servuction flexibility, and process, programming and volume flexibility) have positive and significant relationships on non-financial performance.

Beside direct relationship, correlation between new product flexibility and market base performance (measure using profitability, market share and unit growth rate in sales) is observed in the study by Swink et al. (2005). A simulation-based experiments to dictate the influence of machine flexibility and routing flexibility on average flow time was conducted by Tsubone and Horikawa (1999), where result of simulation yield supportive result as average flow time decrease when machine flexibility and routing flexibility increase.

Based on above discussions, there are evidences to support the existence of significant relationships between manufacturing flexibility and business performance.

2.6 The Relationship between the Manufacturing Performance and Business Performance

Table 2.12 below showed the association between manufacturing performance measures and business performance measures either at the individual level or at the aggregated level identified in the past empirical studies.

Table 2.12

Correlations between Manufacturing Performance Measures and Business Performance Measures Used in Past Research

Performance		Business Performance Measures				Aggregated Business Performance
		Profitability	**Product market performance**	**Customer satisfaction**	**Delivery Performance**	
Manufacturing Performance Measures	**Product Quality**	[4] [8]	[4] [8] [11]	[3] [4] [8] [10]		[6]
	Cost Reduction	[4] [8]	[4] [8]	[4] [8] [10]	[1]	[10]
	Lead time reduction	[9]				
	Productivity	[2] [4] [8]	[4] [8]	[4] [8]	[1]	
	Inventory Minimization	[4] [5] [8]	[4] [8]	[4] [8]	[1]	
Aggregated Manufacturing Performance		[4] [8]	[4] [8]	[4] [8]	[7]	[4] [6] [8] [12]

[1]=Rogers (2008); [2]=Roca-Puig, Beltrán-Martín, Bou-Llusar, and Escrig-Tena (2008); [3]=Kaur et al. (2016); [4]=Nawanir et al. (2013); [5]=Capkun, Hameri, and Weiss (2009); [6]=Vinuesa and Hoque (2011) ; [7]=D'Souza (2006); [8]=Nawanir (2011); [9]=Fullerton and Wempe (2009); [10]=Fynes and Voss (2001); [11]=Forker et al. (1996); [12]=Voss, Åhlström, and Blackmon (1997)

*significant at $\alpha = 0.10$; Others are significant at $\alpha = 0.05$

By using canonical correlation analysis, Nawanir (2011) showed that the set of operations performance measures has positive and significant correlation with the set of business performance measures at $\alpha = 0.05$. Meanwhile, study by D'Souza (2006) found that composite manufacturing performance measure has positive and significant correlation with delivery performance. As indicated in Table 2.12, there are significant and positive correlation between manufacturing performance measures and business performance measures (Nawanir, 2011; Nawanir et al., 2013; Rogers, 2008).

Specifically, in a study to investigate the interrelationships between lean manufacturing practices, operations performance, and business performance in the context of Indonesian manufacturing firms, Nawanir (2011) found that operations performance measures (i.e. quality, inventory minimization, delivery, productivity and cost reduction) have positive and significant correlation with business performance measures (i.e. profitability, sales and customer satisfaction).

On the other hand, Rogers (2008) concluded that on-time delivery has significant and positive association with scrap and rework cost, unit manufacturing costs, workers productivity, machine utilization, work in process and finish goods inventory. Meanwhile, study by Vinuesa and Hoque (2011) in total quality management context where data was collected from 130 Spanish furniture firms has reported positive and significant relationships between quality performance (e.g. degree of conformity of our products within specifications, reduction of customer complaints or claims, customers satisfaction with the quality of our products), operational performance (e.g. unitary manufacturing costs reduction, short supply cycle), non-financial performance (e.g. number of orders delivered on time, number of satisfied customers, time taken to deliver products), and financial performance (in terms of cash flow and return of investment).

In a study by Fynes and Voss (2001) using path analytic model to gauge the relationships amongst quality management practices, quality performance and business performance that collect data from 200 electronics firms in Republic of Ireland, it was found that quality performance (e.g. conformance quality and external quality-in-use) and product cost are significant correlated with customer satisfaction. Besides that, product cost was also found to be negatively correlated (a positive result) with business performance (measures using growth with respect to return on investment, sales, earnings before tax and market share).

Past studies such as Nawanir (2011), Nawanir et al. (2013), Rogers (2008), and Shah (2003) indicated positive and significant correlation between manufacturing performance measures (product quality, cost reduction, lead time reduction, productivity and inventory minimization). Similarly, some past studies such as Combs et al. (2005), Evans (2004), Nawanir (2011), Nawanir et al. (2013), Santos and Brito (2012), and Rust, Moorman, and Dickson (2002) also support the existence of positive and significant correlation between business performance measures (profitability, product market performance and customer satisfaction). Research conducted by D'Souza (2006) concluded that composite manufacturing performance measure has positive and significant correlation with performance dimensions in terms of quality (conformance with design specification) and cost (cost of production per unit output).

Online survey by Evans (2004) conducted within manufacturing, service, and not-for-profit (including education and health care) sectors, found that organization with more mature performance measurement system reported better performance in terms of market share (measured using market share, market position, percent of new product sales as well as sales growth); customer satisfaction (such as overall customer satisfaction, gains and losses of customer, customer retention, customer complaints, returns and warranty claims) and financial performance (e.g. revenue, operating profit, Return on Investment (ROI), Return on Assets (ROA), revenue per employee, cost savings from improvements, value added per employee, earnings per share, cost of quality). In addition, the study also found significant correlation between market share and customer satisfaction, between market share and financial performance, and between customer satisfaction and financial performance.

Table 2.13 below summarized the impact of manufacturing performance on business performance reported in past empirical studies employing regression, path analysis or structure equation modelling approach.

Table 2.13
Impact of Manufacturing Performance on Business Performance

	Performance	**Business Performance Measures**		
		Profitability	**Product Market Performance**	**Customer satisfaction**
Manufacturing Performance Measures	**Product Quality**	[2] [3] [4]	[2] [3] [4][6]	[3] [4]
	Cost Reduction	[3] [4]		[5]
	Lead time reduction	[1]*		
	Productivity	[3] [4]		
	Inventory Minimization	[3]* [4]*	[3]* [4]*	
Aggregate Manufacturing Performance		[3] [4]	[3] [4]	[3] [4]

[1]=Fullerton and Wempe (2009); [2]=Agus and Shukri Hajinoor (2012) ; [3]=Nawanir et al. (2013); [4] = Nawanir (2011); [5]=Fynes and Voss (2001); [6]=Forker et al. (1996)
*significant at α = 0.10; Others are significant at α = 0.05

As indicated in Table 2.13, product quality has significant and positive impact on profitability (e.g. return on investment (ROI), profit margin, revenue growth), product market performance (sales, market share and sales growth) and customer satisfaction (in relation to pricing, product quality, delivery and others) and this statement is support by research done by Nawanir (2011), Nawanir et al. (2013), Agus and Shukri Hajinoor (2012) and Forker et al. (1996).

In addition, Nawanir et al. (2013) also reported that cost reduction and productivity have positive impact on profitability while the effect of product cost on customer satisfaction is support by Fynes and Voss (2001). Inventory minimization has positive and marginal significant impact (at α = 0.10) on two of the business performance measures (profitability and product market performance) based on the study by Nawanir et al. (2013).

Meanwhile, the study by Nawanir (2011) concluded that aggregate manufacturing performance affects all three dimensions of business performance (product market performance, profitability and customer satisfaction). Whereas, study by Fullerton and Wempe (2009) found that lead time reduction has positive impact on profitability, at α = 0.10. Last but not least, by collecting data from 65 firms in furniture industry, Forker et al. (1996) found that quality (conformance to specifications) has positive and significant influence on sales growth.

In short, relationships between business performance and manufacturing performance have been studied by past researchers, their results tend to support significant and positive relationships between the two constructs. Therefore, manufacturing performance can be viewed as an antecedent of business performance, where the potential of manufacturing performance as a mediator between the relationship of manufacturing flexibility and business performance is unleashed.

2.7 The Interrelationship between Manufacturing Flexibility, Manufacturing Performance and Business Performance

Based on the discussion in Section 2.4, Section 2.5 and Section 2.6 (also refer to Table 2.10, Table 2.11 and Table 2.13), the interrelationships amongst firm's manufacturing flexibility, firm's manufacturing performance, and firm's business performance can be summarized and represented in Figure 2.2. Based on the figure, once again the potential of manufacturing performance as a mediator is highlighted. Specifically, all the seven dimensions of manufacturing flexibility may have positive and significant impact on manufacturing performance and business performance with manufacturing performance acts as a potential mediator.

Past manufacturing flexibility related literature provided evidences supporting positive correlation within the manufacturing flexibility components. It means that implementation of one particular flexibility types will affect the others. As an examples, Gupta and Somers (1996) found positive and significant correlation between material handling, routing, and volume flexibility. Moreover, structural equation modelling analysis carried out by Rogers et al. (2011) provided supporting evidences about the existence of synergistic effect between manufacturing flexibility components. In consistent with the above statement, together with past studies highlighted in Section 2.4 and Section 2.5 (refer to Table 2.10 and Table 2.11), it can be concluded that aggregated manufacturing flexibility has shown significant and consistent impact on firm performance (manufacturing performance or business performance or both, either at individual level or aggregated level), if compared with individual component of manufacturing flexibility. A summary of the past study on the various relationships among manufacturing flexibility components is depicted in Table 2.14. Based on the table, associations among manufacturing flexibility components are highlighted, and this portrayed that potential synergy effects may occur among them.

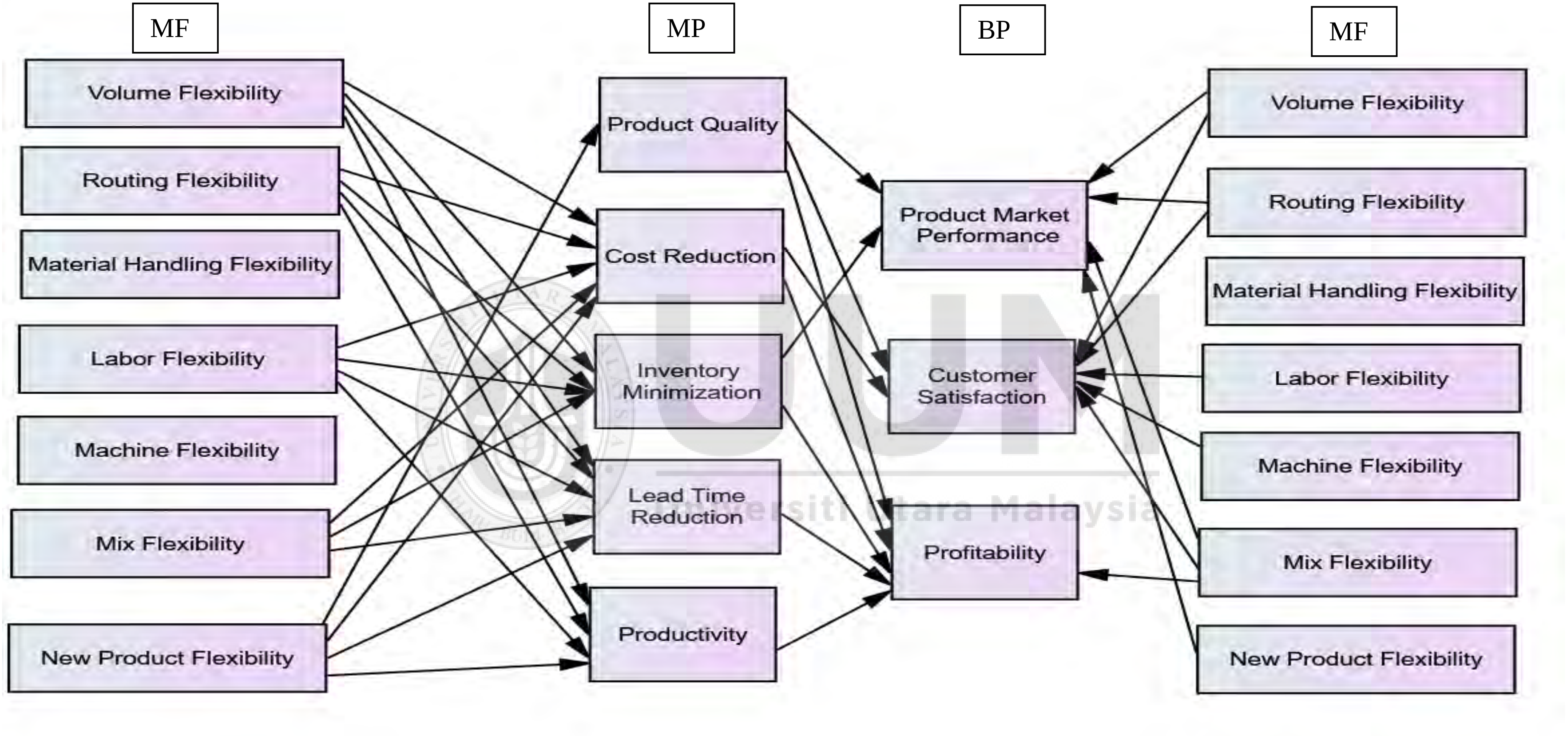

Figure 2.2

Interrelationship between Manufacturing Flexibility, Manufacturing Performance and Business Performance

Remark: Material handling flexibility did affect manufacturing performance and business performance, in an aggregate way

Table 2.14
Relationships among the Manufacturing Flexibility Components from the Past Study

MF Components	**Mix Flexibility**	**New Products Flexibility**	**Labor Flexibility**	**Machine Flexibility**	**Material Handling Flexibility**	**Routing Flexibility**	**Volume Flexibility**
Mix flexibility	**-**						
New Product Flexibility	**[5] [9] [10] [11]**	**-**					
Labor Flexibility	**[10] [11]**	**[4] [10] [11]**	**-**				
Machine Flexibility	**[3] [8]**	**[4] [10]**	**[4] [10]**	**-**			
Material Handling Flexibility	**[6] [7] [10]**	**[4]**	**[4] [10]**	**[1] [7]**	**-**		
Routing Flexibility	**[6] [7]**	**[4]**	**[4]**	**[1][4] [7] [8]**	**[1][4] [6] [7]**	**-**	
Volume Flexibility	**[6] [9] [11]**	**[2][4] [9][11]**	**[4]**	**[1] [4]**	**[1][4] [6]**	**[1][4] [6]**	**-**

[1]=Gupta and Somers (1996) ; [2]=Narasimhan and Das (1999); [3]=Karuppan and Kepes (2006) [4]=Larso et al. (2009); [5]=Suarez et al. (1996); [6]=Judi and Beach (2008); [7]=Tamayo-Torres, Ruiz-Moreno, and Lloréns-Montes (2011); [8]=Parker and Wirth (1999) ; [9]= Jantan et al. (2006); [10]=Patel et al. (2012); [11]=Mendes and Machado (2014)

Narasimhan and Das (1999) revealed positive and significant correlation (0.4995, significant at α = 0.05) between new product flexibility and volume flexibility, whereas Karuppan and Kepes (2006) reported positive and significant relationship between mix flexibility and machine flexibility (0.19 at α = 0.05 (between mix flexibility (RN - number of options available) and machine flexibility) and 0.53 at $\alpha = 0.001$ (between mix flexibility (RH - extent of variation between options) and machine flexibility).

In addition, Larso et al. (2009) also found positive and significant correlation between volume, new product, routing, material handling, labor, and machine flexibility (refer Figure 2.3); where correlation range from 0.191 (between machine flexibility and labor flexibility) to 0.555 (between routing flexibility and new product flexibility) was reported. Judi and Beach (2008) have reported that there are positive and significant correlation between variety flexibility (also known as mix flexibility) and volume flexibility ($r = 0.88$), between variety flexibility and material handling flexibility ($r = 0.38$) and also between volume flexibility and material handling flexibility ($r = 0.49$).

As highlighted by Combs et al. (2005), firm’s performance is one of the critical elements in strategic management research but the boundaries and dimensionality of firm’s performance have not yet been fully understood. Since organization performance is affected by the summation of the firm’s operational performance across different value chain activities in various divisions, therefore, operational performance can be seen as an antecedent to firm’s business performance.

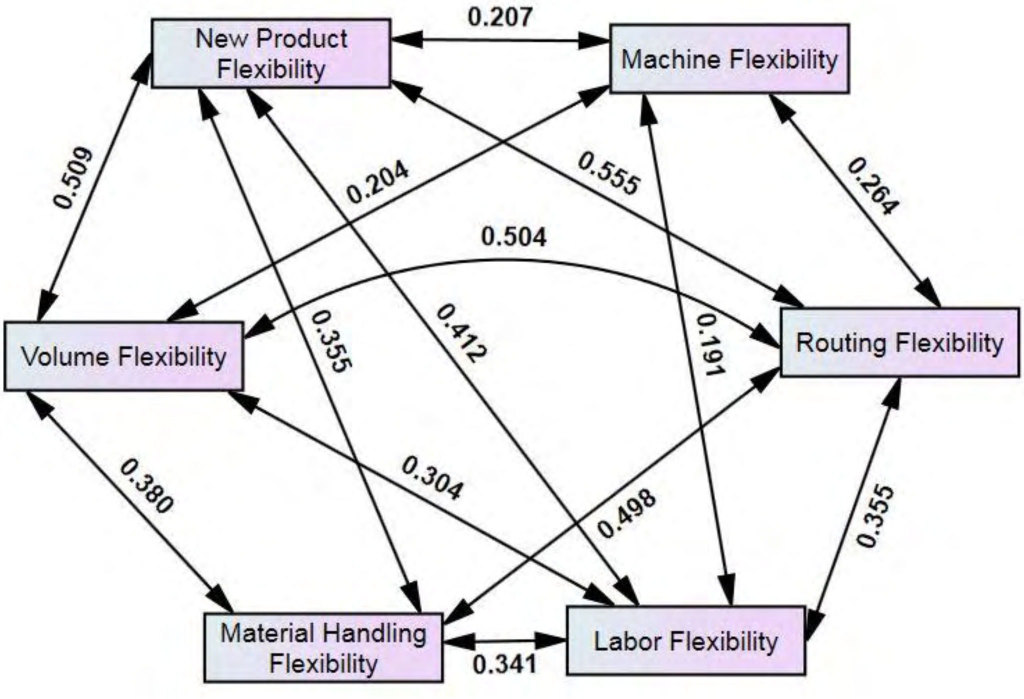

Figure 2.3
Correlations between Manufacturing Flexibility
Source: Adapted from Larso et al. (2009)

Significant relationship between manufacturing flexibility and firm performance is found in past studies (refer to Table 2.10, Table 2.11, Table 2.15). Based on Table 2.15, past researchers tend to support that manufacturing flexibility has significant and positive effect on either manufacturing performance or business performance. However, none of the researches involve investigating the three construct (manufacturing flexibility, business performance and manufacturing performance) simultaneously, which indicates a need for further study.

Table 2.15

Summary of Past Study on Impact of Manufacturing Flexibility on Manufacturing Performance or Business Performance

No	**Author**	**Manufacturing Flexibility**	**Manufacturing Performance**	**Business Performance**	**Moderator**	**Mediator**	**Findings**
1	Gupta and Somers (1996)	1. Expansion Flexibility 2. Material Handling Flexibility 3. Routing Flexibility 4. Machine Flexibility 5. Market Flexibility 6. Product Flexibility 7. Process Flexibility 8. Programming Flexibility 9. Volume Flexibility	N/A	1. Financial Performance 2. Growth Performance		N/A	Path analysis model indicated that Expansion flexibility, routing flexibility, product flexibility, process flexibility and volume flexibility have direct effect on growth performance; process flexibility have significant effect on financial performance.
2	Narasimhan and Das (1999)	1. Volume flexibility 2. Modification flexibility 3. New product flexibility	Manufacturing cost reduction	N/A	N/A	N/A	Only modification flexibility has significant effects on manufacturing cost reduction.
3	Jack (2000)	1. Volume flexibility	N/A	1. Delivery performance 2. Financial performance 3. Growth performance	Firm's Size	N/A	Volume flexibility moderated by firm's size has a significant effect on business performance

Table 2.15 (Continued)

No	Author	Manufacturing Flexibility	Manufacturing Performance	Business Performance	Moderator	Mediator	Findings
4	Rogers (2008)	1. Mix flexibility 2. Routing flexibility 3. Volume flexibility 4. Labor flexibility 5. Supply Management flexibility	1. setup time 2. throughput time 3. scrap and rework cost 4. worker productivity 5. raw materials inventory 6. WIP inventory 7. finished goods inventory 8. number of backorders 9. on-time delivery 10. unit manufacturing cost 11. cost of purchased materials 12. machine utilization	N/A	1. Strategic integration 2. Organization infrastructure	N/A	Manufacturing flexibility moderated by strategic integration and organization infrastructure has significant effect on manufacturing performance
5	Camisón and López (2010)	Aggregated manufacturing Flexibility (instrument indicate it was a mixture of mix, modification and volume flexibility)	Aggregated firm performance 1. Economics performance 2. Satisfaction performance		N/A	Product/process and organizational innovations	Product/Process and organizational Innovations mediate the relationship between manufacturing flexibility and firm performance.
6	Al-jawazneh (2012)	1. machine flexibility 2. volume flexibility 3. material handling flexibility 4. mix flexibility 5. routing flexibility	1. Quality 2. Cost 3. Speed	N/A	N/A	N/A	Manufacturing flexibility has significant effect on operational performance

In addition, past studies have reported that different manufacturing flexibility dimensions have different impact on different firm performance measures (Beach et al., 2000; Swamidass & Newell, 1987). Meanwhile, Camisón and López (2010) argued that the manufacturing flexibility may not necessarily result in significant impacts on firm's performance, thus suggesting there may be factor(s) mediating the relationship between firm's manufacturing flexibility and firm's performance. Researches by Nayak and Ray (2012) and Rogers (2008) have shown that manufacturing flexibility is the antecedent of manufacturing performance, which make manufacturing performance a potential mediator. Likelihood of manufacturing performance as a moderator is void when the manufacturing flexibility (independent variable) is different level from manufacturing performance and have effects on it (Baron & Kenny, 1986).

Based on resource-based view reasoning, manufacturing flexibility should help to improve a firm's capabilities in terms of product, process, and organizational innovations because this capability can lead to competitive advantage. Their study provided support that product, process and organizational innovations mediates the relationship between manufacturing flexibility (aggregated manufacturing flexibility involved mix flexibility, volume flexibility and others) and firm performance (economic performance involved profitability and growth; and also satisfaction performance involve customers and stakeholders satisfaction, labors productivity and strength of competitive position). On the other hand, the study done by Nawanir (2011) provided evidence about the role of operations performance as important mediator in the relationships between lean practices and business performance.

Based on the above discussions, it is reasonable to claim that the interrelationship between manufacturing flexibility, manufacturing performance, and business performance is still unclear and further studies are required to enhance the understanding towards them.

2.8 Summary

This chapter reviewed the literature on the meaning of flexibility and its benefits, the concept of manufacturing flexibility and its components and effect of manufacturing flexibility on manufacturing performance and business performance. In this chapter, correlations among manufacturing flexibility, manufacturing performance and business performance have been foreseen by various past researches. On the other hand, the effects of manufacturing performance on business performance has been spelled out by various past researchers which indirectly support the existence of manufacturing performance as a potential mediator in current study. Potential mediation effect of manufacturing performance on the relationship between manufacturing flexibility and business performance is highlighted by prior researches, where manufacturing performance was considered as an antecedent of business performance. In layman term, manufacturing flexibility affects manufacturing performance before business performance. Besides, high correlation among manufacturing flexibility components did suggest that potential synergy among the components and also potential multicollinearity when undertaking multiple regression analyses. These reviews provided a foundation to establish the theoretical framework for this study, which will be discussed in Chapter 3. Together with this, the next chapter will also provide the detail of research methodology, the underlying theories and hypotheses proposed to be tested in this study.

CHAPTER 3

UNDERPINNING THEORIES, RESEARCH FRAMEWORK AND METHODOLOGY

3.1 Introduction

After the initial information gathered in Chapter 1, research problems and literature review were presented in Chapter 2. Chapter 3 presents the underpinning theories, theoretical framework and research methodology used in this study. Theoretical framework was developed based on the literature review done in the preceding chapter and it will describe the relationships between the variables and elaborate the flow of the relationships. Based on the theoretical framework, research hypotheses were developed. Apart from that, sampling frame and samples, data collection method, measurement of data, and data analyzing methods were explained.

3.2 The Underpinning Theories of the Study

A theory provides a logical linkage between specific concepts or constructs, allowing researchers to have a better understanding about their relationships, and how they affect each other (Zikmund, Babin, Carr, & Griffin, 2013). Literature review indicates the resource-based view theory (RBV) and complementarity theory can complement manufacturing flexibility strategy strongly in helping the firm to enhance the performance and competitive advantage (Camisón & López, 2010; Lucas & Kirillova, 2011; Ngamsirijit, 2011; Rogers et al., 2011). Besides, the potential mediating effect of manufacturing performance in the relationship between manufacturing flexibility and business performance were also explained by using

RBV theory. This subsection serves to explain the two theories underpin the relationships between manufacturing flexibility, manufacturing performance and business performance i.e. resource-based view theory (RBV) and complementarity theory.

RBV theory explains that a company’s sustainable competitive advantage is grounded within the firm, in its unique resources being rare, valuable, inimitable, and non-substitutable, as well as firm-specific (Barney, 1991; Makadok, 2001) that enable it to perform particular tasks effectively. In other words, a firm may enhance its performance through unique resources which it holds, where neither of these resources can be easily bought, transferred, nor copied. Concurrently, they add value to a company while being rare. The theory also highlights the fact that not all resources of a company may contribute to a firm’s sustainable competitive advantage(s). Differences in performance amongst firms are an outcome of heterogeneity in firm resource endowments (Akio, 2005; Barney, 1991; Lucas & Kirillova, 2011; Peteraf, 1993).

The RBV proposed that the primary determining factor of a firm’s performance is the resource possessed by the firm, and this may contribute to sustainable competitive advantages of the firm. Further, RBV distinguishes resources into two categories, one of it is resources that can be acquired externally (mostly through market factor and often shared between competitors, government policy is one of the examples) and the other one is those developed internally inside an organization (Schroeder, Bates, & Junttila, 2002). As external resource did not allow a firm to gain competitive advantage (as they are shared by competitors), internal resource is often the focus. Zhang et al. (2003) noted that some researchers (Das &

Nagendra, 1993) give special attention to manufacturing flexibility as an important internal resource. Similarly, Kuo, Li, Wang, and Ding (2006) had adopted a resource based theory, considering flexibility as a special resource of a firm, to study whether flexibility can effectively lessen the impacts caused by environmental changes.

According to Gross and Raymond (1993), a resource may be defined as "*anything, tangible or intangible, that is under the control of the organization and that may be used in the pursuit of its mission*" (Gross & Raymond, 1993; Ray, Barney, & Muhanna, 2004). They identified five main classes of resources that underpinned the flexibility approaches or strategies employed in the organization:

1. Physical resources: This class includes tools, machines, energy resources and raw materials under the firm's control;
2. Personnel resources: This covered the human resources, but goes beyond the labor capacity of available person-hours to accomplish prescribed tasks. This class of resource is uniquely distinguished as a result of human attributes (e.g. learning, social motivations, emotional requirements) that do not apply to the other factors of production;
3. Information resources: This class encompasses two subsets: those related to the collection, storage and dissemination of information and those concerning the models and tools utilized in analysis and summation of information and the support of decision making;
4. Structural resources: This class refers specifically to the design of the organization itself; where flexibility can be used to replace unfavourable procedures, specialization, task specificity, repetition and formal controls. Besides, it also

works to improve decision-making validity, reduces obsolescence and the multiple interfaces common in traditional structures; and

5. Procedural resources, that represents the management processes used in an organization and in the relationships between an organization and its environment. Efforts to simplifying firm policies and procedures should be prioritized to improve this class of resources.

According to Gross and Raymond (1993), flexibility of tangible resources helps combat randomness and obsolescence. Flexibility in intangible resources promotes *"greater validity in decision making and works against redundancy and multiple interfaces within organization"*. Therefore, flexibility is an important attribute for most of the firms' resources, and leveraging as well as its management is crucial to handle uncertainty well.

Similarly, Barney (1991) suggested classifying firm resources into three categories as shown below:

1. Physical capital resources: This category encompasses all physical technologies used in a firm, as well as its equipment, plant, geographic location, and access to raw materials;
2. Human capital resources: This category includes training, judgments, intelligences, experiences, relationship, as well as insight of individual managers/workers in a firm; and
3. Organizational capital resources: This category includes firm's formal reporting structure, its formal/informal planning, controlling and coordinating systems, other than informal relations amongst groups within and between a firm and its environment.

Barney (1991) noted that company’s resources encompass all types of assets, capabilities, organizational processes, organization attributes, information, knowledge and others that can be managed by a firm, which enable it to execute company’s strategies that lead to higher efficiency and effectiveness.

As evidence from the above descriptions, firm’s resources tend to include everything in the firm. However, not all resources in a firm are useful for generating sustained competitive advantages. When a firm is implementing a value creating strategy not concurrently implemented by both current and potential competitors, and the competitors are unable to duplicate the benefits of the strategy, the firm is said to has a sustained competitive advantage (Barney, 1991). Therefore, finding the right resource(s) that enable the sustained competitive advantage is crucial. In line with the RBV, Barney (1991) stressed the important of the four key attributes (VRIN) for a resource to be strategically important:

1. Valuable (V): Resources must provide value to the organization. Resources that are unable to deliver value to the organization are of no use.
2. Rare or Unique (R): Resources that are held by a large number of organizations cannot be translated into competitive advantage; they bring neither distinctive strategy nor strategic advantage.
3. Imperfectly imitable (I): Resources that enable long term competitive advantage are resources that are difficult to duplicate due to causal ambiguity, social complexity, or specific historical circumstances.
4. Non-substitutable (N): There is no other resource that could be used as an adequate and worthy replacement for the current resource.

Barney (1991) argued that companies that possessed resources that were rare and valuable would achieve a competitive advantage and enjoy enhanced performance in the short term. However, in order for a company to sustain these advantages over time, its resources must also be inimitable and non-substitutable.

The RBV theory has increased the importance of the manufacturing function, in general, and leveraged the importance of manufacturing flexibility, more specifically. The manufacturing function has played a significant role in the firm's quest for a competitive advantage, while manufacturing flexibility is now considered as a critical capability within the manufacturing function (Koste, 1999; Lucas & Kirillova, 2011; Rogers, 2008; Rogers et al., 2011) that providing the competency to respond quickly to shifts in market requirements.

In the context of current study, flexibility performance is critical because it is: (i) one of the important factors which determine the competitive position of the company; (ii) one of the four competitive priorities besides cost, quality and time; and (iii) one of the important capabilities that provides the firm the ability to maintain customer satisfaction, growth performance and profitability under conditions of change and uncertainty (Gupta & Somers, 1996; Hallgren, 2007; Krajewski et al., 2015; Swamidass, 2000b; Zhang et al., 2003).

Manufacturing flexibility capability is “*an organizationally embedded non-transferable firm-specific-resource”* that has the potential to influence the competitive position and the business performance of an organization (Koste & Malhotra, 2000). This ability is becoming increasingly essential to the design and operation of manufacturing systems, as these systems are urged to operate in highly volatile and ambiguous environments. Specifically, manufacturing systems must be able to respond to uncertainty due to rapid changes in volume, product mix, cost, technology and competition (Swamidass, 2000b). Empirical literature in many studies have determined that manufacturing flexibility (dimensions wise or collectively) has significant influence on firm performance, which involved both manufacturing (operational) and business performances (Chang et al., 2003; Gupta & Somers, 1996; Larso et al., 2009; Rogers, 2008; Swamidass & Newell, 1987; Zhang et al., 2003). Therefore, manufacturing flexibility creates value to the extent that it affects firm performance and this may contribute to a sustainable competitive advantage of the firm.

Manufacturing flexibility has long been recognized as a complex and multidimensional construct with a set or bundle of flexibility components (Araujo & Spring, 2002; D'Souza & Williams, 2000; Gerwin, 1993; Koste & Malhotra, 1999a; Larso et al., 2009; Lucas & Kirillova, 2011; Narasimhan & Das, 1999; Ramasesh & Jayakumar, 1991; Rogers et al., 2011; Sethi & Sethi, 1990; Shewchuk & Moodie, 1998; Suarez et al., 1996; Zhang et al., 2003). Findings from past empirical studies (Gupta & Somers, 1996; Larso et al., 2009; Narasimhan & Das, 1999) indicated that the components of manufacturing flexibility are interrelated and together supporting a single construct (Rogers et al., 2011). The bundles of manufacturing flexibility components were developed within the company’s own organizational structure and embedded within the firm’s manufacturing function, therefore they are not always visible to the competitors on how this manufacturing capability is developed and led to improved performance, i.e. they are causally ambiguous. The flexible manufacturing system with all the complementarities and interdependencies among the set of manufacturing flexibility components would be impossible to duplicate or imitate (Lucas & Kirillova, 2011).

Moreover, effective manufacturing system is developed through a firm's experience and effort over time (Chang et al., 2003). Therefore, a path-dependent process will make the manufacturing flexibility capability unique for each organization (Barney, 1991).

In addition, different types of manufacturing flexibilities have different impact on performance (Das, 2001; Larso et al., 2009). Hallgren and Olhager (2009a) found that configurations of flexibility (based on combinations of high or low levels of flexibility types) show significant differences in terms of operational performance. For this reason, the final configuration of manufacturing flexibility capability in each organization will be unique and non-substitutable depending on the particular business strategic objective (such as types of manufacturing strategies, dimensions of competitive advantages i.e., product differentiation, low cost and timing of new product/technology) and other specific attributes of the firm (such as culture, process type, managerial support, information flow, strategic integration and infrastructure) (Chang et al., 2003; Gupta & Somers, 1996; Rogers, 2008).

The use of modern technology such as fully automated systems might be possible to substitute manufacturing flexibility capability in the short term, but it is highly unlikely that such substitution could result in sustained competitive advantage as technology will become vulnerable for substitution or will become obsolete. Therefore, technological substitution is not, in and of itself, rare, inimitable, or non-substitutable, and it will be imitated (purchase the technology in the marketplace) and manufacturing flexibility capability will once again become a competitive advantage. From the above discussion, it is clear that manufacturing flexibility capability meet the criteria of RBV.

Meanwhile, manufacturing performance have been pursued ("to increase/improve" in current study) as a method to achieve higher end objective, the increment of business performance. However, the concurrently existence of relationship between "manufacturing flexibility and manufacturing performance" and "manufacturing flexibility and business performance" indicated that potential mediation relationship is foreseen between the three variables. Specifically, there are direct and indirect effect of manufacturing flexibility on manufacturing performance and business performance, which consistence with RBV theory that stated different manufacturing processes and activities within manufacturing system have different effects on firm's business performance. These outcomes of these processes and activities (manufacturing performance) have competing influences on business performance (Combs et al., 2005; Ray et al., 2004).

The second underpinning theory of this study is complementarity theory. According to Milgrom and Roberts (1995), and Rogers et al. (2011), the complementarity theory assumes that the benefits from using complementary practices are greater than the summation of benefits from using the individual practice. Specifically, complementarity theory assumes that separate manufacturing flexibility component cannot be independently fine-tuned to reach better performance (Furlan, Dal Pont, & Vinelli, 2011; Furlan, Vinelli, & Dal Pont, 2011).

That is, this approach takes a holistic view of manufacturing flexibility components and their synergistic interrelationships. Complementarity occurs when the value of one flexibility type increases in the presence of other related flexibility types compared to if it is used alone in which it may even lead to the reduction in performance. Accordingly, collective or bundle of manufacturing flexibility components works synergistically. The concept of complementarity provides an explanation for these synergistic interrelationships (Choi, Poon, & Davis, 2008; Roca-Puig et al., 2008; Roca-Puig et al., 2005; Rogers et al., 2011).

Even if manufacturing flexibility is vital to the survival of manufacturing companies, manufacturing flexibility often employed partially in an unsystematic way, which leads to less than desired benefits or may be detrimental to performance (Milgrom & Roberts, 1995; Rogers, 2008). As evidence from prior studies, (a) Based on the Pearson correlation analyses, manufacturing flexibility components were interrelated among themselves (See Table 2.14) (Gupta & Somers, 1996; Karuppan & Kepes, 2006; Larso et al., 2009; Narasimhan & Das, 1999); (b) The aggregated manufacturing flexibility measure had significant relationships with a number of performance measures (Rogers, 2008); (c) The structural equation modelling analysis carried out by Rogers et al. (2011) revealed that there was a synergistic effect when several manufacturing flexibility components were present; and (d) The stochastic mathematical programming approach by Ramasesh and Jayakumar (1991) indicated that "*different types of flexibility impact manufacturing system's performance in dissimilar ways and combinations of manufacturing flexibility components created a synergy that affects performance beyond any single component*".

Therefore, in the sense of the complementarity theory, it was the collective of manufacturing flexibility components that were considered as a valuable capability, and a bundle of flexibility types can be a source of competitive advantage. The collective or complementarity based implementation rather than competitive base implementation of manufacturing flexibility types was needed for performance excellence.

All of the above support the complementarity theory where absence of one manufacturing flexibility components decreases the improvements from the others. In the contemporary literature, however, some researchers still proposing implementing of flexibility partially rather than in a complete way (Chou, Teo, & Zheng, 2008; Muriel, Somasundaram, & Zhang, 2006). This resulted in a loss of the synergistic benefits.

Manufacturing requires multiple systems with interacting elements. The manufacturing flexibility components when considered simultaneously represent one of the systems. It is expected that when manufacturing flexibility is comprised of two or more components, a synergistic effect is created. Therefore, with aggregated manufacturing flexibility, it is expected that setup times, throughput time, scrap/rework cost, all types of inventory, unit manufacturing cost, and material cost will decrease more when compare with piecemeal implementation of manufacturing flexibility (only one or subset of manufacturing flexibility components are implemented). This situation is also applied to worker productivity, on-time delivery, and machine utilization, where increments offered by aggregated manufacturing flexibility provided better results than subset of manufacturing flexibility components.

In sum, the complementary nature of the manufacturing flexibility components implies that manufacturing system that practices full flexibility should perform better than manufacturing system that implements partial flexibility. Therefore, manufacturing flexibility should be implemented holistically and comprehensively, not individually or partially, so that firm's manufacturing performance will be significantly improved, which in turn, lead to superior business performance (Combs et al., 2005; Rogers et al., 2011).

The collaboration between manufacturing flexibility and the integrated approach of the theories namely, RBV and complementarity, will boost up the firms' performance; While RBV theory also served as the pinning point to support the existence of mediation effect within the three variables (Combs et al., 2005; Ray et al., 2004). In the view of RBV theory, manufacturing flexibility is the resource to achieve superiority of manufacturing performance while manufacturing performance served as the resource to achieve high business performance. Therefore, potential mediating effects of manufacturing performance is expected.

3.3 Theoretical Framework and Hypotheses

Literature reviews as discussed in Chapter 2 lead to a theoretical research framework as displayed in Figure 3.1 below. A mediation model was proposed that includes manufacturing flexibility as the independent variable, manufacturing performance as the mediating variable and business performance as the dependent variable. In detail, the research framework suggests that manufacturing flexibility has direct impact on manufacturing performance (Path a). Meanwhile, manufacturing flexibility has both direct impact and indirect impact on business performance through manufacturing performance as the mediating variable (Path c for direct impact and Path ab for indirect impact).

Specifically in this research, manufacturing flexibility is referred as the overall capability of the manufacturing system to response to changes (whether external and internal) (Rogers, 2008; Shewchuk & Moodie, 1998). Accordingly, the measurements used in this research for manufacturing flexibility are mix flexibility, new product flexibility, labor flexibility, machine flexibility, material handling flexibility, routing flexibility and volume flexibility. Meanwhile, manufacturing performance indicators used in this study are product quality, cost reduction, inventory minimization, productivity and lead time reduction. Whereas business performance indicators are profitability, customer satisfaction and product market performance. This proposed framework is also in line with suggested framework presented by Swamidass (2000a)'s "*Encyclopedia of Production and Manufacturing Management*", where aggregate manufacturing flexibility is expected to influence lead time, inventory, lot sizes, frequent new products introduction and ultimately leads to business profitability and growth.

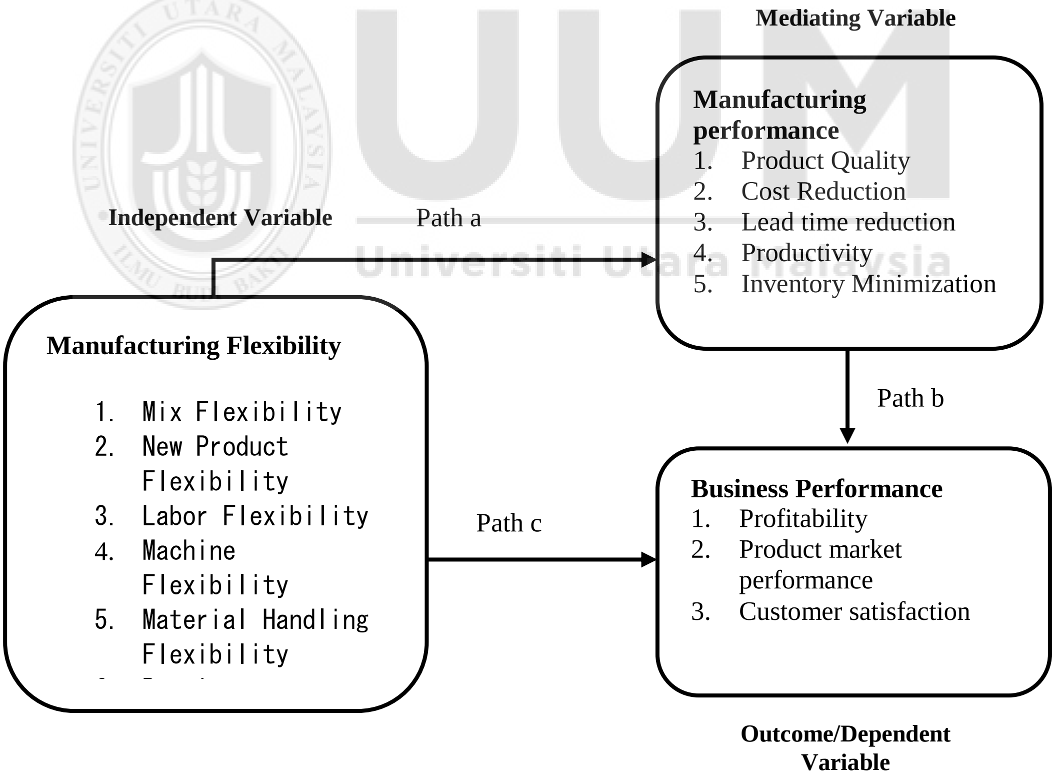

Figure 3.1
Research Framework for the Relationships between Manufacturing Flexibility and Organizational Performance

One important reason to adopt the manufacturing performance as the mediating variable is that manufacturing flexibility as a critical capability within the manufacturing function (Koste, 1999; Lucas & Kirillova, 2011; Rogers, 2008; Rogers et al., 2011), logically it should have significant effect on the outcomes of manufacturing operations, therefore, the measures of manufacturing performance are the relevant performance criterion in this scenario (Camisón & López, 2010; Vokurka & O'Leary-Kelly, 2000). Therefore, in the context of this study, simply examining the relationship between manufacturing flexibility and business or overall performance can lead to misleading conclusion, and is also not supported entirely by resource-based logic (Ray et al., 2004). Moreover, manufacturing performance is viewed as an antecedent to business performance and this is consistent with the view of Combs et al. (2005), Camisón and López (2010), Nawanir (2011) and Nawanir et al. (2013).

Research questions in Chapter 1 and discussions of literature review in Chapter 2 (Section 2.4, 2.5, 2.6 and Figure 2.2), together with the research framework as depicted in Figure 3.1 raised four important hypotheses to be tested. The main hypotheses and their specific/additional hypotheses were as follows:

Hypothesis 1:

H_1: Manufacturing flexibility has a positive relationship with manufacturing performance.

Manufacturing flexibility was hypothesized to have a positive relationship with manufacturing performance because a flexible manufacturing system is able to adapt to the changing manufacturing conditions as well as process and product requirements more effectively. This leads to the following specific hypotheses:

H_{1a}: *Manufacturing flexibility has a positive relationship with product quality.*

H_{1b}: *Manufacturing flexibility has a positive relationship with cost reduction.*

H_{1c}: *Manufacturing flexibility has a positive relationship with lead time reduction.*

H_{1d}: *Manufacturing flexibility has a positive relationship with productivity.*

H_{1e}: *Manufacturing flexibility has a positive relationship with inventory minimization.*

Hypothesis 2:

$H_{2:}$ *Manufacturing flexibility has a positive relationship with business performance.*

Manufacturing flexibility was hypothesized to have a positive relationship with business performance because manufacturing flexibility allowed an organization to adapt successfully to environmental changes such as changing of customer requirements and market conditions. This leads to the following specific hypotheses:

H_{2a}: *Manufacturing flexibility has a positive relationship with profitability.*

H_{2b}: *Manufacturing flexibility has a positive relationship with product market performance.*

H_{2c}: *Manufacturing flexibility has a positive relationship with customer satisfaction*

Hypothesis 3:

$H_{3:}$ *Manufacturing performance has a positive relationship with business performance.*

Acknowledging that the outcomes of operational performance are logical antecedents of organizational performance hence manufacturing performance was hypothesized to have a positive influence on business performance. This leads to the following specific hypotheses:

H_{3a}: Manufacturing performance has a positive relationship with profitability.

H_{3b}: Manufacturing performance has a positive relationship with product market performance.

H_{3c}: Manufacturing performance has a positive relationship with customer satisfaction

Basically, the null hypothesis predicts that the correlation between two variables is not significantly different from zero. If stated in variance terms, it predicts that the relationship explains no significant variance. The last hypothesis was:

Hypothesis 4:

$H_{4:}$ Manufacturing performance mediates the relationship between manufacturing flexibility and business performance.

This hypothesis highlights the role of manufacturing performance as a variable mediating the relationship between manufacturing flexibility and business performance. In specific, manufacturing flexibility can have direct and indirect impacts on business performance with manufacturing performance acts as the mediator. This is also consistence with RBV theory, where different manufacturing processes and activities within manufacturing system have both direct and indirect effects on firm’s business performance, where the outcomes of manufacturing processes and activities (the manufacturing performance) have direct impacts on business performance (Combs et al., 2005; Ray et al., 2004). The mediation effect of manufacturing performance proposed is also in-line with research done by Camisón and López (2010), Nawanir (2011), Nawanir et al. (2013) and Combs et al. (2005), while Vokurka and O'Leary-Kelly (2000) stressed the important of validating the impact of manufacturing flexibility towards business performance via direct and indirect relationships.

3.4 Research Design

Research design is the master blueprint that defined how researchers collect and analyse the essential information. This research adopted cross-sectional study using survey methodology where data were collected only once at the same and single point in time (Cooper & Schindler, 2013). Data were collected from selected manufacturing firms in Malaysia (listed in Malaysian Investment Development Authority (MIDA) directory and Federation of Malaysian Manufacturers (FMM) directory) using a set of structured questionnaire.

3.4.1 Population

The categories of industry investigated in the past manufacturing flexibility studies is as shown in Table 3.1. Industries such as electrical and electronic related sector, machine and equipment fabricators, chemicals and chemical products producers, food products and beverages manufacturers and also metal related products have been deem likely candidate for manufacturing flexibility researches (Gupta & Somers, 1996; Koste et al., 2004; Rogers, 2008; Zhang et al., 2003), therefore these categories of industry were the focus of this study.

Population sizes of the five manufacturing industries were obtained by combining the firms listed in the MIDA directory and the FMM directory. As per data provided by FMM and MIDA listings, the electrical and electronic industry (such as fabricator for printed circuit board, wafer, light-emitting diode (LED), electronic sensor, vacuum cleaner, battery, household electronics appliance, computer components, liquid crystal display (LCD), television, compact disc (CD), speaker, transistor, car radio, transformer and others) provided 745 firms, machine and equipment fabricator industry (such as fabricator for factory automation, automated machine, fabricator of transportation equipment, reflow oven, food processing machine, hydraulic machine, radiator, tank and container, filtration system, lifting machine, moulding and packing machines, smelting equipment, elevator, aerospace parts, medical equipment, automobile assembly and others) with 517 firms, chemicals and chemical products producers (such as soap, paint, fertilizers, pesticides and pharmaceuticals products producers) with 493 firms, food products and beverages manufacturers (such as dairy products, bakery products, soft drinks and mineral waters producers) with 500 firms and metal and metal related products (such as

Table 3.1

Industry Categories Used in Past Research

	Authors	Gupta and Somers (1996)	(Upton (1995), 1997))	Koste (1999)	Narasimhan and Das (1999)	Jack (2000)	Petroni and Bevilacqua (2002)	Zhang et al. (2003)	Chang et al. (2003)	Oke (2003)	Koste et al. (2004)	Larso (2004)	Sawhney (2006)	D'Souza (2006)	Jantan et al. (2006)	Judi and Beach (2008)	Rogers (2008)	Zhang et al. (2009)	Nassirnia and Tap (2010)	Al-jawazneh (2012)	Chauhan and Singh (2014)
Industry Categories	**Electrical & Electronics**	✓		✓	✓			✓		✓	✓	✓	✓		✓	✓	✓	✓			
	Machinery and Machines	✓		✓	✓	✓	✓	✓	✓		✓			✓			✓	✓			✓
	Metal and Metal Products	✓		✓				✓			✓			✓			✓	✓			✓
	Chemical and chemical products				✓									✓			✓			✓	
	Food Products and Beverages									✓				✓			✓				
	Transportation							✓									✓	✓			
	Plastic and Rubber																✓				
	Paper, Wood & Allied Products		✓																		
	Textiles & Textile Products																		✓		

Remark: Sort descending based on industry's frequency chassis fabrication, car spare parts fabricator, finishing services, fabricator for door frame and structural steels, aluminium products, machines parts, jig and fixture, machining parts, copper wire, metal furniture, stamping parts, mould, screw, plate and die, pipe, tin can, spring, compressor and others) provided 910 samples with the sum of 3165 firms as the sampling frame.

The sum of 3165 samples represent more than 80 percent of the total manufacturing firms registered with MIDA and FMM (3165 out of 3943) and deem representable. Table 3.2 below showed the detail composition of the sampling frame.

Table 3.2
Detail Composition of Sampling Frame

Industry Categories	**Population**	**%**	**Stratum Size (n=1000)**
Metal and Metal Products	910	28.8%	288
Electrical & Electronics	745	23.5%	235
Machinery & Equipment	517	16.3%	163
Chemicals and Chemical Products	493	15.6%	156
Food Products and Beverages	500	15.8%	158
SUM	3165	100.0%	1000

According to Sekaran and Bougie (2013), sample size is preferred to be at least 5 times more than the number of independent variables in the relationship study. Sample size larger than 30 but not more than 500 is appropriate for most of the researches. Sample size larger than 500 is not desirable as statistical significance can be identified even with only weak relationships (correlation of 0.10 or less) exist among them.

Based on the generalized scientific guideline for sample size decisions for a given population size as provided by Sekaran and Bougie (2013) and Dillman, Smyth, and Christian (2014), the suggested sample size for this study is about 340 firms.

However, the minimum number of sample size required for a study also depend upon the type of research conducted, complexity of the research model and technique of analysis employed (Hair, Black, Babin, & Anderson, 2013; Sekaran & Bougie, 2013). For example, in multiple regression analysis, Hair et al. (2013) have suggested minimum ratio of samples to independent variable of 5:1, with more desirable level at 15 to 20 samples for each independent variable. In the current study with manufacturing flexibility consist of seven independent variables, 105 to 140 samples is sufficient for regression analysis while correlation can be done with a sample size as minimum as 30 (Hair et al., 2013; Sekaran & Bougie, 2013).

On the view point of factor analysis to establish construct validity (Hair et al., 2013; Sekaran & Bougie, 2013; Zikmund et al., 2013), the manufacturing flexibility construct which has the most number of items (i.e. 40 items) compare with others construct in this study, with minimum 5 samples per item and preferable 10 samples per item as suggested by Hair et al. (2013), the required sample size will range from 200 to as large as 400 samples. However, the usage of a sample size as high as 400 is not advisable as difficulty to obtain sufficient samples will be too high to be considered manageable (Dillman et al., 2014).

To overcome the problem of limited sample size, another approach used by past studies (for instance: in manufacturing flexibility by Koste (1999), in total quality management by Zwain, Lim, and Othman (2012) and in lean manufacturing by Nawanir et al. (2013)) to establish construct validity of each critical dimension is by factor analyzing the measurement items for each of the critical dimensions separately. If the items used to measure specific critical dimension formed a single factor, it provides tentative evidence of construct validity as well as unidimensionality for that particular critical dimension (Nawanir et al., 2013; Zwain et al., 2012). Taking into account the number of items used to measure specific critical dimension (maximum 7 items), the required sample size is 35 to 70 samples. Therefore, the minimum sample size for this study was determined at 105 and seems to be justified.

Considering the above discussion as well as the resource constraints, the conditions for the multivariate analysis and the possible return of incomplete questionnaires, questionnaires have been sent to 1000 firms, which are selected using proportional stratified random sampling performed on the five types of industry. Proportional stratified random sampling was selected to minimizing sample selection bias. This technique helps researcher to obtain a sample population that best represents the entire population being studied while ensuring certain sections of the population are not over-represented or under-represented (Sekaran & Bougie, 2013).

3.4.2 Sampling Design

This study was conducted in the manufacturing sector in Malaysia in uncontrolled, natural environments. It was a field study that examines the interrelationship between the variables of interest. The survey data were collected through printed questionnaires that were distributed to the respondents who possess adequate knowledge on manufacturing flexibility and firm’s performance data in order to complete the research questionnaire. Since this information is accessible by executive management, therefore production managers, director of production/manufacturing or the head of production/manufacturing department were the targeted respondents.

This research was a cross-sectional study in which data were collected only once. Unit of analysis of current study was manufacturing plant. Manufacturing plant was chosen as unit of analysis because of it is anticipated to reflect certain degree of all of the seven manufacturing flexibility components encompassed in this research (Koste et al., 2004). Meanwhile, analysis at level of manufacturing plant was also consistent with the previous empirical manufacturing flexibility researches (Koste et al., 2004; Larso, 2004; Larso et al., 2009; Suarez et al., 1996; Upton, 1997).

3.4.3 Method of Data Collection

Mail-based survey approach was employed to collect the data required for this study. This method was chosen because it allowed "*large amounts of information to be collected from a large number of respondents in a short period of time in a relatively cost effective way"* (Dooley, 2001; Sekaran & Bougie, 2013). The actual data collection began early December 2015 (refer Appendix D for "Letter for Data Collection and Research Work" and Appendix E for "Survey Questionnaire"). Each firm was given two weeks to complete and return the questionnaire by mail with a stamped envelope that had been prepared in advance. After 2 weeks of initial mailing, a reminder letter with a fresh copy of the questionnaire was mailed to the non-response firms in an attempt to increase the response rate.

3.4.4 Operational Definition and Measurement Instrument

In this section, operational definitions and measurements of the study's variables are provided. Specifically, there are three main constructs involved in this study; they are manufacturing flexibility, manufacturing performance and business performance. As all the constructs are multidimensional, each of the dimensions are measured using multiple item measures (Koste, 1999; Nawanir et al., 2013; Rogers, 2008; Santos & Brito, 2012).

As mentioned earlier, questionnaire approach was used to collect the required information for this study. In this research, the main questionnaire consists of four main sections. Section One includes mixture of open-ended and closed-ended questions regarding background information of the targeted firm, which included the nature of business, type of ownership, products manufactured, type of process and number of employees. "Product(s) manufactured" was used as a control item to ensure the respondent correctly identify the firm's industry group. Besides, respondents' profiles such as position in the firm, tenant with the firm (length of service) and years holding the managerial position in the firm were also collected and served as control measures to ensure that the correct respondent with adequate knowledge and experience was filling in the questionnaire.

Section Two includes questions about current practices of manufacturing flexibility components within the firm's manufacturing system. Section Three includes questions about the manufacturing performance of the firm, and Section Four covers questions about the firm's business performance. In order to reduce the influence of temporary fluctuations of performance, manufacturing performance and business performance were measured based on the performance achieved by the firm over the past three years (Nawanir, 2011).

Six point Likert scale was used for section two, three and four. The scale consists of a set of the six-point scale descriptors that represent level of agreement from strongly disagree (1), disagree (2), somewhat disagree (3); somewhat agree (4); agree (5) and strongly agree (6). The researcher favoured to use six-point Likert scale because the usage of Likert scale without the choice of “neutral” will encourage the respondents to give a firm answer (Grandzol & Gershon, 1998). With the respondent being the executive management of the organization, they should have adequate knowledge to answer the questions (Grandzol & Gershon, 1998; Krosnick, 1999).

The independent variable in this study was manufacturing flexibility (MF). Meanwhile the dependent variable was manufacturing performance (MP) and also business performance (BP). Manufacturing performance (MP) was also considered as a mediating (intervening) variable consistent with the theoretical framework. The measurements of the study’s variables were rated by using the perceptual scale (Hair et al., 2013; Zikmund et al., 2013).

The following sub-sections will present the operationalization of the three constructs.

3.4.4.1 Manufacturing Flexibility

A review of prior studies on manufacturing flexibility had been presented in Chapter 2. Variation in the ways of measuring the construct of manufacturing flexibility is noticeable. With the aim to capture the core elements of manufacturing flexibility, instruments were developed based on the core elements of manufacturing flexibility as conceptualized and tested in preceding manufacturing flexibility literature (Al-jawazneh, 2012; Gupta & Somers, 1996; Koste, 1999; Rogers, 2008; Rogers et al., 2011; Sethi & Sethi, 1990; Slack, 2005; Upton, 1995).

Manufacturing flexibility components refer to the characteristics of a manufacturing system that increase the system's ability to response to changes whether internally or externally. Based on the discussion in Chapter 2, the manufacturing flexibility components focused in this study were (1) mix flexibility; (2) new product flexibility; (3) labor flexibility; (4) machine flexibility; (5) material handling flexibility; (6) routing flexibility; (7) volume flexibility. In this study, there were two characteristics emphasized as the manufacturing flexibility measurements. The first was the range of states a system can adopt, and the second was the mobility or the ease (cost or time) to move from one state to another (Gupta & Buzacott, 1989; Slack, 1983). These characteristics were chosen because they were the most common measurement approach in practice (Judi & Beach, 2008).

The specific dimensions of manufacturing flexibility are discussed in the following subsections.

3.4.4.1.1 Mix Flexibility

Mix flexibility is an important aspect of manufacturing flexibility exercised by the organization that seek to achieve long-term competitive advantage in the ever changing customer requirement (Koste, 1999), where mix flexibility is defined as the ability of the manufacturing system to switch between different products in the product mix (Judi & Beach, 2008).

Manufacturing systems that have high mix flexibility often able to produce a number of different types of product at the same time (extensive in product variation) and product mix can be changed economically, quickly, easily without major changeovers (Al-jawazneh, 2012; Dixon, 1992; Judi & Beach, 2008; Koste, 1999; Rogers, 2008; Suarez et al., 1996; Tamayo-Torres et al., 2011). Mix flexibility was operationalized into (5) questions for its measurement and sources where the items were adapted or adopted were presented in Appendix C1.

3.4.4.1.2 New Product Flexibility

New product flexibility is defined as the ability of the manufacturing system to incorporate new product into the existing range of products (Dixon, 1992; Gupta & Somers, 1992, 1996; Judi & Beach, 2008; Koste, 1999; Sethi & Sethi, 1990). This facet of manufacturing flexibility is important to fulfill the demand for new product at the market place.

Organization with high new product flexibility frequently introduces new products into the production line and incorporates them into production scheduled easily, where they fit into existing products range quickly without involving major changeovers. Besides, having good capability in handling customer request for design changes also indicated good new product flexibility rating (Chang et al., 2002; Das, 2001; Dixon, 1992; Gupta & Somers, 1992, 1996; Judi & Beach, 2008; Koste, 1999;

Rogers, 2008; Rogers et al., 2011; Sethi & Sethi, 1990). New product flexibility was operationalized into (5) questions for its measurement as shown in Appendix C1.

3.4.4.1.3 Labor Flexibility

Labor flexibility is "*the ability of production workers to perform more than one task"* in the manufacturing system (Rogers et al., 2011). This facet of manufacturing flexibility is consider one of the most fundamental elements in manufacturing flexibility and consider as the basic building block of manufacturing flexibility (Koste & Malhotra, 1999b). However, Rogers (2008) noted that labor flexibility is a newer dimension compares with others dimensions of manufacturing flexibility, even though it have been suggested and studied in many past studies.

Specifically, a flexible workers should be able to perform or responsible for a wide variety of tasks/operations, can be assigned to another task easily and economically; can use different types of tools effectively, and they operate various type of machines or tasks that differ greatly from one another (Chang, 2004; Chauhan & Singh, 2014; Cox, 1989; Kher et al., 1999; Koste, 1999; Ramasesh & Jayakumar, 1991; Rogers, 2008). In this study, labor flexibility was operationalized into (7) questions for its measurement as shown in Appendix C1.

3.4.4.1.4 Machine Flexibility

Machine flexibility is the ability of the manufacturing machine to perform more than one operation to produce different parts or products (Al-jawazneh, 2012;

Lucas & Kirillova, 2011; Rogers et al., 2011; Sethi & Sethi, 1990). Based on the past literature, this is a popular facet of manufacturing flexibility and its importance is high and tangible in manufacturing systems (Koste et al., 2004).

Flexible machine flexibility often mean machines can execute many types of operations while equally reliable for all processes; general purpose machines is favourable at the production line, as it can be used in a numbers of operations and allowed substitution of machine when one machine is stopped (either due to failure or routine maintenance) (Al-jawazneh, 2012; Chauhan & Singh, 2014; Gupta & Somers, 1992, 1996; Hirano, 1989; Koste, 1999; Larso et al., 2009; Rogers, 2008; Russell & Taylor, 2014; Sethi & Sethi, 1990; Tamayo-Torres et al., 2011; Wahab et al., 2008). Machine flexibility was operationalized into (5) items as shown in Appendix C1.

3.4.4.1.5 Material Handling Flexibility

Material handling flexibility encompasses the ability of material handling system to handle various types of material. It is an important element in manufacturing flexibility that always linked with product quality, cost and profitability in the past literature (Al-jawazneh, 2012; Koste, 1999).

Manufacturing systems with high material handling flexibility are able to handle a wide variety of parts with material handling changeovers between parts can be done economically, quickly, easily, and reconfigurable (Al-jawazneh, 2012; Chang et al., 2003; Judi & Beach, 2008; Koste, 1999; Larso et al., 2009; Mohsen, 2010; Rogers, 2008). Material handling flexibility was operationalized into (6) items as shown in Appendix C1.

3.4.4.1.6 Routing Flexibility

Routing flexibility is defined as the ability of the manufacturing system to manufacture products through a variety of different routes (Das & Nagendra, 1993; Koste, 1999; Nishith et al., 2013; Rogers, 2008; Rogers et al., 2011; Sethi & Sethi, 1990; Zhang et al., 2003).

It was an important element in manufacturing flexibility that together with material handling flexibility, have been associated with cost and production lead time in the past literature (Pinilla & Prinz, 2003; Rogers, 2008). On the meantime, past literature have stressed the important of routing flexibility to overcome unforeseen circumstance (machine breakdown as an example) in manufacturing system (Browne et al., 1984; D'Souza & Williams, 2000; Koste & Malhotra, 1999b; Narasimhan & Das, 1999; Sethi & Sethi, 1990; Watts et al., 1993; Zhang et al., 2003).

Last but not least, high routing flexibility often means that routing path for a typical part can be routed to another machines or paths. Many different routes can be used to produce a part type and the manufacturing system has alternative routes if machines break down. On the other hand, sequence of steps in production process can be changed, part used in production has many different routes to reach the next process, which lead to ease of changes in machine visitation sequence (Al-jawazneh, 2012; D'Souza & Williams, 2000; Gerwin, 2005; Judi & Beach, 2008; Koste, 1999; Rogers, 2008; Slack, 2005; Tamayo-Torres et al., 2011; Zhang et al., 2003). Routing flexibility was operationalized into (6) items as presented in Appendix C1.

3.4.4.1.7 Volume Flexibility

Volume flexibility is the ability of the manufacturing system to alter the output volume of a manufacturing process (Carter, 1986; Judi et al., 2004; Sethi & Sethi, 1990). Volume flexibility is an important variable in manufacturing flexibility as the ability to manipulate the output is crucial to meets volatile customer demand (Agus, 2011; Slack, 2005).

High Volume flexibility often means high range of production volumes; high variation of output rates for all products; production volume that can be changed (increase or decrease) quickly and easily; and able to run various batch sizes (Al-jawazneh, 2012; Gerwin, 1993; Gupta & Somers, 1992, 1996; Judi & Beach, 2008; Koste, 1999; Larso et al., 2009; Rogers, 2008; Sethi & Sethi, 1990). Volume flexibility was operationalized into (6) items as shown in Appendix C1.

3.4.4.2 Manufacturing Performance

Manufacturing performance is an important performance measure of manufacturing flexibility, and indicated that how well the manufacturing system transformed inputs to outputs in terms of quality, cost, speed, and others (Al-jawazneh, 2012). Manufacturing performance is a multifaceted construct (Combs et al., 2005; Das, 2001; Ketokivi & Schroeder, 2004; Maltz, Shenhar, & Reilly, 2003; Santos & Brito, 2012). Based on the literature review, manufacturing performance is considered as part of the manufacturing system's internal properties which represented by quality, cost, lead time, and productivity (Combs et al., 2005; Das, 2001; Ketokivi & Schroeder, 2004; Khanchanapong et al., 2014; Nawanir et al., 2013).

Accordingly, this study examined manufacturing performance from the perception of senior-level managers in the dimensions of product quality, cost reduction, lead time reduction, productivity and inventory minimization. The following sections discussed the specific dimensions of manufacturing performance.

3.4.4.2.1 Product Quality

Product design results in design specifications that determined the desired quality. Once the product design has been decided, the manufacturer perceives quality of conformance to be how effectively the manufacturing operations are able to conform to the specifications required by the design. In this study, product quality reflects an outcome performance of the firm's manufacturing activities to produce products that meets the quality specifications required by the design (Combs et al., 2005; Russell & Taylor, 2014). Product quality as a key dimension of manufacturing performance was operationalized into (5) questions as presented in Appendix C2.

3.4.4.2.2 Cost Reduction

Global competition has intensified pressure on manufacturing plants to improve cost performance (Khanchanapong et al., 2014; Narasimhan & Das, 1999). Most firms today, therefore, require manufacturing and total cost reduction as a component of continuous improvement. Manufacturing costs are the costs incurred during the production of a product. These costs include the costs of direct material, direct labor, and manufacturing overhead. Obviously, inventory is also an obvious candidate for cost reduction. Operations management literature reviews (Heizer & Render, 2013; Nawanir et al., 2013; Russell & Taylor, 2014) have showed that the most frequently used measures of cost performance are unit manufacturing cost, inventory cost and quality cost (cost associated with poor quality products). Therefore, cost reduction as manufacturing performance dimension was operationalized into (6) questions as shown in Appendix C2.

3.4.4.2.3 Lead Time Reduction

Lead time in manufacturer point of view is the time from placing of an order to actually receipt of goods ordered (Alad & Deshpande, 2014). It is also referred to throughput time by some authors (Johnson, 2003; Nawanir et al., 2013). In general, lead time consists of the following four elements (Cheng & Podolsky, 1993; Fullerton & McWatters, 2001; Heizer & Render, 2013; Russell & Taylor, 2014):

a) Setup time: The time use for preparing machines, materials and work centers for subsequent processes.
b) Processing time: The time needed to perform the value added processes.
c) Waiting time: The time waiting for the parts/components/raw materials to be moved to the next operation/station.
d) Moving time: The time needed for transportation from/to warehouses or between workstations.

Shorter lead time is important for customer satisfaction (Alad & Deshpande, 2014), and hence, competitive advantage (Nawanir, 2011). Lead time reduction will allow a firm to react swiftly to customer requirement solely by reducing the time needed to fabricate products and having them accessible to customers as soon as possible (Cheng & Podolsky, 1993). This dimension of manufacturing performance was operationalized into (6) questions as shown in Appendix C2.

3.4.4.2.4 Productivity

The most common measure of competitiveness is productivity (Russell & Taylor, 2014). In general, productivity has always been defined as the ratio of units of outputs to units of inputs, i.e. the relationship between the output of the manufacturing system and the input resources utilized (Heizer & Render, 2013; Sahar Sauian, 2002). In the manufacturing context, output can be expresses in units or dollars of products produced. Input may include human, equipment, material, capital, and overhead.

Productivity improvement can be achieved in several ways (Russell & Taylor, 2014): (1) Become more efficient – output increases with little or no increases in input; (2) Expand – both output and input grows with output growing more rapidly; (3) Achieve breakthroughs – output increases while input decreases; (4) Downsize – output remains the same and input is reduced; and (5) Retrench – both output and input decreases, with input decreasing at a faster rate. Productivity in the current study was operationalized into (5) questions as presented in Appendix C2.

3.4.4.2.5 Inventory Minimization

One way of competing in today's diverse business environment is to reduce prices through reduced inventory costs (Russell & Taylor, 2014). In the manufacturing context, inventory can take on several forms, including (1) finished goods inventory; (2) raw material inventory; and (3) work in process inventory.

However, too much inventory creates a financial liability, consumes physical space, and increases the possibility of loss and damage. Moreover, excessive inventory are often linked to unsystematic and inefficient management, poor forecasting, haphazard scheduling, and inadequate attention to operation and procedures. Therefore, it is important to reduce the total inventory cost by reducing inventory. Overproduction also indicate that a large amount of finished goods inventory is required to satisfy demand (Russell & Taylor, 2014; Waters, 2003). In this study, inventory minimization was operationalized into (5) questions (refer Appendix C2 for detail).

3.4.4.3 Business Performance

For business performance, many studies are using single indicator and treat this concept as unidimensional, even while admitting its multidimensionality (Miller et al., 2013). Distinct from manufacturing performance (operational performance), business performance (organizational performance) is different facet of firm performance (Combs et al., 2005; Nawanir, 2011; Nawanir et al., 2013; Santos & Brito, 2012; Venkatraman & Ramanujam, 1986). In this study, business performance is defined as the outcomes attributed to the interaction amongst all value-creating activities and the firm's environment, which includes economic properties such as profitability, product market performance and customer satisfaction. Subjective measurement was used to reduce the barrier for researcher to gather performance data due to sensitivity and confidentiality (Anand & Ward, 2004; Carr & Kaynak, 2007; Santos & Brito, 2012). Moreover, measurement of performance must take into account on heterogeneity of environments, firm characteristics, practices and strategies. Subjective measurements are more appropriate for cross-industry studies (Richard et al., 2009). Next sections discussed about the specific dimensions of business performance.

3.4.4.3.1 Profitability

Profit making is the main goal of a business firm. The concept of profitability is widely measured by using revenue growth and return on investment (Finch, 2008; Santos & Brito, 2012). Firm with higher revenue growth designates a more profitable firm as a higher surplus of revenues over expenses denotes making more profit (Carton & Hofer, 2006). Return on investment indicates how efficient management is at using their assets to generate earnings (Finch, 2008). Profitability in the current study was operationalized into (4) questions as shown in Appendix C3.

3.4.4.3.2 Product Market Performance

Product market performance is referred as firm's products performance in the market which can be measured through market share, sales and market share growth (Richard et al., 2009). In the present study, the (3) indicators for product market performance were presented in Appendix C3.

3.4.4.3.3 Customer Satisfaction

Customer satisfaction is the degree to which customers perceive that they received products that worth more than the price they paid (Tracey, 1996; Zhang et al., 2003). Satisfaction increases as the firm builds capabilities (e.g. manufacturing flexibility) that provide value to customers. From the stakeholder perspective (using the customer as stakeholder perspective), customer satisfaction is also an outcome and thus part of firm’s business performance (Santos & Brito, 2012). Stakeholders are group or individual that are affected by the success of the firm’s objectives and customer can be treated as one of them since they have a direct exchange relationship with the firm (Freeman, 2010).

The use of customer satisfaction as indicator of firm’s business performance was also adopted by numerous authors (Camisón & López, 2010; Kaplan & Norton, 2005; Nawanir, 2011; Richard et al., 2009; Santos & Brito, 2012; Tracey, 1996; Venkatraman & Ramanujam, 1986). Literature reviews (Anderson et al., 1994; Aranda, 2003; Koufteros, 1995; Nawanir, 2011; Powers & Jack, 2008; Santos & Brito, 2012; Schroeder, Anderson, & Cleveland, 1986; Tracey, Vonderembse, & Lim, 1999; Tracey, 1996; White, 1996) indicated that quality of products, delivery performance, number of customer complaints, and the ability to respond to customer changing needs as the commonly used measures for customer satisfaction. In this study, the (5) indicators for customer satisfaction were as shown in Appendix C3.

3.4.5 Pre-Test of Questionnaire

Face validity examining whether the items that are intended to measure a concept, on the face of them, reads as if they truly measure what they are supposed to measure (Sekaran & Bougie, 2013). Content validity is referring to whether the measures included are adequate and representative to tap the concept of interest (Sekaran & Bougie, 2013). In order to warrant the face validity, content validity, as well as readability and conciseness of the questionnaire, the instrument in the questionnaire was pre-tested and reviewed by three academicians from the field of operations management and three industry practitioners. Specifically, the following aspects of the questionnaire are examined in the pre-test:

1. The appropriateness of questions being asked.
2. Clarity of the questions and questions easy to understand.
3. Whether there are any additional questions that need to be included in the survey.

The advice and criticism from the pre-test were used to modify (adding, editing and deleting of measurement items) and improve the questionnaire. Important comments and theirs resolutions are presented in Table 3.3.

Table 3.3
Pre-Test Comments and Resolutions

Comments	**Resolutions**
Doubt of confidentiality.	Addressed the confidentiality in the questionnaire and restressed in the official letter sending to the respondents.
Suggest to include supply chain related components.	Out of the scope of this research as manufacturing flexibility is defined as flexibility of the manufacturing system which is one of the internal functions of the firm.
Minor typo and clean up.	Edited as per suggestions.
Expanding the range of working years.	Done as per suggested.

3.5 Techniques of Data Analysis

For the purpose of data analyses, the Statistical Package for the Social Sciences (SPSS) version 22.0 was employed. Data collected was analyzed using descriptive analysis, where the percentage and the mean value for specific variable(s) were calculated. In addition, correlation analysis, regression analysis and mediation test were conducted to investigate the relationship between the variables of interest (i.e. manufacturing flexibility, manufacturing performance and business performance). Besides, the hypotheses developed for this study were tested. Detail descriptions of each of the analytical methods are presented in the following subsections.

3.5.1 Descriptive Analysis

Descriptive analysis is performed to describe the *"phenomena of interest"* (Sekaran & Bougie, 2013). It leads to summarization of data in a meaningful way. For this study, data was examined statistically in terms of how frequent certain phenomena take place. Besides, the mean (or average) and the standard deviation were calculated. In this study, descriptive analyses were performed on respondents' background information, manufacturing flexibility capabilities and performance measures.

3.5.2 Pearson Correlation Analysis

Correlation analysis is used to examine the association between two variables in a study i.e. how a variable relates to another variable (Cooper & Schindler, 2013).

By applying this analysis method, the direction and significance of the bivariate relationship of the variables investigated can be determined (Sekaran & Bougie, 2013). This analysis tests the null hypothesis that the sample correlation coefficient (r) between the two variables does not differ significantly from zero.

In this study, Pearson correlation analyses were conducted to assess the association among the manufacturing flexibility components, between manufacturing flexibility components and manufacturing performance measures, between manufacturing flexibility components and business performance measures, among manufacturing performance measures, among business performance measures and between manufacturing performance measures and business performance measures.

3.5.3 Regression Analysis

According to Sekaran and Bougie (2013), although correlation coefficient r indicates the strength of the relationship between any two variables, however, it does not tell how much variation in the dependent variable being explained by multiple independent variables which are hypothesized to concurrently affect it.

Subsequently, multiple regression analysis was carried out with the aimed to measure the simultaneous effects of multiple independent variables on a single dependent variable (Cooper & Schindler, 2013; Sekaran & Bougie, 2013). The regression analysis may provide further understanding and information about the relationships among the variables (Cooper & Schindler, 2013). This analysis tests the null hypothesis that the amount of variation in the dependent variable explained by the regression model (R^2) does not differ significantly from zero.

In this study, regression analyses were employed to assess the relationship between manufacturing flexibility components (independent variables) and each manufacturing performance measure (dependent variables), between manufacturing flexibility components (independent variables) and each business performance measure (dependent variables), and between manufacturing performance measures (independent variables) and each business performance measure (dependent variables). In other words, the analyses determine the contribution of manufacturing flexibility components to both manufacturing performance measures and business performance measures and also the contribution of manufacturing performance measures to business performance measures.

In addition, principal components analysis and simple regression were applied to handle the multicollinearity problems that existed among the independent variables in the multiple regression models. Specifically, one simple regression model was developed to measure the contribution of manufacturing flexibility components (collectively) to each manufacturing performance measure, while the second simple regression model was developed to find out the contribution of manufacturing flexibility components (collectively) to each business performance measure. Meanwhile, another simple regression model was developed to determine the contribution of manufacturing performance measures (collectively) to each business performance measure.

3.5.4 Mediation Test

This study also intended to investigate the interrelationship between manufacturing flexibility, manufacturing performance and business performance. To examine the mediating roles of manufacturing performance, the procedure as proposed by Baron and Kenny (1986) was adopted.

In supplement to Baron and Kenny (1986) method, bootstrapping was also used to test the significance of the mediating effect and confirming the mediation relationship (Hayes, 2009). Past researches shown that bootstrapping is one of the powerful tools to test mediating variable effects (Biesanz, Falk, & Savalei, 2010; Hayes, 2009; Hayes & Scharkow, 2013). Bootstrapping makes inference based on an estimate of the indirect effect itself and makes no assumptions about the shape of the sampling distribution of the indirect effect. Besides, standard error for the indirect effect is not needed to make the inference, eliminating the argument on the best way to estimate the standard error. Additionally, bootstrapping is a very general method that can be used to test the indirect effects in any mediating variable model, even if the model is complex with numerous paths between the dependent variable and the independent variable. The bootstrapping method provides indirect effect estimates and confidence intervals to allow researchers to assess the significance or non-significance of a mediation effect (Biesanz et al., 2010; Hayes, 2009; Hayes & Scharkow, 2013; Ng & Lin, 2016; Preacher & Kelley, 2011). For testing the mediation effect, Hayes and Scharkow (2013) provided a macro with the name "PROCESS", which is available at www.processmacro.org that calculates bootstrapping directly within SPSS.

3.6 Summary

The underpinning theories, the theoretical framework and the methodology were presented in this chapter and are used to achieve the research objectives established in Chapter 1. The next chapter will present the results of data analyses and findings of this study.

CHAPTER 4

RESEARCH FINDINGS

4.1 Introduction

The chapter contains the results of data analyses and hypothesis testing. These encompassed information regarding variables involved in this study, results of data screening, detailed profile of the respondent and also hypothesis testing of current research, where Pearson correlation analysis, principal component analysis and regression analysis are carried out using software such as SPSS 22.0 and Statgraphics XVII. As a final point, a summary of the research findings is presented.

4.2 Data Description

The population of this study comprised of manufacturing firms in Malaysia encompassed industries such as electrical and electronic related sector, machine and equipment fabricators, chemicals and chemical products producers, food products and beverages manufacturers and also metal related products. 3165 manufacturing firms are listed as population of the study and 1000 firms have been selected as samples following a stratified random sampling method. Questionnaires were sent to the executive management (i.e. production manager or production director) of the selected firms starting on 6 December 2015. After three months, 181 questionnaires were returned. After discarding the incomplete questionnaire (24 questionnaires with too many missing values, 12 unanswered questionnaires (refuse to participate, shifted, retoured or unknown reason)) and 2 unusable questionnaires (inappropriate respondents), 143 usable questionnaires were obtained (effective response rate of

14.30%). The 143 samples fulfilled the minimum sample size required for current study (143>105).

4.3 Data Screening

Outlier refers to observation that is substantially different from other observations on one or more characteristic(s)/variable(s). Typically, it is judged unusually high or low value on a variable, or a unique combination of values across several variables in the data. Therefore, extreme outliers may affect the mean, standard deviation and the normality of the data. Because of this, outliers must be removed from the data set. According to Hair et al. (2013), outliers can be identified from the univariate, bivariate and multivariate perspective based on the number of variables/constructs considered. The purpose of data screening was to identify outliers from the data to ensure that the data obtained is suitable for further analyses (where chances of bad data or the need for robust statistical techniques can be ruled out). Screening of outliers ensures that the normality assumption is fulfilled before further analyses are carried out. Hence, this section examines the outlier for all the variables under study from the three perspectives.

4.3.1 Univariate Outlier

Univariate outliers of all the variables in the study have been identified individually. Box plots have been used to assess the cases falling at the outer ranges (high or low) of the distribution, where value with 1.5 box-lengths extended from the edge of the box is considered as outlier while extreme outlier is value that are 3 box-lengths away from the edge of the box (Pallant, 2013). Table 4.1 exhibits the outliers from the univariate perspective.

Table 4.1
Summary of Univariate Outliers (n = 143)

No	**Variable**	**Case ID**
Manufacturing Flexibility Components		
1	Mix Flexibility (Mix)	No Case
2	New Product Flexibility (New)	No Case
3	Labor Flexibility (Labor)	No Case
4	Machine Flexibility (Mach)	127,137,138,139
5	Material Handling Flexibility (MHan)	No Case
6	Routing Flexibility (Rou)	5,10,36,61,124,127,137,138
7	Volume Flexibility (Vol)	No Case
Manufacturing Performance Measures		
1	Product Quality (Qua)	5
2	Cost Reduction (Cost)	5,9,10,61,68,84
3	Lead time reduction (Lead)	No Case
4	Productivity (Prod)	5*,9,10,16
5	Inventory Minimization (InMi)	16*,23,25,55
Business Performance Measures		
1	Profitability (Profit)	6,61,84,88
2	Product market performance (Market)	84
3	Customer satisfaction (CSatis)	No Case

Note:
*Case with extreme value

Based on Table 4.1, cases 5, 9, 10, 61, 84, 127, 137, and 138 appeared in more than a single variable. In addition, case number 5 in productivity as well as case number 16 in inventory minimization are identified as extreme outliers, which might affect the overall measures of the variable. Further investigations in both bivariate and multivariate perspective are necessary to decide whether these cases should be included in the subsequent analyses.

4.3.2 Bivariate Outlier

Scatter plots have been used to assess bivariate outlier and linearity between two variables i.e., manufacturing flexibility components against manufacturing performance measures, manufacturing flexibility components against business performance measures, and manufacturing performance measures against business performance measures (Hair et al., 2013).

Linearity of the bivariate data can be assessed by looking at the scatter plot where positive related data will show that high score in one variable is associated with high score on the other variable, and vice versa on negative related data, where high score in one variable is associated with low score on the other variable (Hair et al., 2013). A summary of visual identification of bivariate outliers from 105 scatter plots are depicted in Table 4.2, where cases 16, 5, 23, 9, 10 and 99 registered high frequency of appearance. Hence, these cases may become outliers in this study. Ignoring the effect of some of the outliers, all scatter plots have shown linear relationship(s) between the pairing variables being examined, where linearity can be assured.

According to Hair et al. (2013), due to the nature of multivariate analyses that involved more than two variables, bivariate perspective alone is inadequate to ascertain whether or not the cases are outliers. Subsequent diagnostic from the multivariate perspective is needed and is presented in the following section.

Table 4.2

Summary of Bivariate Outliers (n = 143)

Independent Variable vs. Dependent Variable	**Case ID**
MeanMix vs. MeanNew	80,81,82,83
MeanMix vs. MeanMHan	51, 57
MeanMix vs. MeanProd	5,9,10
MeanMix vs. MeanInMi	16,23
MeanNew vs. MeanLabor	80,81,83,16
MeanNew vs. MeanMach	80
MeanNew vs. MeanMHan	80,81
MeanNew vs. MeanQua	99,81
MeanNew vs. MeanProd	5,9,10
MeanNew vs. MeanProfit	80,81
MeanNew vs. MeanMarket	80,81
MeanNew vs. MeanCSatis	81
MeanLabor vs. MeanMach	16,23
MeanLabor vs. MeanMHan	99
MeanLabor vs. MeanRou	16,23
MeanLabor vs. MeanVol	99
MeanLabor vs. MeanQua	99
MeanLabor vs. MeanCost	99,5,9,10
MeanLabor vs. MeanLead	99
MeanLabor vs. MeanProd	5,9,10,16,23
MeanLabor vs. MeanInMi	16,23
MeanLabor vs. MeanProfit	99
MeanLabor vs. MeanMarket	99,84
MeanLabor vs. MeanCSatis	99
MeanMach vs. MeanMHan	27,138,124,127
MeanMach vs. MeanVol	99,101
MeanMach vs. MeanQua	99,101,16,23
MeanMach vs. MeanCost	99,101,16
MeanMach vs. MeanLead	36,127,137
MeanMach vs. MeanProd	5,9,10
MeanMach vs. MeanProfit	99,101,84,88
MeanMach vs. MeanMarket	99,84,101
MeanMach vs. MeanCSatis	99,16,23
MeanMHan vs. MeanQua	46
MeanMHan vs. MeanCost	51,57
MeanMHan vs. MeanInMi	16,23
MeanRou vs. MeanQua	23,16
MeanRou vs. MeanInMi	16,5
MeanRou vs. MeanProfit	84,88
MeanRou vs. MeanMarket	84
MeanRou vs. MeanCSatis	16,23

Table 4.2 (Continued)

Independent Variable vs. Dependent Variable	Case ID
MeanVol vs. MeanQua	9,5,10
MeanVol vs. MeanCost	9,5,10
MeanVol vs. MeanProd	5,9,10
MeanVol vs. MeanInMi	16,23
MeanVol vs. MeanCSatis	69,57
MeanQua vs. MeanLead	5,9,10
MeanQua vs. MeanProd	16,23
MeanQua vs. MeanInMi	16,23
MeanQua vs. MeanProfit	84,88
MeanQua vs. MeanMarket	84,5,10
MeanCost vs. MeanLead	5
MeanCost vs. MeanProd	16
MeanCost vs. MeanInMi	16,23
MeanCost vs. MeanProfit	5
MeanCost vs. MeanMarket	5,9
MeanLead vs. MeanProd	5,9,10
MeanLead vs. MeanInMi	16,23
MeanLead vs. MeanMarket	84
MeanProd vs. MeanInMi	5,9,10
MeanProd vs. MeanProfit	5,9,10
MeanProd vs. MeanMarket	5,9,10
MeanProd vs. MeanCSatis	5,9,10,16,23
MeanInMi vs. MeanProfit	16,23
MeanInMi vs. MeanMarket	16,23
MeanInMi vs. MeanCSatis	16,23
MeanMarket vs. MeanCSatis	84

Note:
Scatter plots containing no outlier are not included in this table; Outlier case ID sorted in severity (from more severe towards less severe)

4.3.3 Multivariate Outlier

In order to detect multivariate outliers, Hair et al. (2013) and Byrne (2010) have proposed the usage of Mahalanobis distance that evaluates the position of each case compared with the center of all cases on a set of variables to identify the extreme score on two or more variables (multivariate outliers). In this research, the number of variables (degree of freedom) is 15 (i.e. 7 manufacturing flexibility variables, 5 manufacturing performance variable and 3 business performance variables), which suggested that cases with Mahalanobis Distance of more than 24.996 are considered outliers (Byrne, 2010). Several cases are detected having very high Mahalanobis distance as shown in Table 4.3. In other words, in multivariate perspective there are some cases (cases 16, 84, 99, 5, 23, 2, 43, 62, 135, 104, 6, 9, 41, 42 and 11) whose Mahalanobis Distance are greater than 24.996.

Table 4.3
Summary of Multivariate Outliers (n = 143)

Case ID	**Mahalanobis Distance**
16	58.959
84	50.222
99	46.555
5	38.371
23	37.252
2	34.730
43	33.217
62	32.130
135	31.155
104	29.196
6	29.018
9	28.069
41	27.023
42	25.867
11	25.297

Table 4.4 provided the summary of outlier identification in the perspective of univariate, bivariate and multivariate. Based on Table 4.4, 6 of the 143 cases are identified as outliers, as they are those that frequently appeared on univariate, bivariate and multivariate perspectives. The 6 outlier cases are case number 16, 84, 99, 5, 23 and 9. In addition, from Table 4.4, nine other cases (case number 2, 43, 62, 135,

104, 6, 41, 42 and 11) are not considered as outliers, so they are maintained in the current data set.

Specifically, 6 cases are discarded from the subsequent analyses. Therefore, the analyses that follow and all reported statistics after this subsection are based on 137 cases (i.e. 143 - 6). The sample size of 137 cases is actually enough to be analysed in this study. In general, sample sizes larger than 30 and smaller than 500 are appropriate for most of the research (Sekaran & Bougie, 2013). Hair et al. (2006) also postulated that minimum sample size for applying correlation and multiple regression analysis is 50 and preferably 100. Moreover, 137 samples also fulfilled the desired level of 15-20 samples for each independent variable in multiple regression analysis.

Table 4.4
Results of Univariate, Bivariate and Multivariate Outlier Identification

Case ID	**Mahalanobis Distance**	**Frequency***	
		Univariate	**Bivariate**
16	58.959	2	23
84	50.222	3	9
99	46.555	0	15
5	38.371	3	19
23	37.252	1	19
2	34.730	0	0
43	33.217	0	0
62	32.130	0	0
135	31.155	0	0
104	29.196	0	0
6	29.018	0	0
9	28.069	1	15
41	27.023	0	0
42	25.867	0	0
11	25.297	0	0

Notes:
Sorted based on value of Mahalanobis Distance; *Frequency of certain cases considered as outlier

4.4 Respondent Profile

Respondent firms are from five industries: the electrical and electronic related sector, machine and equipment fabricator, chemicals and chemical products producers, food products and beverages manufacturers, and also metal related products manufacturers.

According to Table 4.5, the sample provides diverse and fairly representative industrial coverage.

Table 4.5
Distribution of Population and Sample

Industry	**Population**	**%**	**Frequency**	**%**
Basic metals and fabricated metal products	910	28.8%	31	22.6%
Machinery & Equipment	745	23.5%	26	19.0%
Electronic, electrical equipment and components	517	16.3%	34	24.8%
Chemicals and Chemical Products	493	15.6%	21	15.3%
Food Products and Beverages	500	15.8%	25	18.2%
Total	**3165**	**100.0%**	**137**	**100.0**

Table 4.6 describes the profile of sampled firms. Based on Table 4.6, the firm ownership distribution of the respondent firms is 48.2% private enterprises, 41.6% foreign invested enterprises, 8.0% joint venture, and 2.2% state owned enterprises. In terms of number of employees, 83.2% of the firms have more than 99 employees, 12.4% of them have a number of employees range from 50 to 99 and only 4.4% (6 cases) of them have less than 50 employees.

Table 4.6

Firm's Background Information

Firm Type	**Frequency**	**Percent**
State owned enterprise	3	2.2
Private enterprise	66	48.2
Foreign invested enterprise	57	41.6
Joint venture	11	8.0
Total	**137**	**100.0**
Workers Number	**Frequency**	**Percent**
<50 employees	6	4.4
50 – 99 employees	17	12.4
100 – 149 employees	21	15.3
150 - 199 employees	33	24.1
200 – 499 employees	31	22.6
500 employees and above	29	21.2
Total	**137**	**100.0**
Annual Sales	**Frequency**	**Percent**
Less than RM 10 million	15	10.9
RM 10 million – RM 25 million	41	29.9
More than RM 25 million to RM50 million	38	27.7
More than RM50 million	43	31.4
Total	**137**	**100.0**
Process	**Frequency**	**Percent**
Job shop	27	19.7
Batch	49	35.8
Repetitive	58	42.3
Continuous flow	1	.7
Mass Customization	2	1.5
Total	**137**	**100.0**

Annual sales of the firms according to Table 4.6 depicted that 89.1% (122 cases) of the firms have sales more than RM 10 million. Only 10.9% (15 cases) of the samples registered a sales number of less than RM 10 million. In addition, Table 4.6 also revealed the types of process used by the sampled firms, 19.7% (27 cases) of them are job shop manufacturers, while 35.8% (49 cases) using batch process, 42.3% (58 cases) using repetitive process, and only 2.2% using continuous flow process (0.7%) and mass customization process (1.5 %).

Table 4.7
Respondents' Background Information

Position	**Frequency**	**Percent**
Director of production	19	13.9
Head of production/manufacturing department	51	37.2
Manager of production/manufacturing	47	34.3
Executive Director	1	0.7
Managing Director	2	1.5
General Manager	3	2.2
Departmental Managers	12	8.8
Others	2	1.5
Total	**137**	**100.0**
Working Years	**Frequency**	**Percent**
Less than 3 years	12	8.8
3 – 5 years	24	17.5
6 – 10 years	53	38.7
More than 10 years	48	35.0
Total	**137**	**100.0**
Current Position	**Frequency**	**Percent**
Less than 1 year	1	.7
1 – 3 years	57	41.6
4 – 10 years	47	34.3
More than 10 years	32	23.4
Total	**137**	**100.0**

This study presumes that respondents are in the level of executive management in production or manufacturing area. In line with the assumption, Table 4.7 shown that the majority of respondents are the manager (45.2%), the head of department (37.2%) and the director (16.0%) in production/manufacturing area who are familiar with manufacturing activities, manufacturing performance and business performance of a particular firm. Meanwhile, the remaining 1.5% of the respondents (2 respondents out of total 137) is managerial positions with the title of management representative and quality management representative.

On the other hand, Table 4.7 also depicted that the majority of the individual respondents have been working in the company for more than three years (91.2%). Moreover, 99.3% of the respondents have been working in the current position (job tenure) for more than 1 year with 23.4% of them (32 respondents) had more than 10 years of tenure in their current position, while the remaining 0.7% (1 respondents) have held the job less than 1 year but they have been working in their company for more than 1 years. Therefore, it could be assumed that they are reasonably well-informed of their firm's practices and performance.

4.5 Construct Validity and Reliability

The importance of validity and reliability of measurement instrument have been stressed by many researchers (Cooper & Schindler, 2013; Hair et al., 2013; Sekaran & Bougie, 2013), asserting that researchers have to know the validity (do they measure what are intended to be measured) and reliability (consistency of measurement results) of their instruments. 3 types of validity generally considered are: (1) content validity; (2) criterion-related validity; (3) construct validity (Saraph, Benson, & Schroeder, 1989).

Content validity is described and supported in Chapter 3, Section 3.4.5, where the instrument in the questionnaire was pre-tested and reviewed by three academicians from the field of operations management and three industry practitioners to ensure that it was representable to tap the concept of manufacturing flexibility, manufacturing performance and business performance.

Criterion-related validity is the extent to which a measuring instrument is related to an independent measure of the relevant criterion. Specifically in this study, correlations between manufacturing flexibility components and manufacturing performance measures, correlations between manufacturing flexibility components and business performance measures, and correlations between manufacturing performance measures and business performance measures will be established to ensure that criterion-related validity are fulfilled (Saraph et al., 1989).

Construct validity is important to ensure that whatever which is concluded from a research can be shared confidently (Hair et al., 2013). Construct validity can be assessed with discriminant validity and convergent validity (Sekaran & Bougie, 2013). According to Zikmund et al. (2013), discriminant validity is referring to the uniqueness or distinctiveness of a measure. In other words, a measure should not highly correlate with another measure of different construct. While convergent validity means constructs or measures that should be related to one another are in fact related. Measures can have one of the types of construct validity and not the other.

After taking into the considering of the sample size in this study, the construct validity of each manufacturing flexibility measure, each manufacturing performance measure and each business performance measure are evaluated by factor analyzing the measurement items of each of the measures. If the items measuring the same construct formed a single factor, this can be used as tentative evidence of construct validity for that particular construct.

In factor analysis, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy test is used to assess whether the measurement items are appropriate of applying factor analysis (Hair et al., 2013). The KMO statistic varies between 0 and 1.

The value of 0 indicates that factor analysis is likely to be inappropriate and the value close to 1 indicates that patterns of correlations are relatively compact, and so factor analysis is reliable. Kaiser (1974) and Hair et al. (2013) recommended that KMO should be greater than 0.50. Whereas, Hutcheson and Sofroniou (1999) suggested the values between 0.50 and 0.70 are mediocre, values between 0.70 and 0.80 are good, values between 0.80 and 0.90 are great and values greater than 0.90 are superb. Furthermore, the Bartlett's test of sphericity test was carried out to ensure that the measurement items are correlated high enough to provide a reasonable basis for factor analysis.

Statistical summary of factor analysis performed on the variables understudy is as shown in Table 4.8 and Table 4.9, and indicated that all the KMO values are greater than 0.70 (good) except product market performance with 0.50 (mediocre). In future studies, considerations should be given to include new items to measure this construct (product market performance). Other than that, Bartlett's test of sphericity is also significant at $\alpha = 0.05$, which means there are significant correlations among at least some of the measurement items (Hair et al., 2013).

In addition, only item that has a factor loading of at least 0.70 is retained. Factor loading of 0.70 is chosen to ensure that the variance explained is more than 50% and are considered indicative of well-defined factor structure (Hair et al., 2013).

Table 4.8

Statistical Summary of Factor Analysis for Manufacturing Flexibility Components

No	**Manufacturing Flexibility Components**	**Number of Items***	**Deleted Item****	**Factor Loading for Retained Items**	**KMO**	**Eigenvalue**	**% of Variance Explained**
1	Mix Flexibility	5	-	0.804, 0.843, 0.874, 0.861, 0.922	.879	3.713	74.267
2	New Product Flexibility	5	-	0.834, 0.903, 0.881, 0.880, 0.777	.878	3.667	73.338
3	Labor Flexibility	7	1	0.750, 0.909, 0.836, 0.860, 0.856, 0.891	.891	4.354	72.565
4	Machine Flexibility	5	5	0.895, 0.844, 0.916, 0.776	.818	2.953	73.824
5	Material Handling Flexibility	6	-	0.807, 0.894, 0.921, 0.920, 0.876, 0.880	.927	4.688	78.140
6	Routing Flexibility	6	-	0.901, 0.840, 0.883, 0.855, 0.815, 0.822	.910	4.365	72.755
7	Volume Flexibility	6	1, 6	0.922. 0.907, 0.857, 0.875	.834	3.175	79.365

Notes:
*Number of item before deletion
**Sequence number based on Appendix E (questionnaire)

Table 4.9

Statistical Summary of Factor Analysis for Firm's Performance Measures

No	**Construct**	**Number of Items***	**Deleted Item****	**Factor Loading for Retained Items**	**KMO**	**Eigenvalue**	**% of Variance Explained**
Manufacturing Performance Measures							
1	Product Quality	5	-	0.879, 0.898, 0.916, 0.906, 0.920	.904	4.086	81.725
2	Cost Reduction	6	5, 6	0.873, 0.916, 0.815, 0.887	.833	3.052	76.291
3	Lead Time Reduction	6	1	0.845, 0.774, 0.874, 0.886, 0.843	.868	3.573	71.458
4	Productivity	5	-	0.890, 0.834, 0.875, 0.854, 0.893	.892	3.780	75.608
5	Inventory Minimization	5	2	0.841, 0.841, 0.922, 0.788	.798	2.886	72.160
Business Performance Measures							
1	Profitability	4	-	0.935, 0.885, 0.948, 0.913	.859	3.390	84.751
2	Product Market Performance	3	3	0.953, 0.953	.500	1.816	90.780
3	Customer Satisfaction	5	-	0.899, 0.899, 0.812, 0.862, 0.803	.883	3.664	73.281

Notes:
*Number of item before deletion
**Sequence number based on Appendix E (questionnaire)

Table 4.8 and Table 4.9 exhibited that several items that are recommended to be omitted due to factor loading less than 0.70; labor flexibility (1 item; L1, factor loading 0.67), machine flexibility (1 item; MC5, 0.66), volume flexibility (2 items; V1, 0.67 and V6, 0.59), cost reduction (2 items; CR5, 0.69 and CR6, 0.53), lead time reduction (1 item; LR1, 0.66), inventory minimization (1 item; IM2, 0.64) and product market performance (1 item; PM3, 0.68). Based on both tables, factor loadings for all retained constructs are range from 0.75 to 0.95. Taking out these items does not affect the content validity of the measures in a negative way. Moreover, all constructs have more than 50% of variance explained, where percentage of variance explained range between 71.46% and 90.78%. The above findings provide evidences to support constructs validity for all the measures employed in this study.

Reliability analysis is performed to ensure the internal consistency and stability of measurement items used to measure a construct (Roberts & Priest, 2006). The Cronbach's alpha is commonly used to assess reliability. The closer the Cronbach's alpha to 1.0, the higher the internal consistency of a construct (Hair et al., 2013; Sekaran & Bougie, 2013). The rule of thumb provided by Hair et al. (2013) suggested that alpha values greater than 0.70 as being good for testing the reliability of constructs. The results of reliability analysis for each construct are exhibited in Table 4.10. Following the above criterion, the table shows that all the values of Cronbach's alpha are greater than 0.70 (values range between 0.87 and 0.94), which indicated that internal consistency for all measures are satisfactory. In sum, the measures used in this study are considered valid and reliable.

Table 4.10

Statistical Summary of Reliability Analysis

No	**Construct**	**Number of Items**	**Cronbach's Alpha**
Manufacturing Flexibility Components			
1	Mix Flexibility	5	0.913
2	New Product Flexibility	5	0.908
3	Labor Flexibility	6	0.924
4	Machine Flexibility	4	0.874
5	Material Handling Flexibility	6	0.942
6	Routing Flexibility	6	0.924
7	Volume Flexibility	4	0.910
Manufacturing Performance Measures			
1	Product Quality	5	0.943
2	Cost Reduction	4	0.896
3	Lead Time Reduction	5	0.900
4	Productivity	5	0.918
5	Inventory Minimization	4	0.868
Business Performance Measures			
1	Profitability	4	0.939
2	Product Market Performance	2	0.898
3	Customer Satisfaction	5	0.905

4.6 Descriptive Statistics of Variables

This section discusses the descriptive statistics of manufacturing flexibility components, manufacturing performance measures and business performance measures. Minimum value, maximum value, mean and standard deviation of the data are depicted in Table 4.11. Those measurements are performed by using the perceptual scale where each question is answered using the following six-point Likert scale that represent level of agreement from strongly disagree (1), disagree (2), somewhat disagree (3); somewhat agree (4); agree (5) to strongly agree (6). The descriptive statistics depicted that mean of manufacturing flexibility components range from 3.99 to 4.46, with the standard deviation ranges between 0.72 and 0.86, which indicated that Malaysia manufacturing firms have been implementing manufacturing flexibility components in their manufacturing system, whether consciously or by coincidence. Typically, volume flexibility and routing flexibility are the two components with the highest and the lowest degree of implementation, correspondingly.

Table 4.11
Descriptive Statistics of the Variables

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Manufacturing Flexibility Components					
Mix Flexibility	137	2.000	6.000	4.438	.815
New Product Flexibility	137	2.000	6.000	4.003	.857
Labor Flexibility	137	2.500	6.000	4.320	.750
Machine Flexibility	137	2.000	5.250	4.058	.800
Material Handling Flexibility	137	3.000	6.000	4.406	.717
Routing Flexibility	137	2.000	5.670	3.989	.785
Volume Flexibility	137	2.500	6.000	4.456	.802
Manufacturing Performance Measures					
Product Quality	137	2.600	6.000	4.756	.743
Cost Reduction	137	2.250	5.750	4.219	.692
Lead Time Reduction	137	3.000	5.800	4.324	.576
Productivity	137	2.000	5.800	4.343	.694
Inventory Minimization	137	3.000	5.750	4.135	.638
Business Performance Measures					
Profitability	137	2.000	6.000	4.296	.794
Product Market Performance	137	2.000	5.000	4.040	.793
Customer Satisfaction	137	2.800	6.000	4.372	.717

On the viewpoint of firm performance, manufacturing performance measures registered mean values range from 4.14 to 4.76, with standard deviation ranging between 0.58 and 0.74. Out of the five variables, product quality has the highest mean value of all the manufacturing performance measures, while inventory minimization has the lowest. On the other hand, high mean values of business performance measures are also observed. The mean values range between 4.04 (product market performance) and 4.37 (customer satisfaction), with standard deviation ranging between 0.72 and 0.79. In general, data collected in current study has shown that firms in Malaysia registered moderate performance record (greater than 3.5) in terms of manufacturing performance and business performance.

4.7 Normality and Linearity Test

Since this study is concerned with the relationship between variables by applying correlation analysis and regression analysis, the linearity and normality requirements should be fulfilled before conducting the analyses as they are the critical assumptions of theses analysis methods (Coakes, 2013; Hair et al., 2013). In other word, before conducting the subsequent data analyses, these two assumptions should be accomplished.

4.7.1 Normality Test

Normality test is used to assess whether the data collected are normally distributed. In other words, normality test ensures that the scores for each variable are normally distributed (Coakes, 2013). This assumption of normality is required to use the F and t-statistics (Hair et al., 2013).

Normality test has been carried out for all the 15 variables (n = 137) graphically and statistically by using the normal probability plots (as depicted in Appendix F), as well as skewness and kurtosis statistics that presented in Table 4.12. In the normal probability plot, each of the observed values is matched with projected value from the normal distribution where the cumulative distribution of actual data values with the cumulative distribution of a normal distribution are compared (Hair et al., 2013). Specifically, in a normal probability plot, the normal distribution forms a straight diagonal line and the observed data values will be compared with the diagonal line. If the observed data distribution forms a straight line reasonably follows the diagonal line, the data is considered normal in terms of distribution (Box & Draper, 2007; Pallant, 2013). In this study, the distributions of all the observed variables are reasonably following the diagonal line suggesting that they are normally distributed.

In lieu of skewness and kurtosis statistics, Hair et al. (2013) and Kline (2015) highlighted that if Z-skewness and Z-kurtosis go beyond a critical value i.e. ± 2.58 at the 0.01 significance level, or ± 1.96 at the 0.05 significance level, the data is considered as not normally distributed. Positive values for skewness indicate that majority of the values from the collected data are less than the mean of the data, while negative values for skewness indicate most of the values are higher than the mean. On the other hand, positive values for kurtosis indicate a peaked distribution while negative values for kurtosis indicate a flatter distribution. Skewness and kurtosis are examined for each construct as shown in Table 4.12.

Table 4.12 reports that only three Z-skewness values are over and above the critical value of ± 2.58, i.e. Z-skewness value of the machine flexibility is - 3.70, routing flexibility at -3.10 and profitability at -2.89. Even though a few of the Z-skewness values go beyond the critical value, majority of them are below the threshold value. Besides, all of the Z-kurtosis values are lower than the threshold of +/-2.58. Therefore, the data for all three construct can be assumed to be normally distributed (Hair et al., 2013).

Table 4.12
Univariate and Multivariate Normality: Skewness and Kurtosis Statistics (n = 137)

Construct	**Skewness**			**Kurtosis**		
	Statistic	**Std. Error**	**Z**	**Statistic**	**Std. Error**	**Z**
Manufacturing Flexibility Components						
Mix Flexibility	-0.521	0.207	-2.518	0.369	0.411	0.898
New Product Flexibility	-0.307	0.207	-1.480	-0.195	0.411	-0.475
Labor Flexibility	-0.201	0.207	-0.971	-0.772	0.411	-1.877
Machine Flexibility	-0.766	0.207	-3.700	0.279	0.411	0.678
Material Handling Flexibility	0.075	0.207	0.361	-0.218	0.411	-0.531
Routing Flexibility	-0.641	0.207	-3.097	0.433	0.411	1.052
Volume Flexibility	-0.463	0.207	-2.235	0.099	0.411	0.242
Manufacturing Performance Measures						
Product Quality	-0.428	0.207	-2.067	-0.046	0.411	-0.112
Cost Reduction	-0.382	0.207	-1.844	0.036	0.411	0.088
Lead Time Reduction	-0.253	0.207	-1.222	-0.210	0.411	-0.511
Productivity	-0.297	0.207	-1.437	0.212	0.411	0.515
Inventory Minimization	0.087	0.207	0.422	-0.354	0.411	-0.861
Business Performance Measures						
Profitability	-0.599	0.207	-2.894	-0.062	0.411	-0.151
Product Market Performance	-0.336	0.207	-1.621	-0.819	0.411	-1.992
Customer Satisfaction	-0.207	0.207	-1.001	-0.446	0.411	-1.085

Overall, the assumption of normality is achieved for all the constructs, as both normality plot and also skewness and kurtosis evaluations provide supporting evidence on no serious violation of normality assumption in the data.

4.7.2 Test of Linearity

Linearity test is addressed to ensure the linear relationship between two variables. It is undertaken to see if one variable is related to another variable (Coakes, 2013). In this study, linearity assumption is examined using bivariate analysis using scatter plots that denote the relationship between manufacturing flexibility components and manufacturing performance measures, between manufacturing flexibility components and business performance measures, and between manufacturing performance measures and business performance measures. Linear relationships between variables are observed as elaborated in Section 4.3.2. Meanwhile, Pearson correlation analysis reported in the following section also provides evidence of linear relationship between the variables.

4.8 Associations between the Variables: Pearson Correlation Analysis

Pearson correlation analyses are conducted to assess the linearity and to measure the association between two variables in the study. Magnitude of the correlation coefficients range between −1 and +1, where −1 point out a perfect negative linear correlation, +1 specifies a perfect positive linear correlation, and 0 dictates no linear correlation between two variables (Hair et al., 2013). As a rule of thumb, interpretation of correlation coefficients for social science is denoted as: (a) correlation coefficients from 0.00 to 0.09 equal no correlation, (b) correlation coefficients from 0.10 to 0.29 equal low correlation, (c) correlation coefficients from 0.30 to 0.49 equal medium correlation, and (d) correlation coefficients higher than 0.50 equal the high correlation (Cohen, 1988).

4.8.1 Associations among Manufacturing Flexibility Components

Comprehensive information regarding the relationship among manufacturing flexibility components have been depicted in Table 4.13. All components are positively associated with one another and significant at $\alpha = 0.01$ with the correlation coefficient (r) values range from 0.29 to 0.79. High correlation among manufacturing flexibility components have been portrayed with the exception of relationships between mix flexibility and other components of manufacturing flexibility, which only registered a high correlation value (with machine flexibility), 5 medium correlation values with other components and a low/marginally medium correlation with new product flexibility.

These positive relationships tend to support the previous proposal that combinations of manufacturing flexibility components create synergy and the components should be implemented holistically, not individually (Camisón & López, 2010; Rogers et al., 2011). Table 4.13 also highlighted that the highest correlation is detected between material handling flexibility and labor flexibility. This may be due to the fact that most Malaysia manufacturing using material handling system that are labor intensive. In addition, significant correlation between the variables offers evidence of convergence validity for the seven components of manufacturing flexibility.

Table 4.13
Correlation among Manufacturing Flexibility Components

No	**Manufacturing Flexibility Components**	**Manufacturing Flexibility Components**						
		1	**2**	**3**	**4**	**5**	**6**	**7**
1	**Mix**	1						
2	**New Product**	.294**	1					
3	**Labor**	.424**	.549**	1				
4	**Machine**	.507**	.592**	.578**	1			
5	**Material Handling**	.425**	.562**	.788**	.596**	1		
6	**Routing**	.311**	.578**	.655**	.604**	.620**	1	
7	**Volume**	.447**	.646**	.732**	.641**	.718**	.660**	1

** Correlation is significant at the 0.01 level (2-tailed).

4.8.2 Associations between Manufacturing Flexibility Components and Manufacturing Performance Measures

One of the purposes of manufacturing flexibility is to improve some aspect of performance, especially performance of the production system (Rogers, 2008). According to Table 4.14, all of the manufacturing flexibility components are positively and significantly correlated (at α = 0.01) with all manufacturing performance measures, with r values range between 0.28 and 0.71. With most of the value of correlations fall on medium and high categories (correlation > 0.30), the correlation between manufacturing flexibility components and manufacturing performance measures can be considered substantial (Cohen, 1988).

In sum, it can be assumed that better implementation of manufacturing flexibility in the manufacturing system leads to better manufacturing performance. This result is consistent with several previous studies such as study done by Rogers

(2008) and Rogers et al. (2011). In the meantime, this finding offers evidence of criterion-related validity of manufacturing flexibility components.

Table 4.14
Correlation between Manufacturing Flexibility Components and Manufacturing Performance Measures

Manufacturing Performance Measures	**Manufacturing Flexibility Components**						
	Mix	**New**	**Labor**	**Machine**	**Material handling**	**Routing**	**Volume**
Quality	.490**	.277**	.511**	.381**	.646**	.539**	.573**
Cost Reduction	.314**	.481**	.606**	.380**	.582**	.706**	.603**
Lead Time Reduction	.473**	.567**	.576**	.365**	.641**	.519**	.577**
Productivity	.434**	.535**	.660**	.542**	.706**	.664**	.652**
Inventory Minimization	.499**	.483**	.575**	.499**	.504**	.573**	.620**

** Correlation is significant at the 0.01 level (2-tailed).

4.8.3 Associations between Manufacturing Flexibility Components and Business Performance Measures

As shown in Table 4.15, the association between manufacturing flexibility components and business performance measures are observed with r values range from 0.34 to 0.68 and significant at α = 0.01. However, when comparing information provided in Table 4.14 and Table 4.15, correlation coefficients (r) between manufacturing flexibility components and business performance measures are comparatively lower in magnitude than the correlation coefficients (r) between manufacturing flexibility components and manufacturing performance measures.

Stronger associations have been seen on the relationship between manufacturing flexibility components and manufacturing performance measures than the relationship between manufacturing flexibility components and business performance measures. These findings tend to support the previous studies conducted by Bartezzaghi et al. (1992), Nawanir (2011) and Nawanir et al. (2013), which suggested that business performance should be observed as higher level in the hierarchy of objectives while manufacturing performance representing the lower level objectives that hold the duty of mediator variable. In specific, manufacturing performance will act as an antecedent to business performance that links up the manufacturing flexibility - business performance relationship. In sum, the above discussions show that manufacturing flexibility components are related to both manufacturing performance measures and business performance measures.

Table 4.15
Correlation between Manufacturing Flexibility Components and Business Performance Measures

Business Performance Measures	**Manufacturing Flexibility Components**						
	Mix	**New**	**Labor**	**Machine**	**Material handling**	**Routing**	**Volume**
Profitability	.613**	.501**	.656**	.493**	.675**	.645**	.633**
Product Market Performance	.593**	.397**	.503**	.341**	.526**	.609**	.481**
Customer Satisfaction	.536**	.472**	.562**	.603**	.633**	.587**	.603**

** Correlation is significant at the 0.01 level (2-tailed).

4.8.4 Associations among Manufacturing Performance Measures

Pearson correlation coefficients as depicted in Table 4.16 highlighted that all the manufacturing performance measures are significantly correlated with one another at $\alpha = 0.01$. The correlations among them are high ($r > 0.50$) and positive at the range between 0.52 and 0.78. This suggests that manufacturing performance measures are interdependent.

Table 4.16

Correlation among Manufacturing Performance Measures

Manufacturing Performance Measures	**Manufacturing Performance Measures**				
	Quality	**Cost Reduction**	**Lead Time Reduction**	**Productivity**	**Inventory Minimization**
Quality	1				
Cost Reduction	.684**	1			
Lead Time Reduction	.519**	.584**	1		
Productivity	.698**	.737**	.745**	1	
Inventory Minimization	.533**	.630**	.691**	.779**	1

** Correlation is significant at the 0.01 level (2-tailed).

4.8.5 Associations between Manufacturing Performance Measures and Business Performance Measures

Meanwhile, as portrayed in Table 4.17, all the measures of manufacturing performance and business performance measures are positively correlated (range from 0.51 to 0.80) at α = 0.01. The postulation that manufacturing performance can motivate "broader measure" of business performance is thus supported. This finding is in line with findings of several past studies that tried to clarify the association between manufacturing performance and business performance, e.g. researches done by Fullerton and Wempe (2009), Nawanir et al. (2013), Stede, Chow, and Lin (2006) and also Said, HassabElnaby, and Wier (2003).

Table 4.17

Correlation between Manufacturing Performance Measures and Business Performance Measures

Business Performance Measures	**Manufacturing Performance Measures**				
	Quality	**Cost Reduction**	**Lead Time Reduction**	**Productivity**	**Inventory Minimization**
Profitability	.628**	.661**	.787**	.795**	.779**
Product Market Performance	.511**	.568**	.603**	.551**	.572**
Customer Satisfaction	.710**	.594**	.625**	.760**	.716**

** Correlation is significant at the 0.01 level (2-tailed).

4.8.6 Associations among Business Performance Measures

Pearson correlation coefficients as depicted in Table 4.18 also reviewed that all the business performance measures are significantly correlated with one another at α = 0.01. The correlations among them are positive and ranged between 0.57 and 0.73. All correlations are considered high in this case, which seem to support that all three measures are interdependent and can be used collectively to measure business performance as a single entity.

Table 4.18

Correlation among Business Performance Measures

Business Performance Measures	**Business Performance Measures**		
	Profitability	**Product Market Performance**	**Customer Satisfaction**
Profitability	1		
Product Market Performance	.733**	1	
Customer Satisfaction	.699**	.565**	1

** Correlation is significant at the 0.01 level (2-tailed).

In short, based on the Pearson correlation analyses, all components of manufacturing flexibility are inter-correlated, and all of the manufacturing flexibility components positively and significantly associated with all measures of both manufacturing performance and business performance. Furthermore, positive and significant associations within and between manufacturing performance measures and also business performance measures are also reported. Next section will discuss about the contribution of the independent variables to the dependent variables involved in this study, through multiple regression analyses.

4.9 The Relationships between Manufacturing Flexibility Components, Manufacturing Performance Measures and Business Performance Measures: Multiple Regression Analysis

This section reports the results of regression analyses that were applied to examine the relationships between manufacturing flexibility components and manufacturing performance measures, between manufacturing flexibility components and business performance measures, and also between manufacturing performance measures and business performance measures. The analyses were conducted mainly to determine the effect of manufacturing flexibility components on both manufacturing performance measures and business performance measures.

Power is defined by Hair et al. (2013) as the "*probability of correctly rejecting the null hypothesis when it is false*". Commonly used power and *Type I error (α)* is 0.80 and 0.05 respectively (Cunningham & McCrum-Gardner, 2007). According to power analysis generated by "G*Power 3.1.9.2" (which is available for download at www.gpower.hhu.de), with effect size of 0.25 (medium effect size according to Cohen (1988)), power of 0.80 and $\alpha = 0.05$, 65 samples are required for this study with seven predictors (highest number of independent predictors for this study) (Faul, Erdfelder, Lang, & Buchner, 2007). Therefore, the sample size for this study (137 samples) is deem sufficient for subsequent multiple regression analyses. Details are encapsulated in the following subsections.

4.9.1 The Relationship between Manufacturing Flexibility Components and Manufacturing Performance Measures: Regression Model 1

The results of multiple regression analyses for each of the manufacturing performance measures as the dependent variable are provided in Table 4.19, and the full SPSS output of Regression Model 1 is shown in Appendix G. Regression analysis indicates the existence of significant relationship between manufacturing flexibility components (independent variables) and each of the manufacturing performance measures (dependent variable). The adjusted R^2 values range between 0.477 and 0.587, with value of productivity ranked the highest in all of the manufacturing performance measures, where 58.70% of its variance explained by manufacturing flexibility components, followed by cost reduction effort at 56.10%, product quality at 55.70%, lead time reduction at 55.60% and inventory minimization at 47.70%. The F-statistics, which test $H_0:R^2 = 0$ are significant at $\alpha = 0.05$ for all regression models. So, the $H_0:R^2 = 0$ is negated.

Table 4.19

Results of Multiple Regression Analysis between Manufacturing Flexibility Components and Manufacturing Performance Measures

Manufacturing Flexibility Components	**Dependent Variable: Product Quality**					**Dependent Variable: Cost Reduction**					**Dependent Variable: Lead Time Reduction**				
	Unstandardized		**Standardized Beta**	**t**	**Sig.**	**Unstandardized**		**Standardized Beta**	**t**	**Sig.**	**Unstandardized**		**Standardized Beta**	**t**	**Sig.**
	Beta	**Std. Error**				**Beta**	**Std. Error**				**Beta**	**Std. Error**			
(Constant)	1.206	.305		3.961	.000	1.097	.282		3.885	.000	1.435	.236		6.084	.000
Mix	.271	.063	.298	4.334	.000	.078	.058	.092	1.352	.179	.221	.049	.313	4.556	.000
New	-.218	.070	-.251	-3.115	.002	.051	.065	.063	.791	.431	.226	.054	.336	4.168	.000
Labor	-.201	.103	-.203	-1.956	.053	.108	.095	.117	1.133	.259	.020	.080	.026	.249	.804
Machine	-.187	.080	-.201	-2.326	.022	-.247	.074	-.285	-3.317	.001	-.264	.062	-.368	-4.252	.000
Material Handling	.558	.105	.538	5.339	.000	.121	.097	.125	1.250	.213	.300	.081	.373	3.702	.000
Routing	.314	.081	.332	3.872	.000	.485	.075	.550	6.448	.000	.117	.063	.160	1.868	.064
Volume	.254	.093	.274	2.721	.007	.143	.087	.166	1.651	.101	.046	.072	.063	.628	.531
R2			0.579					0.583					0.579		
Adjusted R2			0.557					0.561					0.556		
Significant F			0.000					0.000					0.000		

Manufacturing Flexibility Components	**Dependent Variable: Productivity**					**Dependent Variable: Inventory Minimization**				
	Unstandardized		**Standardized Beta**	**t**	**Sig.**	**Unstandardized**		**Standardized Beta**	**t**	**Sig.**
	Beta	**Std. Error**				**Beta**	**Std. Error**			
(Constant)	.682	.274		2.488	.014	1.141	.284		4.018	.000
Mix	.112	.056	.131	1.979	.050	.216	.058	.276	3.702	.000
New	.051	.063	.063	.805	.422	.061	.065	.082	.933	.352
Labor	.057	.093	.062	.616	.539	.145	.096	.171	1.516	.132
Machine	-.034	.072	-.040	-.475	.636	-.031	.075	-.038	-.409	.683
Material Handling	.327	.094	.338	3.475	.001	-.100	.097	-.112	-1.023	.308
Routing	.266	.073	.301	3.645	.000	.204	.076	.251	2.701	.008
Volume	.079	.084	.091	.939	.349	.205	.087	.257	2.349	.020
R2			0.608					0.504		
Adjusted R2			0.587					0.477		
Significant F			0.000					0.000		

However, the t-statistics, which test $H_0:\beta_i = 0$ indicate that some of regression coefficients are not significant at $\alpha = 0.05$ level. As an example, regression model of inventory minimization indicates that there are only three manufacturing flexibility components with significant t-statistic; i.e. mix flexibility ($p = 0.00$), routing flexibility ($p = 0.01$) and volume flexiility ($p = 0.02$). Regression model of productivity yield a similar result, with three significant manufacturing flexibility components at $\alpha = 0.05$ level, i.e., mix flexibility ($p = 0.05$), routing flexibility ($p = 0.00$) and material handling flexibility ($p = 0.00$).

Moreover, machine flexibility has significant negative regression coefficient (theory contradict sign) with product quality, cost reduction and lead time reduction at $\alpha = 0.05$; New product flexibility has significant negative regression coefficient with product quality at $\alpha = 0.05$; Labor flexibility has significant negative regression coefficient with product quality at $\alpha = 0.10$. These coefficients take on the negative sign while theory, common sense and also Pearson correlation analysis (refer to Table 4.14) suggest the positive relationship. These findings advocate the possibility for multicollinearity issue (Hair et al., 2013; Wang & Jain, 2003). The influences of multicollinearity together with suggested methods to deal with it will be described systematically in Section 4.10.

4.9.2 The Relationship between Manufacturing Flexibility Components and Business Performance Measures: Regression Model 2

Table 4.20 shows the results of multiple regression analyses using business performance measures as the dependent variables. Similarly, significant relationship is also found between manufacturing flexibility components (independent variables) and each of the business performance measures (dependent variable).

Regression analysis shows that profitability has the highest adjusted R^2 value, where 66.30% of its variances are explained by variances in manufacturing flexibility components, while product market performance and customer satisfaction registered 60.70% and 53.30% respectively. The full SPSS output is attached in Appendix H. Comparable to the Regression Model 1, the F-statistic testing $H_0{:}R^2 = 0$ for Regression Model 2 is significant for all business performance measures at $\alpha = 0.05$. Hence, $H_0{:}R^2 = 0$ is negated.

While F-statistics show the significant relationship between manufacturing flexibility components and each business performance measure, the t-statistics testing $H_0{:}\beta_i = 0$ show that only some of the manufacturing flexibility components have significant impacts on business performance. Regression Model 2 provides facts that customer satisfaction is only supported by mix flexibility ($p = 0.00$), material handling flexibility ($p = 0.01$) and routing flexibility ($p = 0.01$) at $\alpha = 0.05$ and machine flexibility ($p = 0.10$) at $\alpha = 0.10$. Besides, theory contradict sign (significant negative regression coefficient) have been seen with machine flexibility on profitability and product market performance at $\alpha = 0.05$, which misaligned with theory, common sense and also Pearson correlation analysis (refer to Table 4.15),

Table 4.20
Results of Multiple Regression Analysis between Manufacturing Flexibility Components and Business Performance Measures

Manufacturing Flexibility Components	**Dependent Variable: Profitability**				
	Unstandardized		**Standardized Beta**	**t**	**Sig.**
	Beta	**Std. Error**			
(Constant)	-.240	.283		-.848	.398
Mix	.409	.058	.420	7.020	.000
New	.070	.065	.076	1.077	.283
Labor	.096	.096	.091	1.008	.315
Machine	-.213	.075	-.215	-2.860	.005
Material Handling	.283	.097	.256	2.913	.004
Routing	.350	.075	.346	4.641	.000
Volume	.056	.087	.056	.639	.524
R2			0.681		
Adjusted R2			0.663		
Significant F			0.000		

Manufacturing Flexibility Components	**Dependent Variable: Product Market Performance**				
	Unstandardized		**Standardized Beta**	**t**	**Sig.**
	Beta	**Std. Error**			
(Constant)	.106	.306		.347	.729
Mix	.532	.063	.547	8.458	.000
New	.081	.070	.087	1.151	.252
Labor	-.034	.103	-.032	-.328	.743
Machine	-.384	.081	-.388	-4.771	.000
Material Handling	.216	.105	.195	2.058	.042
Routing	.567	.081	.562	6.971	.000
Volume	-.058	.094	-.058	-.614	.540
R2			0.627		
Adjusted R2			0.607		
Significant F			0.000		

Manufacturing Flexibility Components	**Dependent Variable: Customer Satisfaction**				
	Unstandardized		**Standardized Beta**	**t**	**Sig.**
	Beta	**Std. Error**			
(Constant)	.677	.301		2.246	.026
Mix	.228	.062	.259	3.677	.000
New	-.004	.069	-.005	-.059	.953
Labor	-.074	.102	-.077	-.726	.469
Machine	.134	.079	.149	1.682	.095
Material Handling	.289	.103	.289	2.798	.006
Routing	.210	.080	.230	2.617	.010
Volume	.082	.092	.092	.885	.378
R2			0.557		
Adjusted R2			0.533		
Significant F			0.000		

which has suggested a positive relationship have again highlighted the possibility of multicollinearity issue in the regression model.

4.9.3 The Relationship between Manufacturing Performance Measures and Business Performance Measures: Regression Model 3

This section is about the usage of multiple regression analysis to measure the relationship between manufacturing performance measures as the independent variables and business performance measure as the dependent variable. The analysis measures the impacts of manufacturing performance measures to each of the business performance measures.

The results of multiple regression analyses for Regression Model 3 are displayed in Table 4.21, while the output of SPSS is depicted in Appendix I. Similar scenario happened in the analyses, where significant relationships are also revealed. The highest adjusted R^2 value is 0.754. It means that 75.40% variance in profitability is explained by variances in manufacturing performance measures. Meanwhile, about 44.50% of product market performance and 67.70% of customer satisfaction are explained by variances in manufacturing performance measures.

Similar to the preceding models, the F-statistics for Regression Model 3 are also significant at $\alpha = 0.05$ for all business performance measures. Once again, the t statistic shows that only a fraction of the manufacturing performance measures contributing to each business performance measure significantly.

Table 4.21

Results of Multiple Regression Analysis between Manufacturing Performance Measures and Business Performance Measures

Manufacturing Performance Measures	**Dependent Variable: Profitability**				
	Unstandardized		**Standardized**	**t**	**Sig.**
	Beta	**Std. Error**	**Beta**		
(Constant)	-1.122	.281		-3.994	.000
Product Quality	.141	.068	.132	2.080	.039
Cost Reduction	.059	.078	.052	0.762	.448
Lead Time Reduction	.494	.091	.359	5.424	.000
Productivity	.185	.104	.162	1.781	.077
Inventory Minimization	.376	.088	.302	4.264	.000
R2			0.763		
Adjusted R2			0.754		
Significant F			0.000		

Manufacturing Performance Measures	**Dependent Variable: Product Market Performance**				
	Unstandardized		**Standardized**	**t**	**Sig.**
	Beta	**Std. Error**	**Beta**		
(Constant)	-.354	.422		-.838	.403
Product Quality	.186	.102	.174	1.822	.071
Cost Reduction	.269	.117	.235	2.299	.023
Lead Time Reduction	.490	.137	.356	3.580	.000
Productivity	-.220	.156	-.192	-1.411	.161
Inventory Minimization	.293	.133	.236	2.213	.029
R2			0.466		
Adjusted R2			0.445		
Significant F			0.000		

Manufacturing Performance Measures	**Dependent Variable: Customer Satisfaction**				
	Unstandardized		**Standardized**	**t**	**Sig.**
	Beta	**Std. Error**	**Beta**		
(Constant)	.011	.291		.037	.971
Product Quality	.381	.070	.395	5.421	.000
Cost Reduction	-.120	.081	-.116	-1.491	.138
Lead Time Reduction	.076	.094	.061	.808	.420
Productivity	.278	.108	.269	2.584	.011
Inventory Minimization	.368	.091	.327	4.022	.000
R2			0.689		
Adjusted R2			0.677		
Significant F			0.000		

The Regression Model 3 shows that profitability is supported by product quality (p = 0.04), lead time reduction (p = 0.00) and inventory minimization (p = 0.00) at α = 0.05 while supported by productivity (p = 0.08) at α = 0.10. Product market performance is only supported by cost reduction (p = 0.02), lead time reduction (p = 0.00), inventory minimization (p = 0.03) at α = 0.05, and product quality (p = 0.07) at α = 0.10.

On the other hand, customer satisfaction is supported by product quality (p = 0.00), productivity (p = 0.01) and inventory minimization (p = 0.00) at α = 0.05. However, two of the multiple regression model have independent variable taking negative sign (i.e. the linear regression for product market performance on productivity and the linear regression for customer satisfaction on cost reduction), even though the beta coefficients are statistical insignificant. The above discussions have again highlighted the potential presence of multicollinearity in the regression model.

The potential existence of multicollinearity problems has plagued all the above regression models. As a remedy, detail discussion about multicollinearity and how to mitigate its influences in regression analysis are offered in the next section.

4.10 Mitigating the Effects of Multicollinearity among Independent Variables: Principal Component Analysis and Simple Regression Analysis

Multiple regression analysis required that the independent variables are not linearly related as high linear correlation among the independent variables create multicollinearity issues (Hair et al., 2013; Kuhn & Johnson, 2013). Having a quantity of independent variables that are highly correlated with the dependent variable, but with little association amongst them would be the best scenario for regression analysis. Hair et al. (2013) stated that as the severity of multicollinearity increases, the interpretation of relationship become more complicated as it is more difficult to determine the impact of any particular independent variable due to the chaotic interrelationship.

Multicollinearity influences the stability of the parameter estimates calculated in multiple regression analysis and lead to one or several of the following conditions: (i) Large estimated standard errors for the coefficient with small values of the t-statistic; (ii) Insignificant value of estimated coefficients or wrong signs of estimated coefficients (positive or negative); (iii) It will be problematic to evaluate the relative importance of independent variables with the present of large estimated standard errors (Wang & Jain, 2003).

Multicollinearity issues are present if: (i) Absolute value of the correlation between independent variables is relatively high (0.70 or larger); where according to Grewal, Cote, and Baumgartner (2004), a correlation coefficient of 0.60 is sufficient to suggest the risk of multicollinearity and may produce a misleading results of multiple regression analysis; (ii) Theory contradicting signs of regression coefficients (either positive or negative), where the coefficients take on negative values when theory or common sense or Pearson correlation analysis suggests a positive relationship between independent and dependent variables; (iii) Abnormally large standard errors of the beta regression coefficients; (iv) The regression equation has a large overall R^2 and high F-statistics but a number of the independent variables shown insignificant effects (Hair et al., 2013; Kuhn & Johnson, 2013; Maddala & Lahiri, 2009).

In this study, the multicollinearity problems are appearing in all the three regression models. In Regression Model 1 and Regression Model 2, Pearson correlation coefficients among manufacturing flexibility components are statistically high and significant at $\alpha = 0.01$ with the highest value 0.788 (between labor flexibility and material handling flexibility (see Table 4.13)). Moreover, all the regression models developed in this study indicated high adjusted R^2 values; between 0.445 and 0.754 (see Table 4.19, 4.20 and 4.21). In addition, F-statistics for all multiple regression models are statistically significant at $\alpha = 0.05$ but the t-statistics indicate that only several of the manufacturing flexibility components have significant contribution to the dependent variable.

In Regression Model 1, adjusted R^2 values range between 0.477 and 0.587 are reported with F-values that are statistically significant at the level of 0.000. However, t-statistics shown that some of the independent variables exhibit non-significant contribution to dependent variable (refer Table 4.19, e.g. mix flexibility towards cost reduction, labor flexibility towards cost reduction, lead time reduction, productivity and inventory minimization). What further complicated the matter is, negative and significant regression coefficients exists between some of the independent and dependent variables (e.g. product quality with new flexibility and machine flexibility at $\alpha = 0.05$, labor flexibility at $\alpha = 0.10$; cost reduction with machine flexibility at $\alpha = 0.05$; lead time reduction with machine flexibility at $\alpha = 0.05$). In other words, regression coefficient takes on the contradict sign even though the Pearson correlation coefficient is positive and significant at the 0.01 level which indicated the present of multicollinearity issues (Hair et al., 2013).

For Regression Model 2, the same scenario occurs where F-statistics are significant, but as indicated by t-statistics (see Table 4.20), only half of the independent variables are significant contributors toward the dependent variable. In

Regression Model 3, even though the regression equation has a significant F statistic as shown in Table 4.21, significant t-values still only exist among few independent variables. In addition, a number of the regression coefficients take the wrong sign. All of these are warning signals of multicollinearity.

Some authors (Allison, 1999; Hair et al., 2013; Kuhn & Johnson, 2013; Maddala & Lahiri, 2009) have suggested a method to detect multicollinearity in multiple regression analysis, namely “tolerance” or “variance inflation factor” (VIF). According to Hair et al. (2013), tolerance is referred as “the amount of variability of the selected independent variable not explained by the other independent variables” and is calculated using the formula $1 - R^2$ for each variable, while the reciprocal of the tolerance is known as VIF. It shows how much the variance of the coefficient estimate is being inflated by multicollinearity. High tolerance value or low VIF depicted small degree of multicollinearity. Vice versa, high degree of multicollinearity yield low tolerance value and high VIF value.

Commonly used cut-off point to determine the presence of multicollinearity is tolerance < 0.1, or a VIF > 10 and suggested that multicollinearity may be a threat. However, these commonly used threshold values still allowed for high correlation between independent variables, i.e. correlation above 0.90, which may be problematic (Hair et al., 2013; Pallant, 2013).

Nevertheless, some researchers (such as Allison (1999), Al-Zu'bi (2015), and Nawanir et al. (2016)) have suggested that tolerance value of less than 0.40 and the VIF value higher than 2.50 are sufficient to dictate a severe multicollinearity problem. This implies that one needs to get concerned when any of the R^2s is above 0.60 or so. Summary of multicollinearity diagnostics for all manufacturing flexibility components and manufacturing performance measures are shown in Table 4.22, while the SPSS outputs are given in Appendix J.

Table 4.22
Tolerance and VIF Values for Manufacturing Flexibility Components and Manufacturing Performance Measures

No	Construct	Collinearity Statistics	
		Tolerance	VIF
Manufacturing Flexibility Components as Independent Variables			
1	Mix	.691	1.448
2	New	.502	1.991
3	Labor	.303	3.303
4	Machine	.436	2.291
5	Material Handling	.321	3.111
6	Routing	.445	2.248
7	Volume	.321	3.117
Manufacturing Performance Measures as Independent Variables			
1	Product Quality	.447	2.238
2	Cost Reduction	.392	2.554
3	Lead-Time Reduction	.413	2.420
4	Productivity	.219	4.556
5	Inventory Minimization	.359	2.787

Based on Table 4.22, multicollinearity problems did exist in all of the regression models. For Regression Model 1 and Regression Model 2, multicollinearity issues happened particularly on labor flexibility (tolerance = 0.30, VIF = 3.30), volume flexibility (tolerance = 0.32, VIF = 3.12) and also material handling flexibility (tolerance = 0.32, VIF = 3.11). For Regression Model 3, multicollinearity issues happened particularly on productivity (tolerance = 0.22 VIF = 4.56), cost reduction (tolerance = 0.39, VIF = 2.55) and inventory minimization (tolerance = 0.36, VIF = 2.79). Based on the above evidence, it can be concluded that the presence of multicollinearity problems in the regression models examined in this study are quite severe.

The above discussions bring forth the need for effective remedies to reduce the effects of multicollinearity. Hair et al. (2013) and Allison (1999) had suggested a number of remedies for multicollinearity: (i) Omit one or more highly correlated independent variables; (ii) Use simple correlations to interpret the relationship between the independent variables and dependent variables; (iii) Use the model with the highly correlated independent variables for prediction only without attempting to interpret the regression coefficients, and recognizing that this method have lower level of overall predictive ability; (iv) Use simple regression on principal component of independent variables to obtain a simplify model that explained the collective effects of the independent variables on the dependent variable (Kuhn & Johnson, 2013; Maddala & Lahiri, 2009; Wang & Jain, 2003).

Results of Pearson correlation coefficients (see Table 4.13) among manufacturing flexibility components that are statistically significant and positive, have provided the basis that manufacturing flexibility components should not be implemented partially but holistically and comprehensively. Also, in order to ensure content validity, the last option (option iv) is considered more appropriate for used to reduce the effect of multicollinearity in this study. Similar suggestion have been proposed by Nawanir et al. (2016) and also Maddala and Lahiri (2009) as a remedy to deal with the multicollinearity problem in multiple regression analysis. In other word, principal component analysis (PCA) that aimed to summarize most of the original information (variance) in the minimum number of factors/variables for prediction purposes is useful when used in conjunction with simple regression method as it addresses the multicollinearity problem in multiple regression analysis (Abdi & Williams, 2010; Hair et al., 2013; Maddala & Lahiri, 2009).

By definition, the first principal component is the linear combination accounting for the largest possible fraction of the original variables’ variance. Therefore, scores on the first unrotated principal component are a reasonable choice for combining many original variables into a single composite (Hamilton & Press, 1992). In this section, independent variables data are analysed collectively and principal components scores of the independent variables were retrieved using Statgraphic XVII. Subsequently, a simple linear regression analysis was carried out between the dependent variables and the first principal component scores of the independent variables following the model: $Y = \alpha + \beta_1 X_1$ (Adnan, Ahmad, & Adnan, 2006; Hamilton & Press, 1992; Nawanir et al., 2013).

In short, due to the presence of the multicollinearity problem in multiple regression analysis, the contribution of the independent variables to each dependent variable should be analysed collectively with the help of PCA, which will describe the interrelated independent variables as a unified set, rather than as individual.

The succeeding analyses were conducted by linking the independent variables (collectively) with each dependent variable measure.

4.10.1 The Relationship between Manufacturing Flexibility Components and Manufacturing Performance Measures: Simple Regression Analysis

This section aimed to find out the relationship between manufacturing flexibility components (collectively) and each measure of manufacturing performance. The following five hypotheses were tested in this section:

H_{1a}: *Manufacturing flexibility components have a positive relationship with product quality.*

H_{1b}: *Manufacturing flexibility components have a positive relationship with cost reduction.*

H_{1c}: *Manufacturing flexibility components have a positive relationship with lead time reduction.*

H_{1d}: *Manufacturing flexibility components have a positive relationship with productivity.*

H_{1e}: *Manufacturing flexibility components have a positive relationship with inventory minimization.*

As described above, principal component analysis (PCA) is used to generate the first principal component scores and to summarize most of the original information (variance) into a set of independent variables (refer Appendix K for the detail of analyses). The principal component scores of manufacturing flexibility components are calculated based on the following equation:

0.274 (Mix Flexibility) + 0.360 (New Product Flexibility) + 0.407 (Labor Flexibility) + 0.383 (Machine Flexibility) + 0.405 (Material Handling Flexibility) + 0.381 (Routing Flexibility) + 0.416 (Volume Flexibility).

The first principal component explains 63.74% of the total variance in manufacturing flexibility components. The results of simple regression analysis between the principal component scores of manufacturing flexibility components and each measure of manufacturing performance are shown in Table 4.23.

With reference to Table 4.23, regression coefficients of all regression models are statistically positive and significant at $\alpha = 0.05$. It means that manufacturing flexibility components collectively contribute to manufacturing performance, in terms of product quality, cost reduction, lead time reduction, productivity and inventory minimization, significantly with R^2 values range from 36.9% to 56.9%. Therefore, hypotheses H_{1a}, H_{1b}, H_{1c}, H_{1d}, and H_{1e} are not rejected.

Table 4.23

Results of Simple Regression Analysis between the First Principal Component Score of Manufacturing Flexibility and Manufacturing Performance Measures

Model	**Unstandardized**		**Standardized**	**t**	**Sig.**	**R^2**
	Beta	**Std. Error**	**Beta**			
(Constant)	1.723	.345		4.996	.000	0.369*
Regression	.272	.031	.608	8.890	.000	
IV = PCA of Manufacturing Flexibility						
DV = Product Quality						
(Constant)	1.130	.302		3.740	.000	0.442*
Regression	.277	.027	.665	10.333	.000	
IV = PCA of Manufacturing Flexibility						
DV = Cost Reduction						
(Constant)	1.754	.251		6.986	.000	0.443*
Regression	.231	.022	.665	10.352	.000	
IV = PCA of Manufacturing Flexibility						
DV = Lead Time Reduction						
(Constant)	.830	.266		3.121	.002	0.569*
Regression	.316	.024	.754	13.352	.000	
IV = PCA of Manufacturing Flexibility						
DV = Productivity						
(Constant)	1.257	.276		4.553	.000	0.451*
Regression	.259	.025	.672	10.536	.000	
IV = PCA of Manufacturing Flexibility						
DV = Inventory Minimization						

IV = Independent variable; DV = Dependent variable; Principal component score is obtained from PCA; * F statistics are significant at the 0.05 level.

4.10.2 The Relationship between Manufacturing Flexibility Components and Business Performance Measures: Simple Regression Analysis

Three hypotheses as below were tested in this section to find out the relationship between manufacturing flexibility components (collectively) and each business performance measure:

H_{2a}: *Manufacturing flexibility components have a positive relationship with profitability.*

H_{2b}: *Manufacturing flexibility components have a positive relationship with product market performance.*

H_{2c}: *Manufacturing flexibility components have a positive relationship with customer satisfaction.*

Due to the presence of the multicollinearity problem, manufacturing flexibility components are analysed collectively by applying PCA, as discussed in Section 4.10.1. The summary of simple regression analysis is shown in Table 4.24.

All the regression models presented in Table 4.24 have regression coefficients that are statistically positive and significant at $\alpha = 0.05$. This suggests that all of the manufacturing flexibility components collectively contribute to business performance with R^2 values range between 37.0% and 56.3%. In detail, the implementation of manufacturing flexibility components significantly improves business performance in terms of profitability, product market performance, and customer satisfaction. Thus, hypotheses H_{2a}, H_{2b} and H_{2c} are not rejected.

Table 4.24

Results of Simple Regression Analysis between the First Principal Component Score of Manufacturing Flexibility Components and Business Performance Measures

Model	**Unstandardized**		**Standardized Beta**	**t**	**Sig.**	**R^2**
	Beta	**Std. Error**				
(Constant)	.299	.307		.976	.331	0.563*
Regression	.359	.027	.750	13.178	.000	
IV = PCA of Manufacturing Flexibility						
DV = Profitability						
(Constant)	.801	.368		2.179	.031	0.370*
Regression	.291	.033	.608	8.906	.000	
IV = PCA of Manufacturing Flexibility						
DV = Product Market Performance						
(Constant)	.940	.293		3.204	.002	0.509*
Regression	.308	.026	.713	11.826	.000	
IV = PCA of Manufacturing Flexibility						
DV = Customer Satisfaction						

IV = Independent variable; DV = Dependent variable; Principal component score is obtained from PCA; * F statistics are significant at the 0.05 level.

4.10.3 The Relationship between Manufacturing Performance Measures and Business Performance Measures: Simple Regression Analysis

This section aims to examine the relationship between manufacturing performance measures (collectively) and each business performance measure, and the following hypotheses were tested:

H_{3a}: *Manufacturing performance measures have a positive relationship with profitability.*

H_{3b}: *Manufacturing performance measures have a positive relationship with product market performances.*

H_{3c}: Manufacturing performance measures have a positive relationship with customer satisfaction.

The presence of the multicollinearity problems in multiple regression analysis has suggested PCA should be used to analyse the impact of interrelated manufacturing performance measures collectively (Abdi & Williams, 2010; Hair et al., 2013; Maddala & Lahiri, 2009; Nawanir et al., 2013). PCA has produced the first principal component equation of manufacturing performance measures (refer Appendix K for details):

0.419 (Product Quality) + 0.446 (Cost Reduction) + 0.434 (Lead Time Reduction) + 0.488 (Productivity) + 0.447 (Inventory Minimization).

The first principal component explains 72.97% of the total variance in the manufacturing performance measures. The collective contribution of manufacturing performance measures to each measure of business performance is quantify by using simple regression analysis between the first principal component scores of manufacturing performance measures and each measure of business performance (refer Table 4.25). According to the information provided in the table, manufacturing performance measures collectively contributes to business performance at $\alpha = 0.05$ with R^2 values range from 42.6% to 72.3%. Therefore, hypotheses H_{3a}, H_{3b} and H_{3c} are not rejected.

In addition, the utility of the results of regression is in part dependent upon meeting the assumptions of regression analysis. The assumptions to be examined are normality, linearity and heteroscedasticity of residuals, which can be assessed via examination of the residuals scatterplots (Tabachnick & Fidell, 2013). After assessing the residuals scatterplots as depicted in Appendix L, researcher can conclude that all these assumptions have been fulfilled.

Table 4.25
Results of Simple Regression Analysis between the First Principal Component Score of Manufacturing Performance and Business Performance Measures

Model	Unstandardized		Standardized Beta	t	Sig.	R^2
	Beta	Std. Error				
(Constant)	-.835	.275		-3.033	.003	0.723*
Regression	.528	.028	.851	18.790	.000	
IV = PCA of Manufacturing Performance						
DV = Profitability						
(Constant)	.104	.396		.264	.792	0.426*
Regression	.405	.040	.653	10.015	.000	
IV = PCA of Manufacturing Performance						
DV = Product Market Performance						
(Constant)	.016	.284		.058	.954	0.639*
Regression	.448	.029	.800	15.469	.000	
IV = PCA of Manufacturing Performance						
DV = Customer Satisfaction						

IV = Independent variable; DV = Dependent variable; Principal component score is obtained from PCA; * F statistics are significant at the 0.05 level.

4.11 The Relationship between Manufacturing Flexibility and Business Performance: Mediation Role of Manufacturing Performance

The direct and indirect impact of manufacturing flexibility on business performance are the topics of interest in this section, where the indirect relationship is gauged by introducing manufacturing performance as mediator variable. Hypothesis 4 was tested in this section:

H_4: Manufacturing performance mediates the relationship between manufacturing flexibility and business performance.

Table 4.26 depicted the results of factor analyses which confirmed the unidimensionality for all the three constructs, where percent of variance explained are more than 50% (63.74% for manufacturing flexibility, 72.97% for manufacturing performance and 77.79% for business performance). In other words, the results of factor analysis showed that they are unifactoral, and therefore, the manufacturing flexibility components or the manufacturing performance measures or the business performance measures can be analysed collectively. Hence, this section used simple regression paired with principal components scores of the three constructs (principal components scores of the seven manufacturing flexibility components, principal components scores of the five manufacturing performance measures, and principal components scores of the three business performance measures). In other word, three set of principal components scores are extracted, i.e. one for manufacturing flexibility components (collectively), one for manufacturing performance measures (collectively), and one for business performance measures (collectively).

These scores are obtained from the linear combination of the relevant variables as described below (Results of Principal Components Analyses are depicted in Appendix K). The first principal component or linear combination of manufacturing flexibility components (63.74% variance explained) is: 0.274 (Mix Flexibility) + 0.360 (New Product Flexibility) + 0.407 (Labor Flexibility) + 0.383 (Machine Flexibility) + 0.405 (Material Handling Flexibility) + 0.381 (Routing Flexibility) + 0.416 (Volume Flexibility).

Table 4.26
Unidimensionality Analysis for Manufacturing Flexibility, Manufacturing Performance and Business Performance

No	Construct	Factor Loadings	KMO	Eigen value	% of Variance	Cronbach's Alpha
Manufacturing Flexibility						
1	Mix	.579	0.897	4.462	63.739	0.900
2	New Product	.761				
3	Labor	.860				
4	Machine	.809				
5	Material Handling	.856				
6	Routing	.804				
7	Volume	.879				
Manufacturing performance						
8	Quality	.800	0.858	3.649	72.971	0.905
9	Cost Reduction	.851				
10	Lead Time Reduction	.829				
11	Productivity	.932				
12	Inventory Minimization	.854				
Business Performance						
13	Profitability	.924	0.692	2.334	77.794	0.857
14	Product Market Performance	.869				
15	Customer Satisfaction	.852				

While the first principal component or linear combination of manufacturing performance measures (72.97% variance explained) is: 0.419 (Product Quality) + 0.446 (Cost Reduction) + 0.434 (Lead Time Reduction) + 0.488 (Productivity) + 0.447 (Inventory Minimization).

In addition, the first principal component or linear combination of business performance measures (77.79% variance explained) is: 0.605 (Profitability) + 0.569 (Product Market Performance) + 0.558 (Customer Satisfaction).

The mediation role of manufacturing performance in the relationship between manufacturing flexibility and business performance was then tested by using the principal component scores of the measures for the three constructs as stated above. Baron and Kenny (1986) recommended the following steps for mediation test. The steps as below are summarized in Figure 4.1.

a) Step 1: Regressing the dependent variable on the independent variable to show that the independent variable affect the dependent variable. For this step, the first principal component scores of manufacturing flexibility components are used as the independent variable and the first principal component scores of business performance measures are used as the dependent variable in the regression equation (i.e. Path c in Figure 4.1). This step institutes the foundation that there is an effect that can be mediated.

b) Step 2: Regressing the mediator on the independent variable to show that the independent variable has effect on the mediator variable. The first principal component scores of manufacturing flexibility components act as the independent variable while the first principal component scores of manufacturing performance measures are the dependent variable for this regression equation (i.e. Path a in Figure 4.1).

c) Step 3: Regressing the dependent variable on the mediator variable by controlling independent variable. The mediator variable must affect the dependent variable. For this regression equation, the first principal component scores of manufacturing flexibility components and the first principal component scores of manufacturing performance measures act together as the independent variables and the first principal component scores of business performance measures are used as dependent variable (i.e. Path b in Figure 4.1).

d) Step 4: Regressing the dependent variable on the independent variable by controlling mediator variable. Full mediation is indicated when the previously significant relationship between the independent and dependent variables becomes insignificant. If the independent/dependent relationship is absolutely reduced but not to the point of insignificant, this indicates partial mediation and demonstrates that a given mediator is indeed potent (Baron & Kenny, 1986; Fullerton & Wempe, 2009). In other word, the degree to which the effect is reduced indicates how powerful the mediator is (Kim, Kaye, & Wright, 2001).

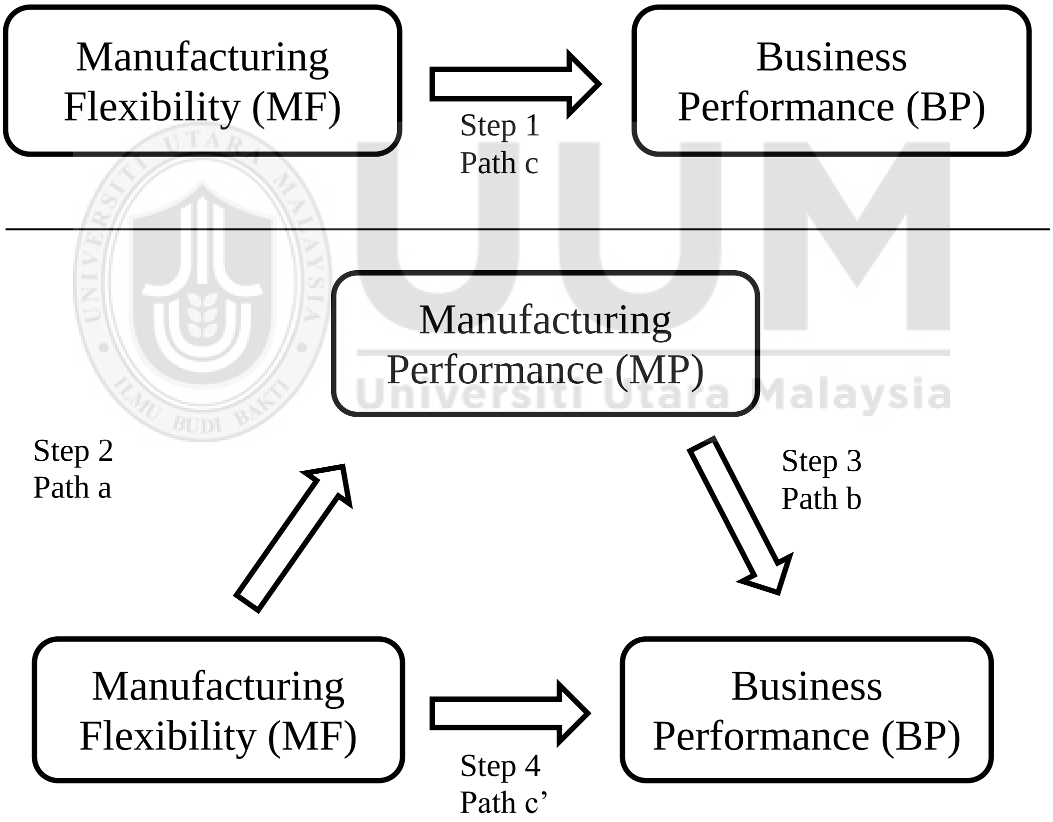

Figure 4.1
Analysis Process of Mediation Test

The results of mediation test are presented in Table 4.27. As depicted in the table, variation in manufacturing flexibility significantly account for 61.1% variance of business performance and also significantly account for 62.1% variance of manufacturing performance. Furthermore, both manufacturing flexibility and manufacturing performance affect business performance positively and significantly, where their variation collectively account for 77.7% variance of business performance.

As shown in Table 4.27, manufacturing performance partially mediates the relationship between manufacturing flexibility and business performance. When regressing business performance on manufacturing flexibility (i.e. Step 1), the results revealed that manufacturing flexibility has significant impact on business performance ($\beta_c = 0.782$, $p < 0.05$).

Table 4.27
Results of Mediation Test

Independent Variable	**Dependent Variable**		
	Manufacturing Performance (MP) Standardized β	**Business Performance (without MP) Standardized β**	**Business Performance (with MP) Standardized β**
Manufacturing Flexibility (MF)	0.788*	0.782*	0.256*
R2	0.621	0.611	0.781
Adjusted R2	0.618	0.609	0.777
R2 change	0.621	0.611	0.781
F change	221.259*	212.463*	238.266*

*significant at p<0.05

Meanwhile, when regressing manufacturing performance on manufacturing flexibility (i.e. Step 2), the results indicated that manufacturing flexibility has significant effect on manufacturing performance ($\beta_a = 0.788$, $p < 0.05$). If business performance is regressed on both manufacturing flexibility and manufacturing performance (i.e. Step 3 and 4), the results indicated that the direct impact of manufacturing flexibility on business performance had a decreasing effect but still significant statistically with the presence of manufacturing performance ($\beta_c = 0.782$

decrease to $\beta_{c'} = 0.256$), thereby implying partial mediation. Specifically, impact of manufacturing flexibility on business performance is significant on both Step 1 and Step 4. The beta value for relationship between manufacturing flexibility and business performance is still potent even though its value on Step 4 has reduced if compared with Step 1. Hence, the result provides support that manufacturing performance partially mediates the relationship between manufacturing flexibility and business performance.

A variable can has direct, indirect, or both direct and indirect impacts on another variable. Findings of this study indicated that manufacturing flexibility could affect business performance directly and indirectly through manufacturing performance as mediator. According to Sobel (1982) and Hair et al. (2013), indirect impact of manufacturing flexibility on business performance can be assessed by multiplying two coefficients together i.e., the partial regression effect of manufacturing performance on business performance (β_b) and the simple regression coefficient of manufacturing flexibility on manufacturing performance (β_a). Table 4.28 recaps the effects of manufacturing flexibility and manufacturing performance on business performance (refer to Appendix M).

Table 4.28
Effects between Manufacturing Flexibility, Manufacturing Performance and Business Performance

Path	**Effect**
Manufacturing Flexibility → Business Performance (Path c)	0.782
Manufacturing Flexibility → Manufacturing Performance (Path a)	0.788
Manufacturing Performance → Business Performance (Path b)	0.668
Manufacturing Flexibility → Business Performance (Path c’)	0.256

From Table 4.28, all the direct effects of manufacturing flexibility on manufacturing performance are high (0.788). Meanwhile, direct effects of manufacturing performance on business performance also registered high value (0.668). Product of coefficient for indirect effect of manufacturing flexibility on business performance is 0.788 * 0.668 = 0.526 and statistically significant at $p < 0.05$. As a result, total effect of manufacturing flexibility on business performance is 0.256 + 0.526 = 0.782. In other words, when manufacturing flexibility go up by 1 standard deviation, business performance goes up by 0.782 standard deviations (Kline, 2015).

To further consolidate the mediation effect, the PROCESS macro for SPSS written by Andrew F. Hayes has been used to assess the mediation effects together with biased corrected bootstrapping of 5000 times (Hayes, 2013). Outputs of the PROCESS (a SPSS Add-in) are depicted in Appendix N.

All the values of β after applying bootstrapping did not crossed the zero for both upper limit and lower limit, which mean the result is consistent and reliable. When assess the result from PROCESS, partially mediation is also suggested in-line with previous finding following Baron and Kenny method. Which at here, it can be concluded that manufacturing performance partially mediates the relationship between manufacturing flexibility and business performance.

The empirical evidences presented in this section indicate that manufacturing flexibility has a significant positive impact on firm's business performance. Moreover, its contributions toward manufacturing performance and ultimately business performance are tremendous. The findings highlight the role of manufacturing performance plays in partially mediating the relationship between manufacturing flexibility and business performance. Therefore, Hypothesis 4 (H_4) is partially supported.

4.12 Summary

This chapter provides the findings of the study regarding the relationship between manufacturing flexibility, manufacturing performance and business performance by employing descriptive analyses, correlation analyses, regression analyses and mediation test. Pearson correlation analysis indicated the positive and significant relationship between manufacturing flexibility components, manufacturing performance measures and also business performance measures. Results from regression analyses suggest that manufacturing flexibility components collectively contributes to each of the manufacturing performance measures (i.e. product quality, productivity, cost reduction, lead time reduction and inventory minimization) and business performance measures (i.e. profitability, product market performance and customer satisfaction). Analysis to examine the mediation effect of manufacturing performance in the relationship between manufacturing flexibility and business performance has provided empirical evidence supporting the fact that manufacturing performance is the partial mediator in the afore mentioned relationship. In the next chapter, the summary and conclusion of the study were discussed. In addition, the implication of the study, research limitations and possible directions for future research will be mentioned.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 Introduction

According to Kaur et al. (2016) and Kumar and Sharma (2015), utilization of advanced manufacturing strategies such as manufacturing flexibility are commonly associated with manufacturing performance because manufacturing flexibility are more frequently implemented in the shop floor and related to production process. Nawanir et al. (2013) also noted that manufacturing performance is actually reflected by some internal properties of the manufacturing system, which is surely influenced by manufacturing practices applied.

Although manufacturing flexibility can be a critical source of competitive advantage, unresolved issues remains, problems such as loose use of definition of manufacturing flexibility, no definitive components list and a weak understanding of how manufacturing flexibility improves performance have plague the efforts to strike for better manufacturing flexibility (Pérez Pérez et al., 2016).

In this research, four key questions are hoped to be answered to fill above gaps in the field of manufacturing flexibility, both literature and practically. They are:

(i) What are the components constituting the concept of manufacturing flexibility?
(ii) Does manufacturing flexibility affects manufacturing performance?
(iii) Does manufacturing flexibility affects business performance?
(iv) Does manufacturing performance mediates the relationship between manufacturing flexibility and business performance?

An in-depth discussion of key results regarding the impact of manufacturing flexibility on manufacturing performance and business performance is provided in this chapter. Important results are presented following the logical order established in preceding chapters. Limitations and contributions of the study are also discussed and suggestions for future research are offered.

5.2 Review of Research Findings

This study intended to investigate empirically and methodically the impact of manufacturing flexibility on firm's performance (manufacturing performance and business performance). Focused on context of Malaysia, four explicit objectives have been established:

First objective aimed to identify the components constituting manufacturing flexibility while the second objective was to determine the relationship between manufacturing flexibility components and manufacturing performance measures. Third objective aimed to determine the relationship between manufacturing flexibility components and business performance measures. Last but not least, the fourth and final objective was to investigate the direct and indirect impact of manufacturing flexibility on business performance.

As an effort to fill the gap in the literature that indicated the limited studies carried out in the area of manufacturing flexibility for developing countries, manufacturing firms in Malaysia have been selected as the entity of the study. The samples collected provided fair representative of industrial coverage with diversity ensured. Data from 137 manufacturing firms comprising 5 industries has been collected, the detailed composition is as followed: basic metals and fabricated metal products (31 cases, 22.6%); machinery and equipment (26 cases, 19.0%); electronic, electrical equipment and components (34 cases, 24.8%); chemicals and chemical products (21 cases, 15.3%); and food products and beverages (25 cases, 18.2%). Individual respondents of the study consisted of managerial position in production or manufacturing area that are familiar with manufacturing activities, manufacturing performance and business performance. The respondents comprised of manager and director of the firm (61.2%), head of department (37.2%), and other managerial positions related to production or manufacturing (1.5%).

In addition, 91.2% of the respondents have been working in the company for more than three years. Hence, the respondents were considered knowledgeable to participate in this study. In order to fulfill the study objectives, manufacturing flexibility was examined by using seven components, which were most frequently used in several past studies i.e. mix flexibility, new product flexibility, labor flexibility, machine flexibility, material handling flexibility, routing flexibility and volume flexibility. Specifically, first objective aimed to identify the core components of manufacturing flexibility, where this objective can be considered as the foundation for subsequent analyses. Without knowing what is manufacturing flexibility and what it consist of, the result of further studying manufacturing flexibility would be less effective. In this study, seven components of manufacturing flexibility (mix flexibility, new product flexibility, labor flexibility, machine flexibility, material handling flexibility, routing flexibility and volume flexibility) have been identified through extensive literature review, where they are the most potent components that emerged from past researches.

Result of descriptive analysis (refer to Section 4.6) showed that the means of all manufacturing flexibility variables ranging from 3.989 to 4.456 (based on 6 point Likert-scale) which reflected that the extent of manufacturing flexibility implementation among Malaysia manufacturing firms was moderate to high. Pearson correlation analysis revealed the positive and significant relationship among manufacturing flexibility components with Pearson correlation coefficients (r) ranged between 0.294 and 0.788. Hence, this provides empirical evidence to support the interdependency of the manufacturing flexibility components.

In this study, manufacturing performance was institutionalized using product quality, inventory minimization, lead time reduction, productivity, and cost reduction. In addition, three measures were used to measure business performance, i.e. profitability, product market performance, and customer satisfaction.

From the performance perspective, descriptive analysis from Chapter 4 showed that manufacturing performance of Malaysia manufacturing firms was relatively high with the mean values ranged from 4.135 to 4.756, while business performance shown similar result with recorded mean values ranged between 4.040 and 4.372. Pearson correlation analysis provided evidences that there were positive and significant relationships among manufacturing performance measures ($0.519 \leq r \leq 0.779$) as well as among business performance measures ($0.565 \leq r \leq 0.733$).

On the viewpoint of relationships between the variables in this study, the results of Pearson correlation analysis indicated that all the seven manufacturing flexibility components were positively and significantly related to all the five manufacturing performance measures ($0.277 \leq r \leq 0.706$). Multiple regression analyses were conducted to measure the contribution of independent variables to a specific dependent variable. However, multicollinearity problems were detected in the regression model developed (see Section 4.9.1). To reduce the effects of multicollinearity in the independent variable, PCA was applied (Hair et al., 2013). Hence, the independent variables were examined collectively, rather than individually. The first principal component (manufacturing flexibility) explained 63.74% of the total variance of manufacturing flexibility components, which was adequate for further analyses.

Result of factor analyses as shown in Table 4.26 also supported the unidimensionality of manufacturing flexibility formed by the seven components, where 63.74% of variance of manufacturing flexibility has been explained by those components, this suggested that seven components of manufacturing flexibility can be grouped and unified as a single construct without major data lost and deem representable. The results shed light on understanding the synergy among the manufacturing flexibility components. That is, the seven components of manufacturing flexibility load on an overall construct which is termed as "manufacturing flexibility (MF)".

Subsequently, simple linear regression was conducted between the first principal component scores of manufacturing flexibility components and each measure of manufacturing performance to investigate the contribution of manufacturing flexibility components (collectively) to the measures of manufacturing performance. The results of the simple regression analysis are given in Table 4.23. In other word, for second objective to be answered, five testable hypotheses were developed and the summary of hypothesis testing is displayed in Table 5.1. Based on Table 5.1, all the specific hypotheses were supported indicating that manufacturing flexibility components (collectively) have positive relationship with manufacturing performance measures.

Table 5.1
Summary of Hypothesis Testing for the Relationship between Manufacturing Flexibility Components and Manufacturing Performance Measures

Hypotheses	**Result**
$H1_a$: Manufacturing flexibility components have a positive relationship with product quality	Supported
$H1_b$: Manufacturing flexibility components have a positive relationship with cost reduction	Supported
$H1_c$: Manufacturing flexibility components have a positive relationship with lead time reduction	Supported
$H1_d$: Manufacturing flexibility components have a positive relationship with productivity	Supported
$H1_e$: Manufacturing flexibility components have a positive relationship with inventory minimization	Supported

Three testable hypotheses have been developed as an effort to accomplish the third objective, which aimed to investigate the relationship between manufacturing flexibility components and business performance measures. Pearson correlation analysis suggested that all the three business performance measures, i.e., profitability, product market performance, and customer satisfaction are positively and significantly associated with manufacturing flexibility components ($0.341 \leq r \leq 0.675$). Once again, presence of multicollinearity detected in the regression model, and PCA and simple regression analysis were also applied to mitigate the influence of multicollinearity.

The results of simple regression analysis (refer Table 4.24) provided support that manufacturing flexibility components (collectively) have positive relationship with business performance measures. Summary of hypothesis testing is as shown in Table 5.2.

Table 5.2
Summary of Hypothesis Testing for the Relationship between Manufacturing Flexibility Components and Business Performance Measures

Hypotheses	**Result**
$H2_a$: Manufacturing flexibility components have a positive relationship with profitability	Supported
$H2_b$: Manufacturing flexibility components have a positive relationship with product market performance	Supported
$H2_c$: Manufacturing flexibility components have a positive relationship with customer satisfaction	Supported

To examine the relationship between manufacturing performance measures and business performance measures, three hypotheses were postulated. Based on Pearson correlation analysis, positive and significant relationship between the measures of manufacturing performance and business performance measures ($0.511 \leq r \leq 0.795$) was supported. Due to the manifestation of multicollinearity in the regression model, PCA was applied to reduce the effects of multicollinearity.

The results of PCA indicated that the first principal component of manufacturing performance explained 72.97% of the total variance of the manufacturing performance measures. To investigate the contributions of manufacturing performance measures (collectively) to each measure of business performance, the first principal scores of manufacturing performance measures obtained from PCA were regressed to each measure of business performance. The results of the simple regression analysis are exhibited in Table 4.25. Based on Table 4.25, manufacturing performance measures (collectively) contributed significantly to all measures of business performance. Table 5.3 shows that all hypotheses regarding the impact of manufacturing performance on business performance measures were supported.

Table 5.3
Summary of Hypothesis Testing for the Relationship between Manufacturing Performance Measures and Business Performance Measures

Hypotheses	**Result**
$H3_a$: Manufacturing performance measures have a positive relationship with profitability	Supported
$H3_b$: Manufacturing performance measures have a positive relationship with product market performance	Supported
$H3_c$: Manufacturing performance measures have a positive relationship with customer satisfaction	Supported

In order to achieve the fourth objective, mediation tests (following Baron and Kenny (1986)'s Approach and consolidated with PROCESS Macro for SPSS developed by Andrew F. Hayes were applied. The analysis led to the conclusion that manufacturing performance partially mediates the relationship between manufacturing flexibility and business performance. Higher direct impact of manufacturing flexibility on manufacturing performance than the direct impact of manufacturing flexibility on business performance have been seen, where manufacturing flexibility directly accounted for 61.10% of the total variance of business performance and also explained 62.10% of the total variance of manufacturing performance.

Additionally, manufacturing flexibility can directly and indirectly affect business performance with manufacturing performance taking the role as the mediator variable with 78.10% of total variance of business performance explained. Therefore, the last hypothesis (i.e. H_4: Manufacturing performance mediates the relationship between manufacturing flexibility and business performance) is partially supported.

The overall conclusions based on the findings are highlighted and listed as follows:

1. Manufacturing flexibility components constituting of (1) mix flexibility; (2) new product flexibility; (3) labor flexibility; (4) machine flexibility; (5) material handling flexibility; (6) routing flexibility; (7) volume flexibility have been implemented by a number of Malaysia manufacturing companies. Besides, most Malaysian firms have high implementations of manufacturing flexibility.
2. The positive and significant relationship among manufacturing flexibility components suggests that manufacturing flexibility components should be implemented collectively, integrally and comprehensively, because the practices are interdependent. Besides, this finding also confirmed the existence of complementarity between manufacturing flexibility components and negligence of those effects might lead to detrimental effect when applying manufacturing flexibility in the production line.
3. The correlations between manufacturing flexibility components and manufacturing performance measures, and between manufacturing flexibility components and business performance measures are positive and significant. This indicated that each manufacturing flexibility component relates individually to performance. This suggested that improving components of manufacturing flexibility would be an important factor in improving the performance position of a firm.
4. Manufacturing flexibility components (collectively) able to explain a significant percentage of the total variance in each of the measures of manufacturing performance (quality, inventory minimization, lead time reduction, productivity and cost reduction) and also a significant percentage of the total variance of business performance measures (profitability, product market performance and customer satisfaction). Thus, enhancing manufacturing flexibility components are

crucial since manufacturing flexibility is found to have tremendous effects on manufacturing performance and business performance.

5. Manufacturing performance measures (collectively) explain a significant percentage of the total variance in each of the measures of business performance. Hence, as a direct consequent, better manufacturing performance leads to better profitability, product market performance and customer satisfaction.
6. The mediation analyses highlight the role of manufacturing performance in mediating the relationship between manufacturing flexibility and business performance. The mediation tests have concluded that manufacturing performance partially mediates the relationship between manufacturing flexibility and business performance. Specifically, the higher extent of manufacturing flexibility implementation leads to higher manufacturing performance. Besides, manufacturing flexibility also leads to better business performance directly and indirectly through manufacturing performance as a mediator variable.
7. The direct effect of manufacturing flexibility on both manufacturing performance and business performance is significant. Based on the current study, the total effects (summation of direct effect and indirect effect) of manufacturing flexibility on business performance are remarkable high (in a positive way) and long-term benefits can be harvested by firms that implementing manufacturing flexibility holistically.

5.3 Discussion of the Results

Previous descriptions have confirmed that manufacturing flexibility components have been implemented by a number of Malaysia manufacturing firms (with mean values ranging from 3.989 to 4.456 as depicted in Table 4.11). This result is in-line with several preceding studies conducted in Malaysia such as Agus (2011) and Judi and Beach (2008). Based on the past studies, manufacturing firms in Malaysia have been committed to the implementation of manufacturing flexibility concept. However, holistic perspective of manufacturing flexibility are needed as an efforts to improve the level of manufacturing flexibility, so that manufacturing firms that practice manufacturing flexibility can gain the most benefits out of it.

This study was generally aimed to understand what constituted manufacturing flexibility, and tried to investigate the impact of manufacturing flexibility components on firm's performance empirically, where firms' performance was measured in two levels of hierarchy objective i.e. manufacturing performance and business performance (Bartezzaghi et al., 1992; Nawanir, 2011; Santos & Brito, 2012). Literature reviews have been carried out and provided support for seven manufacturing flexibility components - mix flexibility, new product flexibility, labor flexibility, machine flexibility, material handling flexibility, routing flexibility and volume flexibility (refer to section 2.2.4). Pearson correlation coefficients among manufacturing flexibility components are high, and results of factor analysis confirmed the unidimensionality for manufacturing flexibility, which suggested that the seven components together are potent enough to represent the concept of manufacturing flexibility.

In the same vein, the results of PCA for the seven manufacturing flexibility components also indicated that the components collectively supporting a single concept, which further supports the idea that manufacturing flexibility components must be implemented holistically. The first principal component or linear combination of the seven manufacturing flexibility components is as followed:

0.274 (Mix Flexibility) + 0.360 (New Product Flexibility) + 0.407 (Labor Flexibility) + 0.383 (Machine Flexibility) + 0.405 (Material Handling Flexibility) + 0.381 (Routing Flexibility) + 0.416 (Volume Flexibility).

The above linear equation has positive loading values and the loadings that are about equal. This provided the basis that each component is about equally represented in the linear composite with same importance of all manufacturing flexibility components on the first principal component. The first principal component obtained from PCA can explain about 63.64% of the variance in manufacturing flexibility components. As implied by Rogers et al. (2011), each of the manufacturing flexibility components is essential and critical for the success in the deployment of manufacturing flexibility concept, as no single component can be singulated. Manufacturing flexibility components that are applied comprehensively are expected to provide better performance. The above findings provide a better understanding of the relationships between various components of manufacturing flexibility. In addition, all the findings tend to support that manufacturing flexibility components should be implemented collectively and comprehensively, because the components are interdependent.

Subsequent subsections will discuss about the relationships between manufacturing flexibility, manufacturing performance and business performance while an in depth discussion regarding the mediation role of manufacturing performance in a link between manufacturing flexibility and business performance is presented.

5.3.1 The Relationship between Manufacturing Flexibility Components and Manufacturing Performance

Results of Pearson correlation analyses have provided empirical evidence that manufacturing flexibility components significantly and positively associated with all the measures of manufacturing performance. Simple regression analyses further emphasized that the first principal component scores of manufacturing flexibility components contributes significantly to all measures of manufacturing performance. The seven manufacturing flexibility components collectively explained a significant percentage of total variance of specific manufacturing performance measure. Henceforth, higher extent of manufacturing flexibility would lead to better manufacturing performance. This finding is consistent with the work by Rogers et al. (2011) and Sawhney (2013). In addition, Nawanir et al. (2013) and Bartezzaghi et al. (1992) also claimed that manufacturing performance is actually the internal properties of the manufacturing system, which is influenced by manufacturing practices applied (such as manufacturing flexibility).

In sum, based on the above findings, this study that focused in the context of Malaysia has provided supportive evidence that firms adopting manufacturing flexibility concept will gain tangible benefits. The benefits gain include lower cost, lower inventory level, higher quality, better productivity and lower lead time.

5.3.2 The Relationship between Manufacturing Flexibility Components and Business Performance

In examining the relationship between manufacturing flexibility components and business performance, Pearson correlation analyses once again providing evidence that manufacturing flexibility components positively and significantly associated with business performance measures. The result of simple regression analysis between the first principal component scores of manufacturing flexibility components and all measures of business performance leads to the conclusion that contributions of manufacturing flexibility on all three measures of business performance are substantial. Accordingly, the findings provide support that higher the extent of manufacturing flexibility, better business performance is expected. Specifically, instilment of manufacturing flexibility holistically can improve sales and market share, stimulate customer satisfaction and increase profitability.

Impacts of manufacturing flexibility on business performance has also been investigated by Mendes and Machado (2014) and Zhang et al. (2009). Both researchers have concluded that manufacturing flexibility significantly and positively affect business performance, which are in line with the findings in this research.

Numerous performance measures are suggested in the manufacturing flexibility literature, however most have not been tested empirically. A comprehensive set of measures was employed in this study to measure business performance and manufacturing performance and is later used to investigate the relationship between manufacturing flexibility and performance. Hence, this findings provide useful perspective for manufacturing firms throughout the world to collaborate and understand the potential benefits that manufacturing flexibility could offer.

5.3.3 The Relationship between Manufacturing Performance and Business Performance

The effect of manufacturing performance on business performance is incontestable (Nawanir et al., 2013; Rogers, 2008; Santos & Brito, 2012). The positive and significant relationship among manufacturing performance measures (refer Table 4.16) provided the evidence that all measures are interdependent. Principal component analysis has been used to generate the first principal component of manufacturing performance measures as show below:

0.419 (Product Quality) + 0.446 (Cost Reduction) + 0.434 (Lead Time Reduction) + 0.488 (Productivity) + 0.447 (Inventory Minimization).

The weights are approximately equal, so that all the manufacturing performance measures (quality, inventory minimization, productivity, lead time reduction and cost reduction) are equally represented in the linear composite. Accordingly, the first principal component of manufacturing performance measures could be interpreted as a measure of manufacturing performance. With the first principal component explained 72.97% of the total variance in manufacturing performance measures. The results of simple regression analysis between the first principal component scores of manufacturing performance measures and each of the business performance measures supported the previous opinions suggested by Roca-Puig et al. (2008) and Kaur et al. (2016) that manufacturing performance can foster business performance. In other word, better manufacturing performance leads to better business performance in terms of better market share growth, higher profitability and more satisfied customers.

5.3.4 The Mediation Role of Manufacturing Performance

The mediation test (refer Section 4.11) has provided evidence to support the role of manufacturing performance in mediating the relationship between manufacturing flexibility and business performance. All the seven manufacturing flexibility components (collectively) can directly enhance manufacturing performance (in terms of quality, inventory minimization, lead time reduction, productivity and cost reduction) and business performance (in terms of profitability, product market performance and customer satisfaction). Manufacturing performance partially mediates the relationship between manufacturing flexibility and business performance, which implies that manufacturing flexibility improves business performance both directly and indirectly via manufacturing performance as the mediator. This was in line with the previous prepositions (Camisón & López, 2010; Combs et al., 2005; Nawanir et al., 2013) that manufacturing performance can affect business performance as a mediator.

The overall results indicate that manufacturing performance asserted direct, positive and significant effects on business performance. Hence, those firms that strive to improve manufacturing performance will benefits in the long run. Therefore, the results substantiated the suspected manufacturing performance proposition regarding their mediation effects within the relationship between manufacturing flexibility components and business performance.

In sum, this study suggests that manufacturing flexibility components have positive impacts on both manufacturing performance and business performance, with manufacturing performance acts as a mediator. Firms may eventually see the benefits of manufacturing flexibility to business performance and also continued to perceive that manufacturing flexibility has great effect in increasing and sustaining manufacturing performance.

5.4 Implication of the Study

The results of this study are valuable as it provides good theoretical as well as methodological contributions to the development of manufacturing flexibility. Academicians and practitioners can have better understanding about the concept of manufacturing flexibility. Besides, it also fosters the practical understanding of manufacturing flexibility particularly on how to apply such concept. Details are explained in the following subsections.

5.4.1 Theoretical Implication

The theoretical relationships postulated in the theoretical framework (refer Figure 3.1) were empirically and theoretically supported, specifically using the local data collected from Malaysia manufacturing firms. Hence, this study should enrich the literature review, theories and ideas in manufacturing flexibility research in

Malaysia. Besides, verification by practitioners on the potential impacts of manufacturing flexibility indeed provides strong foundation for future research after current study.

The foremost implication provided by this study is the understanding regarding what is manufacturing flexibility and what constituted manufacturing flexibility. Without this first step, it was almost impossible for further research regarding the impact of manufacturing flexibility to be carried out. Collective effect of manufacturing flexibility components may be ignored as the concise list of manufacturing flexibility components is nonexistence.

This study providing the basis on what is manufacturing flexibility and what are its components with clarity. Without the clarity provided, confusion tends to arise as the loose use of the term “manufacturing flexibility” and “flexibility”, which sometimes used interchangeably. Without proper classification or definition of manufacturing flexibility, those not related to manufacturing flexibility (that is considered as internal flexibility of manufacturing system in this study) maybe included/perceived as part of its crucial. The most obvious example is supply chain flexibility that goes beyond the scope of manufacturing and involves multiple external parties such as supplier and logistics.

Another worth mentioned example is labor flexibility, within manufacturing system, it is undoubtful a big player in manufacturing flexibility, but if the scope of labor flexibility have been widen to the scope of flexibility (generally), one firm may has high labor flexibility simply by tuning on the fire/hiring of labor(s) (Nassirnia & Tap, 2010; Valverde, Tregaskis, & Brewster, 2000), which seem to be detrimental to the morale of the firm’s workforce. If the definitive definition of manufacturing flexibility is not well defined, volume flexibility may also have detrimental effect to one of the manufacturing performance indicators – the inventory minimization; as sales department of some firms may have very high volume flexibility with the removal of "economy order quantity", where tons of stocks are build and store in warehouse to fulfill the "flexibility in volume".

The confusion between new product flexibility and mix flexibility also arised from the same cause (manufacturing flexibility and its components that has loose end definition). In the viewpoint of manufacturing function, a modification in design (by design department) would be related with both mix flexibility and new product flexibility. If that modification does not substitute the original product, the number of types of product will be increased by one (affected mix flexibility). However, modification of product can also lead to the introduction of new product (affected new product flexibility). In other words, mix flexibility and new product flexibility need a clearer definition among themselves to provide distinction. This restressed the importance of proper definition of manufacturing flexibility and clear boundary within the manufacturing flexibility components (by using proper definition) to avoid confusion, which are in turn provided in this study.

Meanwhile, this study has explicitly confirmed the positive relationships between manufacturing flexibility, manufacturing performance and business performance. The study adds to the knowledge and theories on how manufacturing flexibility and its components can contribute to organizational performance, which encompass both manufacturing performance and business performance.

This study conceptualized the components of manufacturing flexibility and visualized the comprehensive approach of performance measurement. Concept of manufacturing flexibility should be applied holistically as a total system instead of piecemeal. Furthermore, importance of manufacturing performance (and its measures) as an important mediator variable between manufacturing flexibility and business performance has been supported. Existence of substantial direct and mediated effects of manufacturing flexibility on business performance have been found in this study, where improvement of manufacturing flexibility will improve manufacturing performance and eventually will improve business performance. This in turn providing clear evidence that instilment of manufacturing flexibility concept can enhance firms' performance.

Besides, this study provides original analysis of manufacturing flexibility, manufacturing performance and business performance in the manufacturing sector of Malaysia. Within the Malaysia context, this study enhances the understanding about the role of manufacturing flexibility in fostering performance increment, in the eyes of Malaysian manufacturing firms. In line with Swamidass (2000a)'s "*Encyclopedia of Production and Manufacturing Management*", this study further consolidated Swamidass claim where aggregate manufacturing flexibility is able to reduce lead time, inventory, lot sizes, foster new products introduction frequency and ultimately improving business profitability and also market share growth. Besides, this study also supports Swamidass's ideology that manufacturing flexibility can foster customer satisfaction by providing solid empirical evidence.

Additionally, this study supporting the ideas in resource-based view theory (RBV), where selected resources that can be strategically important in improving firms' performance and foster competitive advantage (in this case, the concept of manufacturing flexibility is the right "selected resource") should be focused of development. Other than that, manufacturing flexibility also fit the RBV concepts that focused on selecting a generic strategy and strategic choices that reinforce manufacturing strategy implementation, with the ultimate aim to enhance firm's performance. As manufacturing flexibility components used in this current study have been recognized as the powerful tools to enhance the firms' performance, this implies that the concept of manufacturing flexibility and its components, when pairing with the RBV approach, will reinforce the firms' performance. In other words, high extent of manufacturing flexibility and also the extensive usage of the RBV approach in a firm can lead to better firms' performance.

Another theory that are important to highlight was complementary theory, as manufacturing flexibility has long been recognized as a complex and multidimensional construct with a set or bundle of flexibility components (Larso et al., 2009; Rogers et al., 2011). Manufacturing flexibility components are interdependent; and when considered as a single entity collectively, it enhances the manufacturing performance and also business performance. This finding is in line with complementarity theory that assumes that separations of manufacturing flexibility's (a concept that are complex and multidimensional in the view of complementary theory) components are detrimental to the effort to enhancing firms' performance. Specifically, synergetic effects of manufacturing flexibility components are considered as one of the big players in determining the success of manufacturing flexibility implementation.

On the other hand, complementarity of each of the manufacturing flexibility components in enhancing firms' performance did consolidate the RBV ideology that manufacturing flexibility being valuable (as it foster competitive advantage and increase firms' performance), rare (a skill/concept that did not held by large number of organizations), inimitable (providing long term advantages that are hard to perfectly imitate by competitors due to causal ambiguity), and non-substitutable (cannot be substitute by other resource easily and economically).

Another noteworthy theoretical implication is the impacts of manufacturing performance on business performance. Literature review tend to suggest that manufacturing flexibility has significant impact on firm's performance, however, the findings of current study shown that the existence of indirect impact of manufacturing flexibility on business performance via manufacturing performance as a mediator variable, which in turn confirmed that manufacturing performance has a direct effect on business performance. Specifically, two hierarchy of performance emerged, where instilment of manufacturing flexibility leads to the improvement of manufacturing performance (lower hierarchy of performance) and ultimately leads to improvement of business performance (higher hierarchy of performance).

In sum, the results of this study enhance the theoretical understanding of manufacturing flexibility, its' components and its' relationships to performance.

5.4.2 Practical Implication

The results of this study offer several suggestions to adopters of manufacturing flexibility, where components or characteristics related to manufacturing flexibility have been pointed out (as depicted in Appendix E: Survey Questionnaire). With the aid of the questionnaire, practitioners can easily identify the key elements/actions to implement manufacturing flexibility. Furthermore, the questionnaire provided a guideline about what is manufacturing flexibility and what actions can lead to higher implementation level of manufacturing flexibility.

Besides, this study also allows practitioners and managers to gain further insights about the impact of manufacturing flexibility on organizational performance. For the success of implementing manufacturing flexibility, components of manufacturing flexibility should be implemented holistically because all the seven manufacturing flexibility components (i.e. mix flexibility, new product flexibility, labor flexibility, machine flexibility, material handling flexibility, routing flexibility and volume flexibility) are interdependent and equally important in enhancing organizational performance. That is, the management cannot be selective in implementing certain practices of manufacturing flexibility and ignoring others since all the components serve as building blocks of one philosophy/concept. The findings shed some light on why certain manufacturing flexibility initiatives often fail in firms that view the manufacturing flexibility components as a menu from which they may "pick and choose".

Although some of the practitioners claim that certain production process may require different combinations of manufacturing flexibility components, but nowadays, almost all the manufacturing systems tend to be hybrid (involving both continuous and discrete operations) (Abdulmalek, Rajgopal, & Needy, 2006). These seven components of manufacturing flexibility have been tested across five manufacturing industries involving 137 firms using different process type. Hence, the generalizability of the set of manufacturing flexibility components is enhanced. Thus, the manufacturing systems need all the components of manufacturing flexibility to tap the full benefits that offered by manufacturing flexibility. In practical sense, all seven components of manufacturing flexibility are applicable for most of the industry types, as they have been tested by many past researches across multiple industry groups (refer to Appendix A). Furthermore, this practical implication has consolidated the proposition of Jain et al. (2013) regarding the need to develop generalized sets of measures that span multiple industries for different components of manufacturing flexibility.

Meanwhile, according to Rogers et al. (2011), optimization of the production system is not feasible when manufacturing flexibility components are employed piecemealed due to the complementarity nature of this concept. The less number of manufacturing flexibility components that are employed the further away the firm's performance from being ideal. This has again stressed the important of holistic implementation of manufacturing flexibility. Besides, this study also help to translate manufacturing flexibility components into practices in manufacturing context and thus removing the barriers for manufacturing flexibility to become one of the "best practices" that are at par with Lean Manufacturing or Total Quality Management, as identifying and justifying the types of manufacturing flexibility (components) required with the tools to measure and assess the level of manufacturing flexibility implementation are the very first step for manufacturing flexibility to achieve the status of "best management practices" (Boyle, 2006).

In addition, this study confirms that when manufacturing flexibility is implemented integrally, performance of the firms increase in terms of better product quality, lower inventories, lower lead time, higher productivity, lower costs, higher profit, increment in market share and high customer satisfaction can be realized. Furthermore, the extent of manufacturing flexibility implementation in a firm can be measured using the questionnaire provided in this study, where it can be used to assess and justify the aspects of manufacturing flexibility that should be improved in order to enhance the organizational performance.

On the viewpoint of performance measurement, the success of manufacturing flexibility in improving firms' performance should be measured on both business level and operation level. Consistent with the balance scorecard approach, the questionnaire used in current study provided instrument to measure performance that encompassed the various aspects of organization performance. This provided a better overview of a firm's performance (Kaplan & Norton, 2005).

The questionnaire in Appendix E with instruments regarding performance measure is valuable to determine the firm's areas that need more attention while acting as a useful tool to validate the outcomes (manufacturing performance and business performance) obtained from manufacturing flexibility implementation.

Implementation of manufacturing flexibility is crucial for a firm to gain competitiveness and survive in the ever-changing external environment, and this is support by empirical evidence provided in this study, where increment of manufacturing flexibility enhances both manufacturing performance and business performance. Tremendous benefits can be tapped if manufacturing flexibility is implemented holistically and comprehensively, typically in terms of manufacturing performance and business performance.

Last but not least, current research provides a valuable perspective for manufacturing firms all over the world to appreciate the potential remunerations that manufacturing flexibility can offer. With the aim to build up the sustainable competitive advantage, embracing manufacturing flexibility would be an excellence choice. This study allowed practitioners or managers to gain deeper knowledge about the impacts of manufacturing flexibility. It provides evidence of the importance of manufacturing flexibility to organizational performance. It is hope that suggestions and ideas given in this study will help managers steer their firms toward being more successful in their business.

5.4.3 Methodological Implication

This study assessed the relationship between manufacturing flexibility, manufacturing performance and business performance using PCA scores and simple regression models due to multicollinearity problems that exist inside each of the constructs (refer Section 4.10). In other word, the components of manufacturing flexibility should be analysed collectively in order to determine the contribution of manufacturing flexibility. This raise an important consideration that whether the usage of multiple regression analyses are suitable for the examination of impacts of manufacturing flexibility on performance (both manufacturing performance and business performance), due to the violation of important assumption within regression analyses i.e. the independency amongst the predictor variables/independent variables cannot be assured. Therefore, prospective researchers are advice to focus on the impact of collective manufacturing flexibility components when analyzing manufacturing flexibility – performance relationship.

On the other hand, a limited number of performance indicators have been employed in various past researches in the area of manufacturing flexibility. Moreover, none of the research provided information about how the hierarchy of performance dictate the impact of manufacturing flexibility on them. This study provides some insight on how performance measures should be viewed, multi-layered as manufacturing performance and business performance, and providing comprehensive measures of performance indicators for both of them.

Incorporating these features in future endeavours may further enhance our understanding towards the critical link between manufacturing flexibility and performance. This suggestion also aligned with balance scorecard approach which emphasized that comprehensive view of performance provided better information for managerial decision (Kaplan & Norton, 2005).

5.5 Limitation of the Study and Suggestion for Future Research

There is no study that is without limitation. This study has the following limitations that open up avenues for future research.

Most of survey researches employed a general assumption in data collection, where respondents that participate in the survey were assumed to have sufficient knowledge to answer the questionnaire. It was also assumed that those respondents answered the measurement items meticulously and honestly. Although the manufacturing flexibility and performance scales used in the study has been pre-tested and passed the validity and reliability test, they could be further refined in future endeavours.

While several past studies in manufacturing sector stated that implementation of manufacturing related practices (manufacturing flexibility as an example) require long term commitment and the benefit of such practices cannot be realized in short term. Aside from this cross sectional study that gathering the data just once, longitudinal study may be considered to explore this issue further.

In interpreting the results, it is important to remember that the study was conducted in five industries (such as electrical and electronic related sector, machine and equipment fabricators, chemicals and chemical products producers, food products and beverages manufacturers and also metal related products) where generalization into others industry may be void. Study involving more industries can be carried out to further enhance the generalizability of the study regarding manufacturing flexibility. Besides, it was also potent to look into process type of those firms and try to understand the impact of process type towards the relationships between manufacturing flexibility and performance.

Past studies (refer to Chapter 2) have provided some indication that a number of others factors may have influences on manufacturing flexibility and ultimately firms' performance (some examples of factor are business strategy (Gupta & Somers, 1996), organizational innovation (Camisón & López, 2010) and etc.). This study focus on production area of a firm, future study may include the exterior area of production floor, which include but not limited to supply chain, customer relationships and etc. Once again, incorporating all the above features in future endeavours may further enhance our understanding about the relationships between manufacturing flexibility and performance.

This study employed regression analyses as the main analyses method to test for the mediating role of manufacturing performance on the relationship between manufacturing flexibility and business performance. For triangulation purposes, different data analyses methods such as Covariance-based Structural Equation

Modelling (CBSEM) may be considered. CBSEM is more concern with explanation and is appropriate method for theory testing (Hair et al., 2013). One can be more confident in a result if the use of different method leads to the same results. However, the CBSEM technique generally required higher sample sizes (typically more than 300 samples required for current study), where future researchers should be aware of the constraints in time/cost of applying such technique (Hair et al., 2013).

Data used in this study were collected from managerial personnel that are employed in the production area of Malaysia manufacturing firms through self-reporting survey. As the consequence, existence of common method variance (CMV) may be unavoidable (Hair et al., 2013). Procedural method was used to reduce common method variance. Specifically, the procedural method involved formatting the questionnaire so that manufacturing flexibility components' measurement items (independent variables), followed by manufacturing performance measures' measurement items (mediating variables) and then the measurement items for business performance measures (dependent variables) (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003; Rogers, 2008). This creates a psychological separation that make it appeared that the measurement of specific variable is not connected with or related to the measurement of another variable.

In addition, the Harman-single-factor test was also employed to assess the present of common method variance at the items level in the data. Twelve factors emerged from the factor analysis with eigenvalues greater than one, the first factor explained 47.50 % which is lower than the threshold value of 50% of the variance (Mat Roni, 2014). Alternatively, the results of confirmatory factor analysis also provides no support for a good fit, where less than 50% of the total variance was explained by a single factor model (Craighead, Ketchen, Dunn, & Hult, 2011; Mat Roni, 2014). Therefore, common method variance is not an issue in the current data set (Craighead et al., 2011; Mat Roni, 2014).

Collecting data from multiple individuals in a manufacturing company (for example, future research can consider collecting data regarding business performance from general manager or account director while data regarding manufacturing flexibility and manufacturing performance can be collected from production manager or production director) or employing mixed method of data collection such as collection of data using both primary and secondary data (data obtained from annual report where it is considered as objective data that did not suffer from CMV) and usage of qualitative data or mixture of both qualitative and quantitative data can be considered by future researches (Podsakoff et al., 2003). Different data collection methods can be applied in future studies to clear this uncertainty and consolidate the results from the current study.

On the other hand, even though product market performance (one of the business performance measures) registered a 90.78% percent of variance explained, more items can be added to better represent this performance indicator. Besides, an examination of the applicability or validity of the set of manufacturing flexibility components identified in this study in other contexts such as services operations or the entire supply chain may also provide a viable research avenue.

5.6 Conclusion

This study provided valuable insights for manufacturing firms on manufacturing flexibility, its components, the relationships between the components and effects of manufacturing flexibilities on performance. The results indicate that manufacturing flexibility which comprises of mix flexibility, new product flexibility, labor flexibility, machine flexibility, material handling flexibility, routing flexibility and volume flexibility has a significant positive impact on manufacturing performance which in turn, significantly affect the business performance. Of particular interest is the multidimensionality of manufacturing flexibility, and the interdependency of manufacturing flexibility components that create a synergistic effect to improve organizational performance.

This study is hoped to be beneficial especially to manufacturing firms. Manufacturing flexibility is a critical source of competitive advantage and the message for practitioners/managers is that those firms implementing manufacturing flexibility will benefit in the long run.

Finally, the researcher hopes that the findings and execution of this study would inspire interest towards future researches as more studies on this subject are necessary.

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APPENDICES

Appendix A: Examples of Flexibility Components Focus by Past Researchers

Authors	Manufacturing Flexibility Components
Browne et al. (1984)	1. Expansion Flexibility 2. Machine Flexibility 3. Process Flexibility (similar to mix flexibility) 4. Product Flexibility (similar to new product flexibility) 5. Routing Flexibility 6. Volume Flexibility 7. Operation Flexibility 8. Production Flexibility
Swamidass and Newell (1987) Machinery and machine tools industry, US	Aggregated manufacturing Flexibility (instrument indicate it was a mixture of mix and new product flexibility.
Sethi and Sethi (1990)	1. Material Handling Flexibility 2. Machine Flexibility 3. Operation Flexibility 4. Process Flexibility (similar to mix flexibility) 5. Product Flexibility (similar to modification flexibility) 6. Routing Flexibility 7. Volume Flexibility 8. Expansion Flexibility 9. Program Flexibility 10. Production Flexibility 11. Market Flexibility
Gupta and Somers (1996) Precision machinery; Electrical and electronics; Industrial machinery; Metal products; Automobile and auto part firms, US	1. Expansion Flexibility 2. Material Handling Flexibility 3. Routing Flexibility 4. Machine Flexibility 5. Market Flexibility 6. Product Flexibility (similar to new product flexibility) 7. Process Flexibility (similar to mix flexibility) 8. Programming Flexibility 9. Volume Flexibility
Narasimhan and Das (1999) Mechanical subassembly; Automotive/heavy machinery; Electronics and electrical; Chemicals, US	1. Volume Flexibility 2. Modification Flexibility 3. New product Flexibility
Vokurka and O'Leary-Kelly (2000)	1. Machine Flexibility 2. Material Handling Flexibility 3. Operations Flexibility 4. Labor Flexibility 5. Process Flexibility (similar to mix flexibility) 6. Routing Flexibility 7. Product Flexibility (similar to new product flexibility) 8. New Design Flexibility (similar to new product flexibility) 9. Delivery Flexibility 10. Volume Flexibility 11. Expansion Flexibility 12. Program Flexibility 13. Production Flexibility 14. Market Flexibility

Appendix A (Continued)

Authors	**Manufacturing Flexibility Components**
D'Souza and Williams (2000) Directory of Texas Manufacturers 1996 – Cross industries, US	1. Volume Flexibility 2. Variety Flexibility (mixture of new product flexibility and mix flexibility) 3. Process Flexibility (mixture of machine flexibility and mix flexibility) 4. Material Flexibility (similar to material handling flexibility)
Jack (2000) Various industries including aerospace, chemicals, machinery, agriculture, automotive, electronics and electrical, food, medical and health care, paper, utilities and also packaging, US	Volume Flexibility
Chang et al. (2002) Electronics, Taiwan	1. New Product Flexibility 2. Volume Flexibility 3. Product Mix Flexibility
Zhang et al. (2003) Fabricated metal products; Industrial/commercial machinery; Electronic and electrical; Transportation equipment; Measurements equipment, US	1. Mix Flexibility 2. Volume Flexibility 3. Flexible Manufacturing Competence (mixture of machine, labor material handling and routing flexibility)
Koste et al. (2004) Electronics; Machinery; Metal products, US	1. Machine Flexibility 2. Labor Flexibility 3. Material Handling Flexibility 4. Mix Flexibility 5. New Product Flexibility 6. Modification Flexibility
Jantan et al. (2006) Electronics, Malaysia	1. Product Flexibility (similar to mix flexibility) 2. Volume Flexibility 3. Launch Flexibility (similar to new product flexibility)
Rogers (2008) Metal fabrication; Electronics; Automotive; Healthcare/medical devices; Aviation/aerospace; Food/beverages; Plastics/rubber; Electrical; Pharmaceuticals/Chemicals; Transportation; Software/Hardware, US	1. Mix Flexibility 2. Routing Flexibility 3. Volume Flexibility 4. Labor Flexibility 5. Supply Management Flexibility
Judi and Beach (2008) Electronics industry, UK and Malaysia	1. Volume Flexibility 2. Variety Flexibility (also known as mix flexibility) 3. Process Flexibility (similar to routing flexibility) 4. Material Handling Flexibility
Larso et al. (2009) Electronics, US	1. New Product Flexibility 2. Routing Flexibility 3. Modification Flexibility 4. Operation Flexibility 5. Labor Flexibility 6. Machine Flexibility 7. Material Handling Flexibility 8. Volume Flexibility

Appendix A (Continued)

Authors	**Manufacturing Flexibility Components**
Camisón and López (2010) 19 industries of Spanish industrial firms from SABI database excluding service, agricultural and energy sector, Spain	Aggregated manufacturing Flexibility (instrument indicate it was a mixture of mix, modification and volume flexibility)
Torres, Jose Benitez-Amado, Perez-Arostegui, and Barrales-Molina (2011) SABI database involved 30 industrial sectors, Spain	1. Routing Flexibility 2. Material Handling Flexibility
Tamayo-Torres et al. (2011) SABI database involved 30 industrial sectors, Spain	1. Routing Flexibility 2. Sequence Flexibility (similar to operation flexibility) 3. Modification Flexibility 4. Material Handling Flexibility 5. Machine Flexibility 6. Mix Flexibility
Rogers et al. (2011) Metal fabrication; Electronics; Automotive; Healthcare/medical devices; Aviation/aerospace; Food/beverages; Plastics/rubber; Electrical; Pharmaceuticals/Chemicals; Transportation; Software/Hardware, US	1. Mix Flexibility 2. Volume Flexibility 3. Machine Flexibility 4. Labor Flexibility 5. Routing Flexibility 6. Supplier Management flexibility
Patel et al. (2012)	1. Machine Flexibility 2. Labor Flexibility 3. Material Handling Flexibility 4. Mix Flexibility 5. New Product Flexibility
Al-jawazneh (2012) Pharmaceutical, Jordan	1. Machine Flexibility 2. Volume Flexibility 3. Material Handling Flexibility 4. Mix Flexibility 5. Routing Flexibility
Chauhan and Singh (2014) Automotive; Machinery; Metal industries, India	1. Resource Flexibility (mixture of labor and machine flexibility)
Mendes and Machado (2014) Automotive industry; International (Europe, China, Brazil, US, Africa, Central America)	1. New Product Flexibility 2. Mix Flexibility 3. Volume Flexibility

Appendix B: Definitions of Manufacturing Flexibility's Components for Past Study

Components of Manufacturing Flexibility	Definition	Author(s)
Mix Flexibility	The ability of a manufacturing system to switch between different products in the product mix.	Narasimhan and Das (1999)
	The number and variety of products can be produced without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The capability of producing a number of product lines or numerous variations within a line.	Berry and Cooper (1999)
	The ability of a given manufacturing system to cope with the changes related to product mix.	Gupta (2004)
	The ability to change the range of products made within a given time period.	Slack (2005)
	The ability of the system to produce many different products during the same planning period.	Judi and Beach (2008)
	The ability to offer a broad product line by switching quickly/easily between products.	Rogers (2008)
	The ability to produce variety of products.	Helkiö (2008)
	The ability to manufacture a wide range of products or variants with expected low changeover costs.	Fernandes, Gouveia, and Pinho (2012)
Volume Flexibility	The ability to operate an FMS profitably at different production volumes.	Browne et al. (1984)
	The ability to be operated profitably at different overall output levels.	Sethi and Sethi (1990)
	The ability to vary production with no detrimental effect on efficiency and quality.	Suarez et al. (1996)
	Capability of the system to respond to volume fluctuations and to expand production on short notice beyond normal installed capacity.	Narasimhan and Das (1999)
	The extent of change and the degree of fluctuation in aggregate output level which the system can accommodate without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability to profitably increase or decrease aggregate production (output) in response to changes in customer demand.	Jack (2000)
	The ability of manufacturing system to overcome changes in the aggregate volume.	Gupta (2004)
	The ability to produce varying levels of output at a profit within a minimum planning period.	Sawhney (2006)
	The ability to change the level of aggregated output.	Slack (2005)
	The ability to operate profitably at different output volumes.	Rogers (2008)
	The ability to respond to varying levels of aggregate demand.	Helkiö (2008)
	The ability of the manufacturing system to change the volume or output of a manufacturing process.	Judi and Beach (2008)

Appendix B (Continued)

Components of Manufacturing Flexibility	Definition	Author(s)
New Product Flexibility	The ability of the manufacturing system to incorporate new product into the existing range of products.	Gupta and Somers (1992); Gupta and Somers (1996)
	The time starting from the earliest stage of design (customer product definition) and ending in the date when the first production batch of a "salable" product was made, after prototypes and pilot low-volume runs were completed.	Suarez et al. (1996)
	The number and variety of new products which are introduced into production without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	Capability of the firm to design, prototype, and produce new products to meet stringent time and cost constraints.	Narasimhan and Das (1999)
	The ability to introduce new products into production.	Helkiö (2008)
Machine Flexibility	The ease of making the changes required to produce a given set of part types.	Browne et al. (1984)
	Various types of operations that the machine can perform without requiring a prohibitive effort in switching from one operation to another.	Sethi and Sethi (1990)
	The number and variety of operations a machine performs without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability of machines to perform variety of processing tasks.	Helkiö (2008)
Material handling Flexibility	The ability to move different part types efficiently for proper positioning and processing through the manufacturing facility it serves.	Sethi and Sethi (1990)
	The ability of the material handling system to move material effectively through the plant.	Narasimhan and Das (1999)
	The number of existing paths between processing centers and variety of material which can be transported along those paths without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability of material handling system to transport multiple different materials and ability to transport materials via multiple different paths between processing centers.	Helkiö (2008)
	The ability of the material handling system to transport different materials between various processing centers over multiple paths.	Judi and Beach (2008)

Appendix B (Continued)

Components of Manufacturing Flexibility	Definition	Author(s)
Labor Flexibility	The number and variety of operations a worker performs without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability of workers to perform multiple production tasks.	Helkiö (2008)
	The ability of workers to perform multiple tasks effectively.	Rogers (2008); Rogers et al. (2011)
Modification Flexibility	The number and variety of product modifications that are accomplished without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The amounts of product modifications which are accomplished without increasing change over time, changeover cost and scheduling efforts while maintain its quality, efficiency and productivity.	Koste and Malhotra (1999b)
	Capability of the system to make minor changes in product design to meet customization demand.	Narasimhan and Das (1999)
	The ability to accommodate product design changes in production.	Helkiö (2008)
	The ability to make minor modifications to existing products within a minimum planning period.	Larso et al. (2009)
Routing Flexibility	The ability to handle breakdowns and to continue producing the given set of part types.	Browne et al. (1984)
	The ability to produce a part by alternate routes through the system.	Sethi and Sethi (1990)
	The ability to vary machine visitation sequences for processing a part.	Narasimhan and Das (1999)
	The number of parts that have alternate routes and the extent of variation among the routes used without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability to move different parts between machines/processing centers.	Rogers (2008)
	The ability to change the sequence of machines that perform operations.	Helkiö (2008)
	The ability to vary the path a part may take through the manufacturing system.	Nishith et al. (2013)
Delivery Flexibility	The ability of the system to respond to changes in delivery requests.	Vokurka and O'Leary-Kelly (2000)
	The ability to vary delivery schedule	Chang et al. (2003)
	The ability to change planned or assumed delivery dates.	Slack (2005)
	The ability to shorten or lengthen delivery times.	Sawhney (2006)

Appendix B (Continued)

Components of Manufacturing Flexibility	Definition	Author(s)
Expansion Flexibility	The capability of building a system, and expanding it as needed, easily and modularly.	Browne et al. (1984)
	The ease with which its capacity and capability can be increased when needed.	Sethi and Sethi (1990)
	The ability to expand capacity without prohibitive effort.	Narasimhan and Das (1999)
	The number and variety of expansions which can be accommodated without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability to expand (capacity, capability) production system.	Helkiö (2008)
Program Flexibility	The ability of the system to run virtually untended for a long enough periods.	Sethi and Sethi (1990)
	The ability of equipment to run unattended for long periods of time.	Narasimhan and Das (1999)
Production Flexibility	The universe of part types that the FMS can produce.	Browne et al. (1984)
	The universe of part types that the manufacturing system can produce without adding major capital equipment.	Sethi and Sethi (1990)
	Range of products the system can produce without adding new equipment.	Vokurka and O'Leary-Kelly (2000)
Market Flexibility	The ease with which the manufacturing system can adapt to a changing market environment.	Sethi and Sethi (1990)
	The ability of the manufacturing system to adapt to or influence market changes.	Narasimhan and Das (1999)
	The ability to mass customize and build close relationships with customers, including design and modifying new and existing products.	Duclos et al. (2003)
Operations Flexibility	The ability to interchange the ordering of several operations for each part type.	Browne et al. (1984)
	The ability of a part to be produced in different ways.	Sethi and Sethi (1990)
	The number of parts that have alternate sequencing plans and the variety of the processing sequences used without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The number of alternative processes or ways in which a part can be produced within the system.	Vokurka and O'Leary-Kelly (2000)
	The ability to change the sequence of operations performed.	Helkiö (2008)
Supply Management Flexibility	Suppliers' ability to respond to buyer requests to adjust order quantities without significantly increasing lead time or unit cost.	Rogers (2008)

Appendix C: Measurement Items

Appendix C1: Measurement Items of Manufacturing Flexibility Components

ID	Item	Literature
Mix Flexibility		
MX1	We economically change from producing one product to another.	Das (2001) and Judi and Beach (2008)
MX2	We vary the product combination from one period to the next.	Al-jawazneh (2012) and Rogers (2008)
MX3	We quickly change from producing one product to another.	Al-jawazneh (2012) and Judi and Beach (2008)
MX4	We produce different product types without major changeovers.	Al-jawazneh (2012) and Rogers (2008)
MX5	We easily change from producing one product to another.	Al-jawazneh (2012) and Rogers (2008)
New Product Flexibility		
N1	We frequently introduce new products into the production line.	Rogers (2008)
N2	The introduction of a new product into the production schedule is easy.	Koste (1999)
N3	We quickly add new product(s) into the existing range of products.	D'Souza and Williams (2000) and Koste (1999)
N4	We are able to produce new product types without major changeovers.	Proposed
N5	We are able to respond to customer requests for design changes in a given product.	Proposed
Labor Flexibility		
L1	Production workers are cross-trained to perform a variety of tasks.	Koste (1999) and Rogers (2008)
L2	Production workers are responsible for more than one task.	Chauhan and Singh (2014)
L3	Production workers are able to perform a wide range of operations economically.	Chauhan and Singh (2014) and Koste (1999)
L4	A typical production worker uses different tools effectively.	Rogers (2008)
L5	Production workers operate various types of machines.	Chang (2004) and Rogers (2008)
L6	Production workers can perform tasks which differ greatly from one another.	Chauhan and Singh (2014) and Koste (1999)
L7	We easily assign the production workers another task.	Chauhan and Singh (2014)

Appendix C1 (Continued)

ID	Item	Literature
Machine Flexibility		
MC1	Machines are equally reliable for all operations.	Chauhan and Singh (2014); Koste (1999); Russell and Taylor (2014) and Tamayo-Torres et al. (2011)
MC2	Our production prefers to use general-purpose machine, which might be used to perform a number of operations.	Larso et al. (2009); Rogers (2008) and Russell and Taylor (2014)
MC3	When one machine is stopped, we can use different type of machine to perform the same tasks.	Hirano (1989) and Russell and Taylor (2014)
MC4	Our typical machine performs many types of operations.	Al-jawazneh (2012); Rogers (2008) and Russell and Taylor (2014)
MC5	Machines changeovers between operations are inexpensive.	Chauhan and Singh (2014) and Koste (1999)
Material Handling Flexibility		
MH1	The material handling system can handle a wide variety of parts.	Al-jawazneh (2012); Judi and Beach (2008); Larso et al. (2009) and Tamayo-Torres et al. (2011)
MH2	Material handling changeovers between parts can be done economically.	Judi and Beach (2008)
MH3	Material handling changeovers between parts can be done quickly.	Al-jawazneh (2012) and Judi and Beach (2008)
MH4	Material handling changeovers between parts can be done easily.	Al-jawazneh (2012) and Judi and Beach (2008)
MH5	Our material handling system handles different types of part.	Judi and Beach (2008) and Rogers (2008)
MH6	Our material handling system can be reconfigured quickly.	Al-jawazneh (2012) and Rogers (2008)

Appendix C1 (Continued)

ID	Item	Literature
Routing Flexibility		
R1	The manufacturing system has alternative routes in case machines break down.	Al-jawazneh (2012); Rogers (2008) and Zhang et al. (2003)
R2	A typical part operation can be routed to different machines.	Al-jawazneh (2012) and Rogers (2008)
R3	We use many different routes to produce a product type.	Judi and Beach (2008) and Rogers (2008)
R4	We are able to change sequence of steps in production process economically.	Judi and Beach (2008)
R5	Machine visitation sequence can be changed quickly.	Al-jawazneh (2012) and Rogers (2008)
R6	Routing paths for manufacturing products can be changed economically.	Koste (1999) and Larso (2004)
Volume Flexibility		
V1	We run a range of production volumes.	Al-jawazneh (2012); Judi and Beach (2008) and Koste (1999)
V2	Output rates for all products can be varied.	Al-jawazneh (2012) and Koste (1999)
V3	We are able to increase or decrease our production volume quickly.	Judi and Beach (2008) and Larso et al. (2009)
V4	We are able to run various batch sizes.	Al-jawazneh (2012) and Rogers (2008)
V5	We are able to increase or decrease our production volume easily.	Al-jawazneh (2012); Koste (1999) and Rogers (2008)
V6	We vary total quantity of output from one period to the next.	Al-jawazneh (2012)

Appendix C2: Measurement Items of Manufacturing Performance

ID	Item	Literature
Product Quality		
Q1	We are able to produce quality products.	Al-jawazneh (2012) and Nawanir et al. (2013)
Q2	We have superior product quality compared to our competitors'.	Nawanir et al. (2013)
Q3	The percentage of poor quality products that must be scrapped has reduced.	Nawanir et al. (2013)
Q4	The percentage of production outputs that do not meet quality specifications has reduced.	Nawanir et al. (2013)
Q5	The percentage of products that pass final inspection the first time (first-pass yield) has increased.	Nawanir et al. (2013) and Russell and Taylor (2014)
Cost Reduction		
CR1	Our total manufacturing cost (including labor, material and overhead) to produce the product has reduced.	Al-jawazneh (2012) and Das (2001)
CR2	Our unit manufacturing cost has reduced (unit manufacturing cost is the total cost for producing the units divided by the number of units produced).	Al-jawazneh (2012); Nawanir et al. (2013) and Rogers (2008)
CR3	Our unit manufacturing cost is lower than the competitors.	Al-jawazneh (2012) and Nawanir et al. (2013)
CR4	Our internal failure costs (i.e., cost of defect, scrap, rework, process failure, and downtime) have reduced.	Nawanir et al. (2013) and Rogers (2008)
CR5	Our external failure costs (i.e., complaints, returns, warranty claims, liability and lost sales) have reduced.	Nawanir et al. (2013)
CR6	Our total inventory costs (costs related to storing and maintaining the inventory such as raw materials, work in process, and finished goods over a certain period of time) has reduced.	Sambasivan et al. (2009)

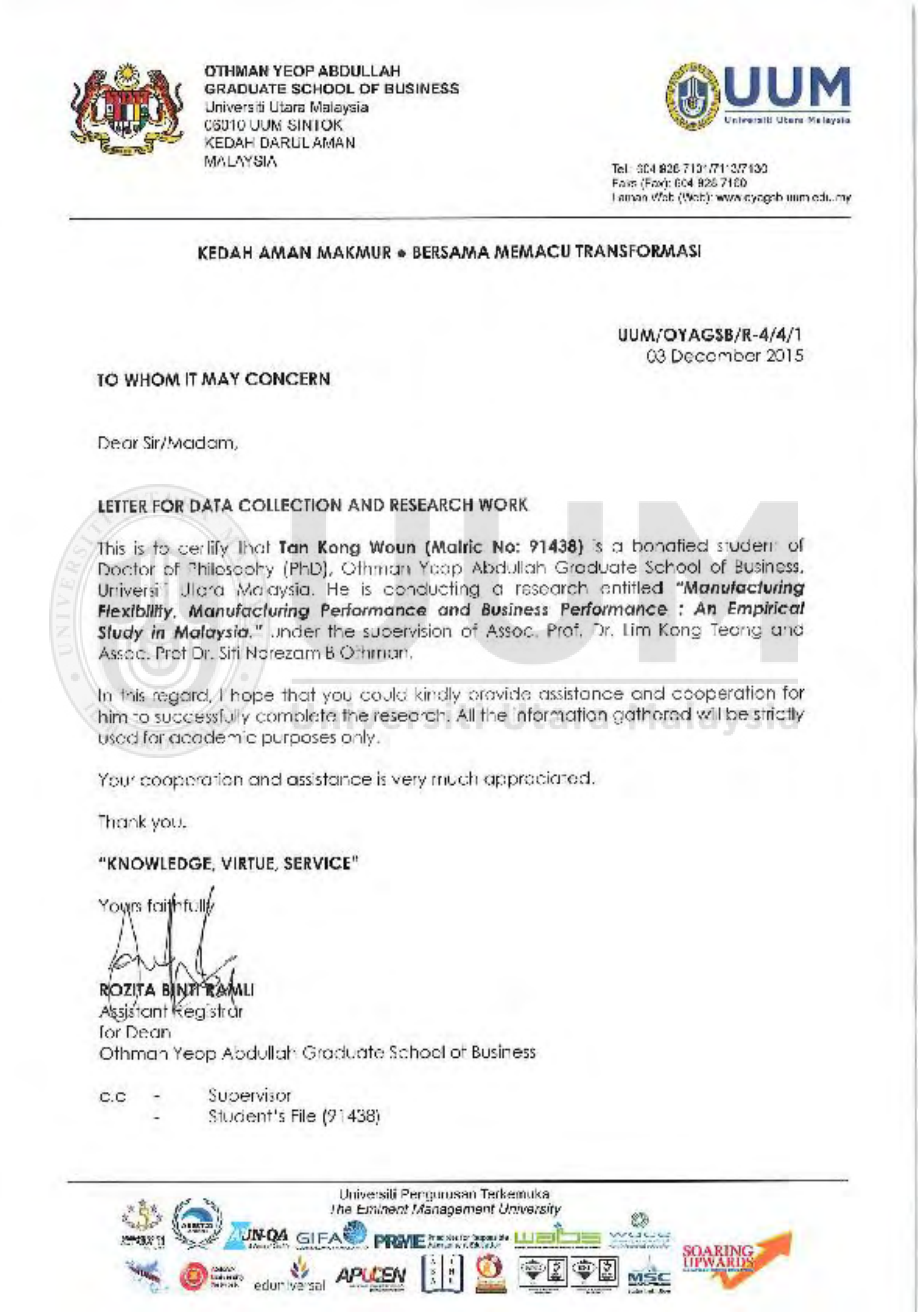
Appendix C2 (Continued)

ID	Item	Literature
Lead Time Reduction		
LR1	Our manufacturing cycle time (i.e., from raw material to finished goods) is competitive.	Al-jawazneh (2012); Nawanir et al. (2013) and Russell and Taylor (2014)
LR2	The moving times for materials from storage to workstation have reduced.	Nawanir et al. (2013) and Russell and Taylor (2014)
LR3	Machine setup times have reduced.	Nawanir et al. (2013) and Russell and Taylor (2014)
LR4	The times required to perform the productive operations have reduced.	Nawanir et al. (2013) and Russell and Taylor (2014)
LR5	The moving times for parts between workstations have reduced.	Nawanir et al. (2013) and Russell and Taylor (2014)
LR6	The queuing times for parts waiting for the works to begin because another order is being processed at a workstation have reduced.	Nawanir et al. (2013) and Russell and Taylor (2014)
Productivity		
PT1	Productivity of our production line has increased due to more efficient machine setups.	Nawanir et al. (2013)
PT2	Productivity of our production line has increased due to more efficient production processes.	Nawanir et al. (2013)
PT3	Productivity of our production line has increased due to reduced inputs (such as labor, material and overhead).	Nawanir et al. (2013)
PT4	Our machine productivity has increased.	Nawanir et al. (2013)
PT5	The overall productivity of our production line has been outstanding.	Nawanir et al. (2013)
Inventory Minimization		
IM1	Work-in-process (WIP) inventory level has reduced.	Nawanir et al. (2013) and Rogers (2008)
IM2	Raw material inventory level has reduced.	Nawanir et al. (2013) and Rogers (2008)
IM3	Finished goods inventory level has reduced.	Nawanir et al. (2013) and Rogers (2008)
IM4	Overall inventory level has reduced.	Nawanir et al. (2013) and Rogers (2008)
IM5	Storage space requirement has reduced.	Nawanir et al. (2013)

Appendix C3: Measurement Items of Business Performance

ID	Item	Literature
Profitability		
PF1	Our revenue growth rate has been outstanding.	Carton and Hofer (2006); Nawanir et al. (2013) and Santos and Brito (2012)
PF2	Our ability to earn a profit has exceeded our competitors'.	Carton and Hofer (2006) and Nawanir et al. (2013)
PF3	Our return on investment (ratio of net income to total investment) reflects sound investments.	Carton and Hofer (2006); Nawanir et al. (2013) and Santos and Brito (2012)
PF4	Our overall financial performance has been outstanding.	Carton and Hofer (2006) and Chearskul (2010)
Product Market Performance		
PM1	Our market share has increased significantly.	Nawanir et al. (2013) and Richard et al. (2009)
PM2	Our market share growth has exceeded our competitors'.	Nawanir et al. (2013) and Richard et al. (2009)
PM3	Our sales (in volume) growth has been outstanding.	Camisón and López (2010); Nawanir et al. (2013) and Richard et al. (2009)
Customer Satisfaction		
CS1	Our customer satisfaction performance has exceeded our competitors'.	Jack (2000) and Nawanir et al. (2013)
CS2	Our customers are satisfied with the quality of our products.	Nawanir et al. (2013) and Zhang et al. (2009)
CS3	Our customers are satisfied with our on time delivery performance.	Jack (2000) and Nawanir et al. (2013)
CS4	Our customers are satisfied with our ability to respond to customer changing needs.	Proposed
CS5	The number of customer complaints has reduced.	Sambasivan et al. (2009) and (Santos and Brito (2012))

Appendix D: Letter for Data Collection and Research Work



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KEDAH AMAN MAKMUR • BERSAMA MEMACU TRANSFORMASI

UUM/OYAGSB/R-4/4/1
03 December 2015

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

LETTER FOR DATA COLLECTION AND RESEARCH WORK

This is to certify that **Tan Kong Woun (Matric No: 91438)** is a bonafied student of Doctor of Philosophy (PhD), Othman Yeop Abdullah Graduate School of Business, Universiti Utara Malaysia. He is conducting a research entitled ***"Manufacturing Flexibility, Manufacturing Performance and Business Performance : An Empirical Study in Malaysia,"*** under the supervision of Assoc. Prof. Dr. Lim Kong Teong and Assoc. Prof Dr. Siti Norezam B Othman.

In this regard, I hope that you could kindly provide assistance and cooperation for him to successfully complete the research. All the information gathered will be strictly used for academic purposes only.

Your cooperation and assistance is very much appreciated.

Thank you.

"KNOWLEDGE, VIRTUE, SERVICE"

Yours faithfully

ROZITA BINTI RAMLI
Assistant Registrar
for Dean
Othman Yeop Abdullah Graduate School of Business

c.c - Supervisor
- Student's File (91438)

Universiti Pengurusan Terkemuka
The Eminent Management University

SOARING UPWARDS

Appendix E: Survey Questionnaire

RESEARCH ON MANUFACTURING FLEXIBILITIES AND PERFORMANCE OF MALAYSIA MANUFACTURING COMPANIES

General Information:
This is a PhD research to determine the impact of the manufacturing practices, which are consistent with the manufacturing flexibility philosophy, on organizational performance. The researchers believed that the outcome of this research will be of immense benefits to improve the performance in the Malaysia manufacturing sector. Your effort in filling the questionnaire is highly appreciated in order to produce a quality research.

General Instruction:
The questionnaire consists of four sections. Please read the items carefully before answering. You are expected to choose the answer that represents your opinion. Your answer plays an important role in the success of this study and you are assured that such information will be treated with **utmost confidentiality**. Please tick, circle the appropriate answer or complete the answer in the space provided.

Thanks for your participation.

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Section One: Company's Background Information

Nature of your business

☐ Basic metals and fabricated metal products
☐ Machinery & Equipment
☐ Electronic, electrical equipment and components
☐ Chemicals and Chemical Products
☐ Food Products and Beverages
☐ Others (please specify): ____________________________

Company's ownership

☐ State owned enterprise
☐ Private enterprise
☐ Foreign invested enterprise
☐ Joint venture
☐ Others (please specify): ___________________________

Number of employees

☐ <50 employees
☐ 150 - 199 employees
☐ 50 – 99 employees
☐ 200 – 499 employees
☐ 100 – 149 employees
☐ 500 employees and above

Annual sales 2015

☐ Less than RM 10 million
☐ RM 10 million – RM 25 million
☐ More than RM 25 million to RM50 million
☐ More than RM50 million

Products Manufactured (please specify):

____
____
____

Which of the following process type best represent your production process?

☐ Job shop process
(Low production volume, High variety)

☐ Batch process
(Medium production volume, Medium variety)

☐ Repetitive process
(High production volume, Low variety)

☐ Continuous flow process
(Very High production volume, No variety)

☐ Mass Customization process
(Very High production volume, High variety)

☐ Others (please specify): ___________________________

Your position in the company

☐ Director of production/manufacturing
☐ Head of production/manufacturing department
☐ Manager of production/manufacturing
☐ Others (please specify): ______________________________

How long have you been working in this company?

☐ Less than 3 years
☐ 3 – 5 years
☐ 6 – 10 years
☐ More than 10 years

How long have you been in the current position?

☐ Less than 1 year
☐ 1 – 3 years
☐ 4 – 10 years
☐ More than 10 years

Section Two: Manufacturing Flexibility

Direction:

This section focuses on the level of manufacturing flexibility capabilities in your manufacturing system. It addresses the components of Manufacturing Flexibility representing each of the dimensions.

On the following scale, please evaluate the level of mix flexibility and new product flexibility in your manufacturing system by circling the appropriate number.

Strongly Disagree	**Disagree**	**Somewhat disagree**	**Somewhat agree**	**Agree**	**Strongly Agree**
1	**2**	**3**	**4**	**5**	**6**

Items/Statements	**Level of Agreement**					
A. Mix Flexibility – The ability of the manufacturing system to switch between different products in the product mix.						
1. We economically change from producing one product to another.	**1**	**2**	**3**	**4**	**5**	**6**
2. We vary the product combination from one period to the next.	**1**	**2**	**3**	**4**	**5**	**6**
3. We quickly change from producing one product to another.	**1**	**2**	**3**	**4**	**5**	**6**
4. We produce different product types without major changeovers.	**1**	**2**	**3**	**4**	**5**	**6**
5. We easily change from producing one product to another.	**1**	**2**	**3**	**4**	**5**	**6**
B. New Product Flexibility – The ability of the manufacturing system to incorporate new product(s) into the existing range of products.						
1. We frequently introduce new products into the production line.	**1**	**2**	**3**	**4**	**5**	**6**
2. The introduction of a new product into the production schedule is easy.	**1**	**2**	**3**	**4**	**5**	**6**
3. We quickly add new product(s) into the existing range of products.	**1**	**2**	**3**	**4**	**5**	**6**
4. We are able to produce new product types without major changeovers.	**1**	**2**	**3**	**4**	**5**	**6**
5. We are able to respond to customer requests for design changes in a given product.	**1**	**2**	**3**	**4**	**5**	**6**

On the following scale, please evaluate the level of labor flexibility and machine flexibility in your manufacturing system by circling the appropriate number.

Strongly Disagree	**Disagree**	**Somewhat disagree**	**Somewhat agree**	**Agree**	**Strongly Agree**
1	**2**	**3**	**4**	**5**	**6**

Items/Statements	**Level of Agreement**					
C. Labor Flexibility – The ability of production workers to perform more than one task in the manufacturing system.						
~~1. Production workers are cross-trained to perform a variety of tasks.~~	**1**	**2**	**3**	**4**	**5**	**6**
2. Production workers are responsible for more than one task.	**1**	**2**	**3**	**4**	**5**	**6**
3. Production workers are able to perform a wide range of operations economically.	**1**	**2**	**3**	**4**	**5**	**6**
4. A typical production worker uses different tools effectively.	**1**	**2**	**3**	**4**	**5**	**6**
5. Production workers operate various types of machines.	**1**	**2**	**3**	**4**	**5**	**6**
6. Production workers can perform tasks which differ greatly from one another.	**1**	**2**	**3**	**4**	**5**	**6**
7. We easily assign the production workers another task.	**1**	**2**	**3**	**4**	**5**	**6**
D. Machine Flexibility – The ability of the manufacturing machine to perform more than one operation to produce different parts or products.						
1. Machines are equally reliable for all operations.	**1**	**2**	**3**	**4**	**5**	**6**
2. Our production prefers to use general-purpose machine, which might be used to perform a number of operations.	**1**	**2**	**3**	**4**	**5**	**6**
3. When one machine is stopped, we can use different type of machine to perform the same tasks.	**1**	**2**	**3**	**4**	**5**	**6**
4. Our typical machine performs many types of operations.	**1**	**2**	**3**	**4**	**5**	**6**
~~5. Machines changeovers between operations are inexpensive.~~	**1**	**2**	**3**	**4**	**5**	**6**

Remark: Strikethrough sentences are omitted items with factor loading less than 0.70 (refer Table 4.8)

On the following scale, please evaluate the level of material handling flexibility, routing flexibility and volume flexibility in your manufacturing system by circling the appropriate number.

Strongly Disagree	**Disagree**	**Somewhat disagree**	**Somewhat agree**	**Agree**	**Strongly Agree**
1	**2**	**3**	**4**	**5**	**6**

Items/Statements	**Level of Agreement**					
E. Material Handling Flexibility – The ability of material handling system to handle various types of material.						
1. The material handling system can handle a wide variety of parts.	**1**	**2**	**3**	**4**	**5**	**6**
2. Material handling changeovers between parts can be done : a. economically.	**1**	**2**	**3**	**4**	**5**	**6**
b. quickly	**1**	**2**	**3**	**4**	**5**	**6**
c. easily	**1**	**2**	**3**	**4**	**5**	**6**
3. Our material handling system handles different types of part.	**1**	**2**	**3**	**4**	**5**	**6**
4. Our material handling system can be reconfigured quickly.	**1**	**2**	**3**	**4**	**5**	**6**
F. Routing Flexibility – The ability of the manufacturing system to manufacture products through a variety of different routes.						
1. The manufacturing system has alternative routes in case machines break down	**1**	**2**	**3**	**4**	**5**	**6**
2. A typical part operation can be routed to different machines.	**1**	**2**	**3**	**4**	**5**	**6**
3. We use many different routes to produce a product type.	**1**	**2**	**3**	**4**	**5**	**6**
4. We are able to change sequence of steps in production process economically	**1**	**2**	**3**	**4**	**5**	**6**
5. Machine visitation sequence can be changed quickly.	**1**	**2**	**3**	**4**	**5**	**6**
6. Routing paths for manufacturing products can be changed economically.	**1**	**2**	**3**	**4**	**5**	**6**
G. Volume flexibility – The ability of the manufacturing system to alter the output volume of a manufacturing process.						
~~1. We run a range of production volumes.~~	**1**	**2**	**3**	**4**	**5**	**6**
2. Output rates for all products can be varied.	**1**	**2**	**3**	**4**	**5**	**6**
3. We are able to increase or decrease our production volume quickly.	**1**	**2**	**3**	**4**	**5**	**6**
4. We are able to run various batch sizes.	**1**	**2**	**3**	**4**	**5**	**6**
5. We are able to increase or decrease our production volume easily.	**1**	**2**	**3**	**4**	**5**	**6**
~~6. We vary total quantity of output from one period to the next.~~	**1**	**2**	**3**	**4**	**5**	**6**

Remark: Strikethrough sentences are omitted items with factor loading less than 0.70 (refer Table 4.8)

Section Three: Manufacturing Performance

Directions:
This section focuses on the manufacturing performance of your plant during the past three years. It examines the level of manufacturing performance of the plant through five main perspectives of achievements namely product quality, cost reduction, lead time reduction, productivity and inventory minimization.

On the following scale, please circle the appropriate number which best reflect your perception.

Strongly Disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
1	2	3	4	5	6

Items/Statements	Level of Agreement					
A. Product Quality						
1. We are able to produce quality products.	1	2	3	4	5	6
2. We have superior product quality compared to our competitors'.	1	2	3	4	5	6
3. The percentage of poor quality products that must be scrapped has reduced.	1	2	3	4	5	6
4. The percentage of production outputs that do not meet quality specifications has reduced.	1	2	3	4	5	6
5. The percentage of products that pass final inspection the first time (first-pass yield) has increased.	1	2	3	4	5	6
B. Cost Reduction						
1. Our total manufacturing cost (including labor, material and overhead) to produce the product has reduced.	1	2	3	4	5	6
2. Our unit manufacturing cost has reduced (unit manufacturing cost is the total cost for producing the units divided by the number of units produced).	1	2	3	4	5	6
3. Our unit manufacturing cost is lower than the competitors.	1	2	3	4	5	6
4. Our internal failure costs (i.e., cost of defect, scrap, rework, process failure, and downtime) have reduced.	1	2	3	4	5	6
~~5. Our external failure costs (i.e., complaints, returns, warranty claims, liability and lost sales) have reduced.~~	1	2	3	4	5	6
~~6. Our total inventory costs (costs related to storing and maintaining the inventory such as raw materials, work in process, and finished goods over a certain period of time) has reduced.~~	1	2	3	4	5	6

Remark: Strikethrough sentences are omitted items with factor loading less than 0.70 (refer Table 4.9)

On the following scale, please circle the appropriate number which best reflect your perception.

Strongly Disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**

Items/Statements	**Level of Agreement**					
C. Lead time reduction						
~~1. Our manufacturing cycle time (from raw material to finished goods) is competitive.~~	**1**	**2**	**3**	**4**	**5**	**6**
2. The moving times for materials from storage to workstation have reduced.	**1**	**2**	**3**	**4**	**5**	**6**
3. Machine setup times have reduced.	**1**	**2**	**3**	**4**	**5**	**6**
4. The times required to perform the productive operations have reduced.	**1**	**2**	**3**	**4**	**5**	**6**
5. The moving times for parts between workstations have reduced.	**1**	**2**	**3**	**4**	**5**	**6**
6. The queuing times for parts waiting for the works to begin because another order is being processed at a workstation have reduced.	**1**	**2**	**3**	**4**	**5**	**6**
D. Productivity						
1. Productivity of our production line has increased due to: a. More efficient machine setups	**1**	**2**	**3**	**4**	**5**	**6**
b. More efficient production processes.	**1**	**2**	**3**	**4**	**5**	**6**
c. Reduced inputs (such as labor, material and overhead)	**1**	**2**	**3**	**4**	**5**	**6**
2. Our machine productivity has increased.	**1**	**2**	**3**	**4**	**5**	**6**
3. The overall productivity of our production line has been outstanding.	**1**	**2**	**3**	**4**	**5**	**6**
E. Inventory Minimization						
1. Work-in-process (WIP) inventory level has reduced.	**1**	**2**	**3**	**4**	**5**	**6**
~~2. Raw material inventory level has reduced.~~	**1**	**2**	**3**	**4**	**5**	**6**
3. Finished goods inventory level has reduced.	**1**	**2**	**3**	**4**	**5**	**6**
4. Overall inventory level has reduced.	**1**	**2**	**3**	**4**	**5**	**6**
5. Storage space requirement has reduced.	**1**	**2**	**3**	**4**	**5**	**6**

Remark: Strikethrough sentences are omitted items with factor loading less than 0.70 (refer Table 4.9)

Section Four: Business Performance

Directions:

This section focuses on the business performance of your plant <u>during the past three years</u>. It examines the level of business performance of the plant through three main perspectives of achievements namely profitability, product market performance, and customer satisfaction.

On the following scale, please circle the appropriate number which best reflect your perception on profitability, sales and customer satisfaction for your plant.

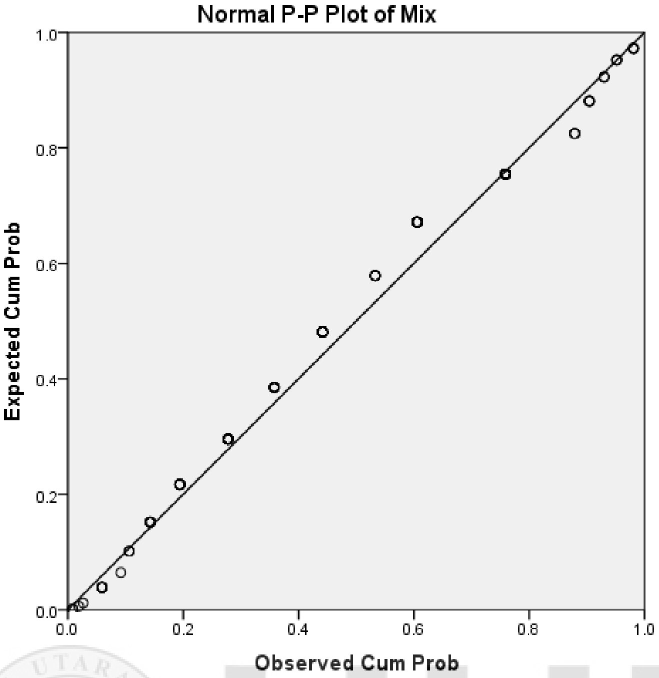
Strongly Disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**

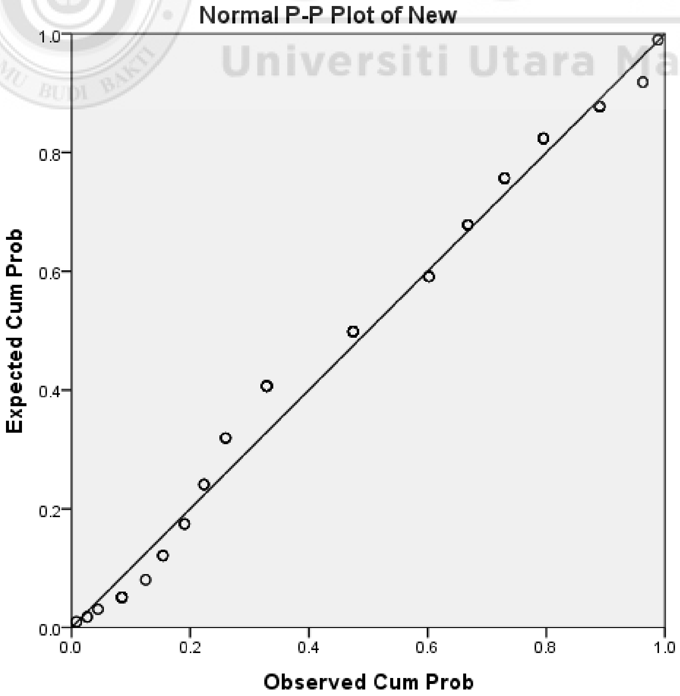
Items/Statements	**Level of Agreement**					
A. Profitability						
1. Our revenue growth rate has been outstanding.	**1**	**2**	**3**	**4**	**5**	**6**
2. Our ability to earn a profit has exceeded our competitors'.	**1**	**2**	**3**	**4**	**5**	**6**
3. Our return on investment (ratio of net income to total investment) reflects sound investments.	**1**	**2**	**3**	**4**	**5**	**6**
4. Our overall financial performance has been outstanding.	**1**	**2**	**3**	**4**	**5**	**6**
B. Product Market Performance						
1. Our market share has increased significantly.	**1**	**2**	**3**	**4**	**5**	**6**
2. Our market share growth has exceeded our competitors'.	**1**	**2**	**3**	**4**	**5**	**6**
~~3. Our sales (in volume) growth has been outstanding.~~	**1**	**2**	**3**	**4**	**5**	**6**
C. Customer Satisfaction						
1. Our customer satisfaction performance has exceeded our competitors'.	**1**	**2**	**3**	**4**	**5**	**6**
2. Our customers are satisfied with: (a) The quality of our products.	**1**	**2**	**3**	**4**	**5**	**6**
(b) Our on time delivery performance.	**1**	**2**	**3**	**4**	**5**	**6**
(c) Our ability to respond to customer changing needs.	**1**	**2**	**3**	**4**	**5**	**6**
3. The number of customer complaints has reduced.	**1**	**2**	**3**	**4**	**5**	**6**

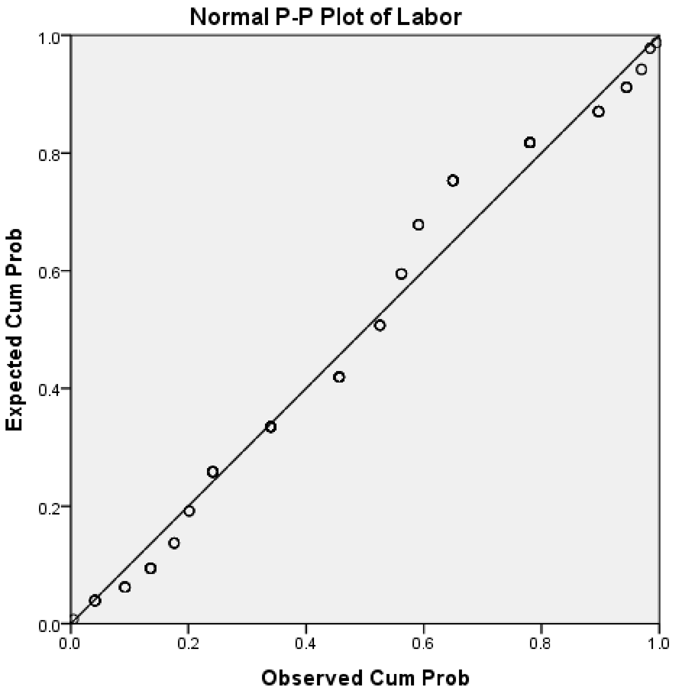
Please send this completed survey booklet in the enclosed self-address envelope provided. Thank you for your participation and your time in answering the survey.

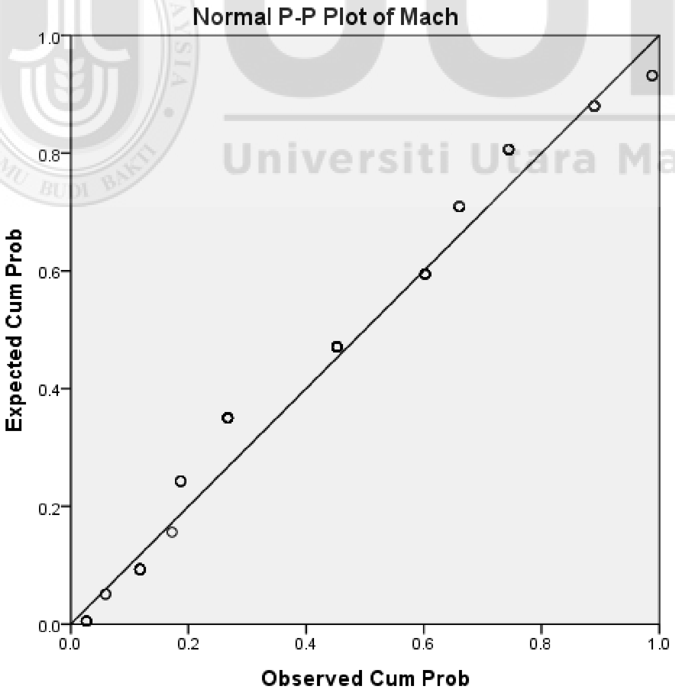
Remark: Strikethrough sentences are omitted items with factor loading less than 0.70 (refer Table 4.9)

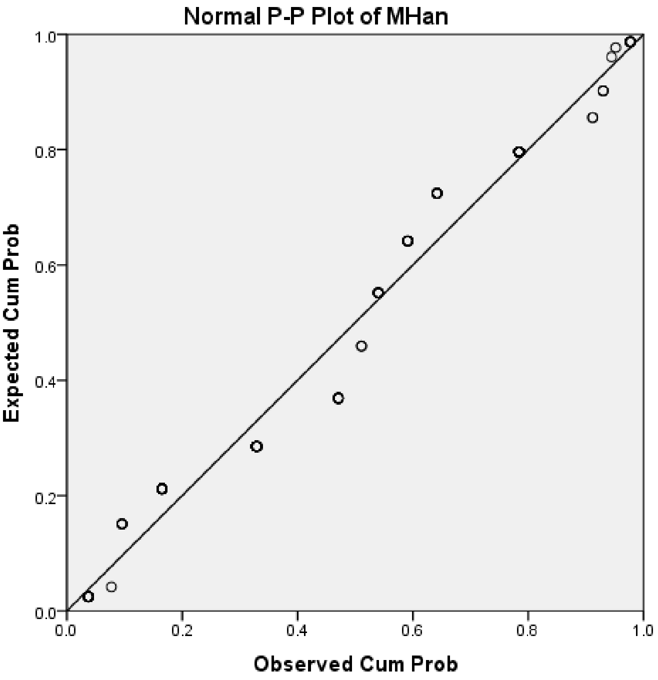
Appendix F: Normal Probability Plots

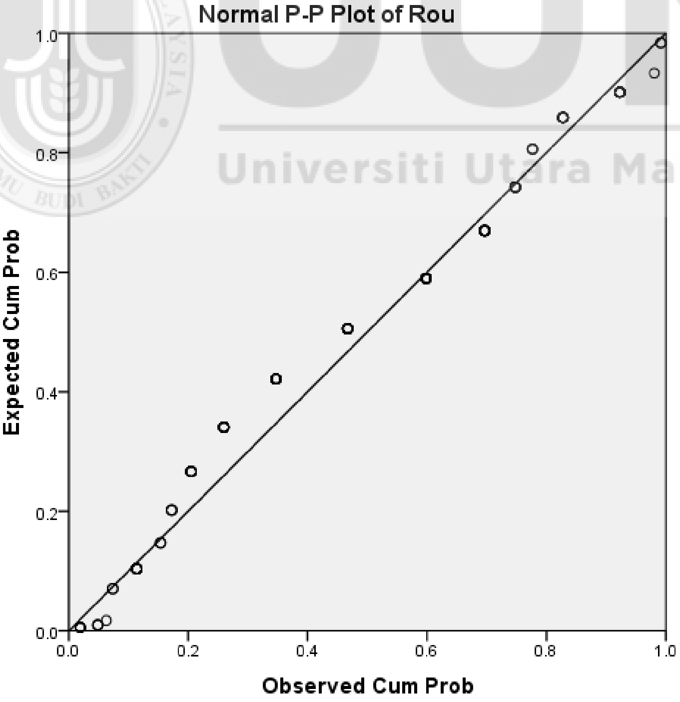


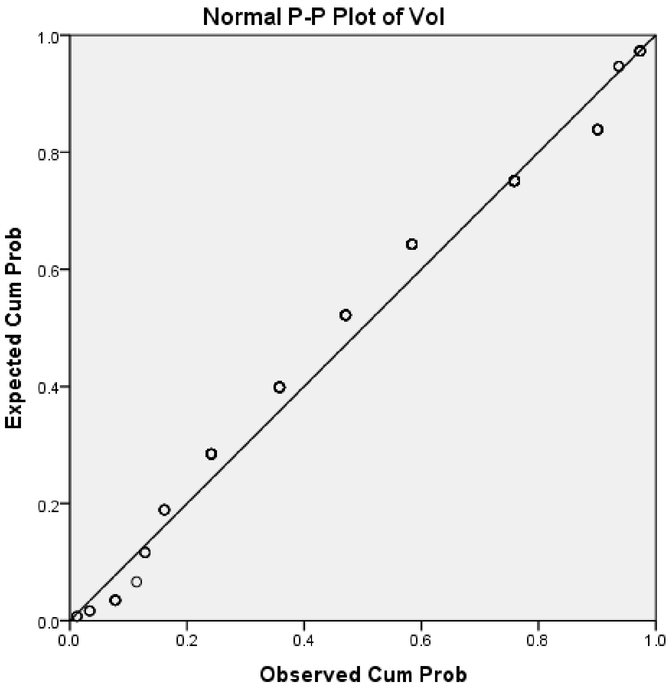


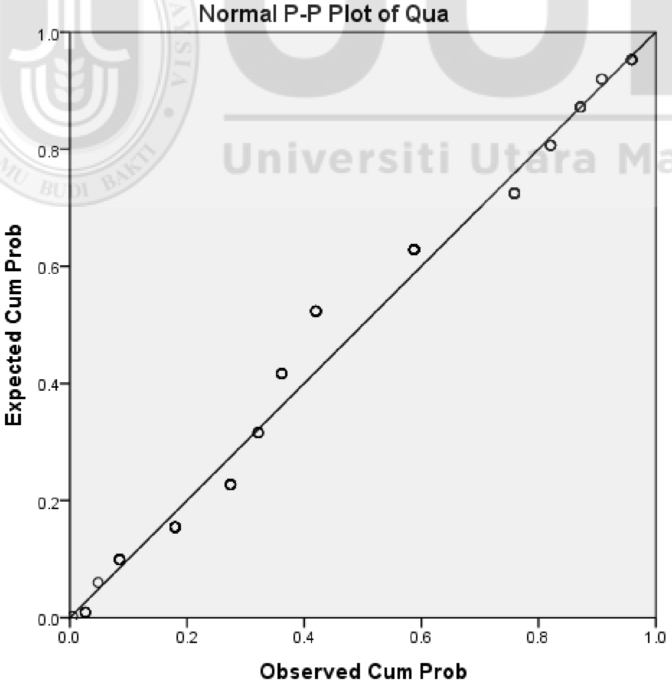

Normal P-P Plot of Labor
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0

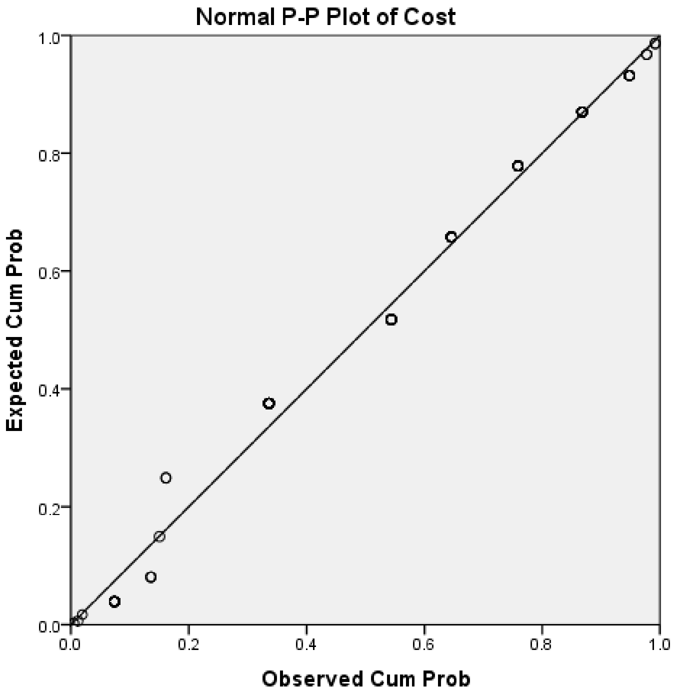

Normal P-P Plot of Mach
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0

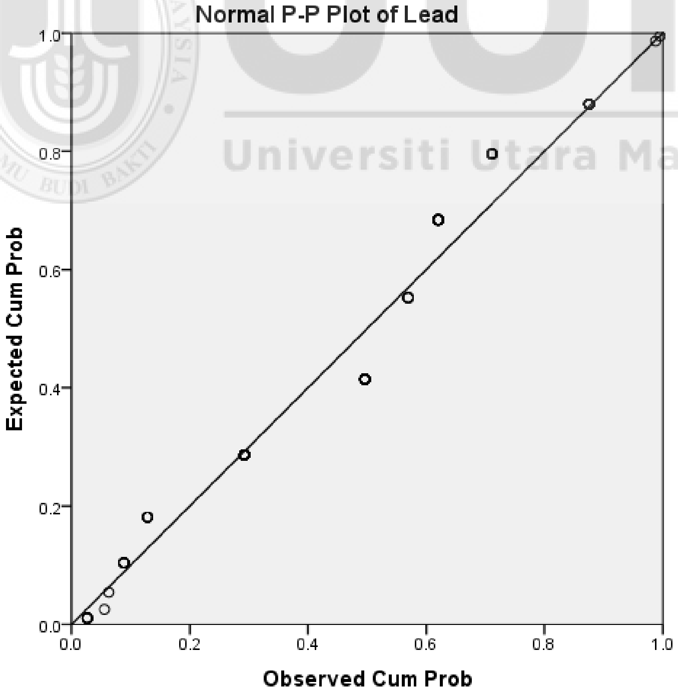

Normal P-P Plot of MHan
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0

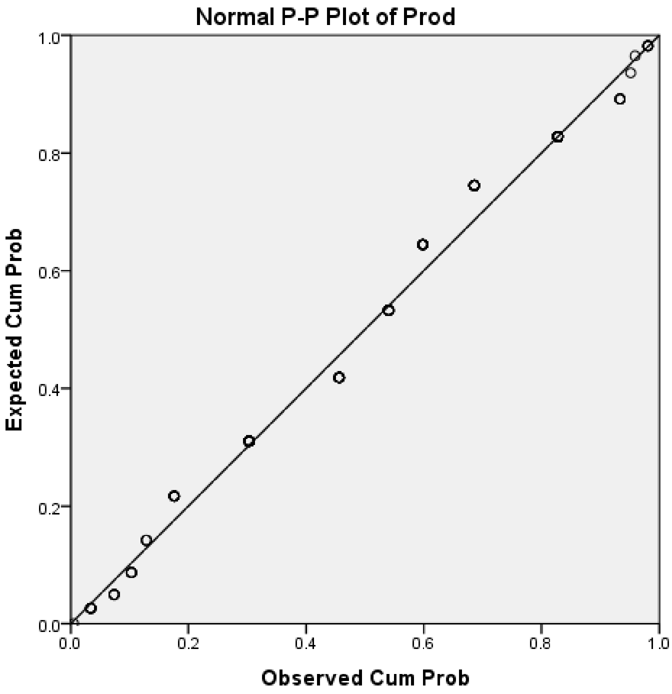

Normal P-P Plot of Rou
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0

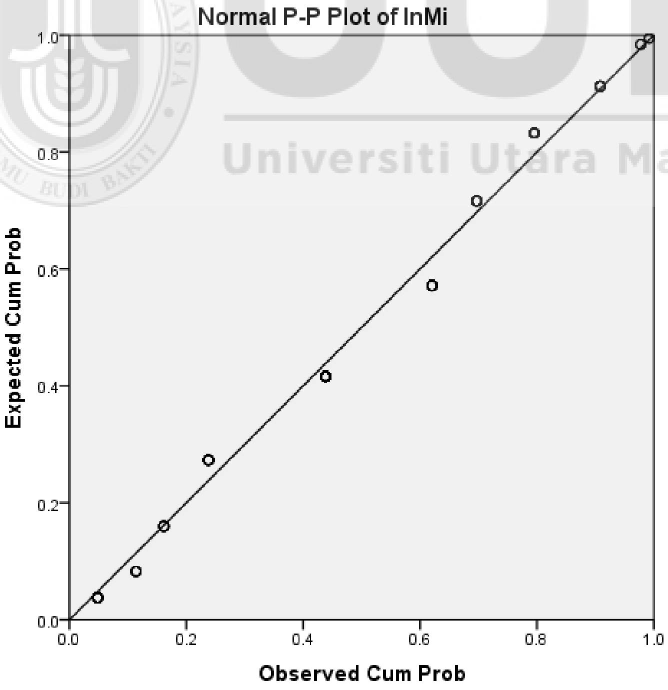

Normal P-P Plot of Vol
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0

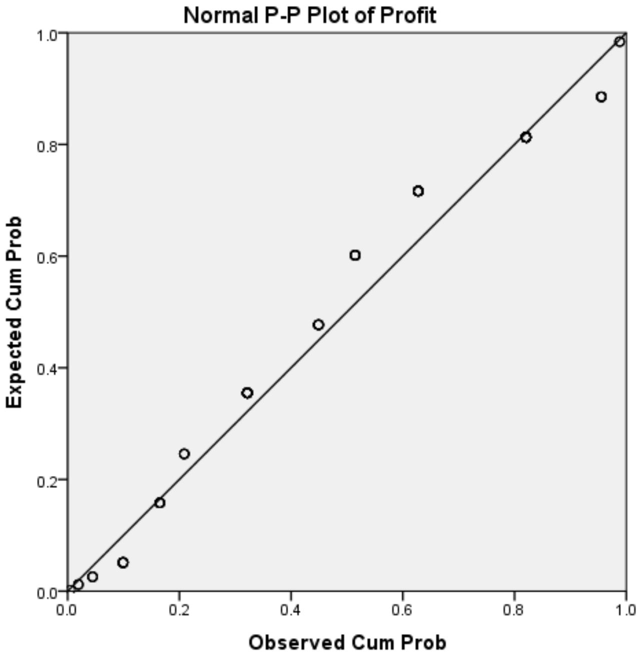

Normal P-P Plot of Qua
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0

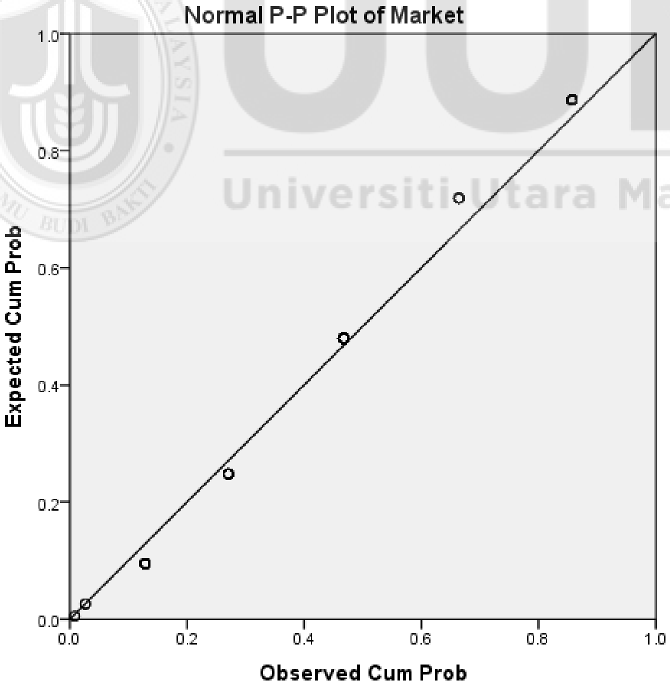

Normal P-P Plot of Cost
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0

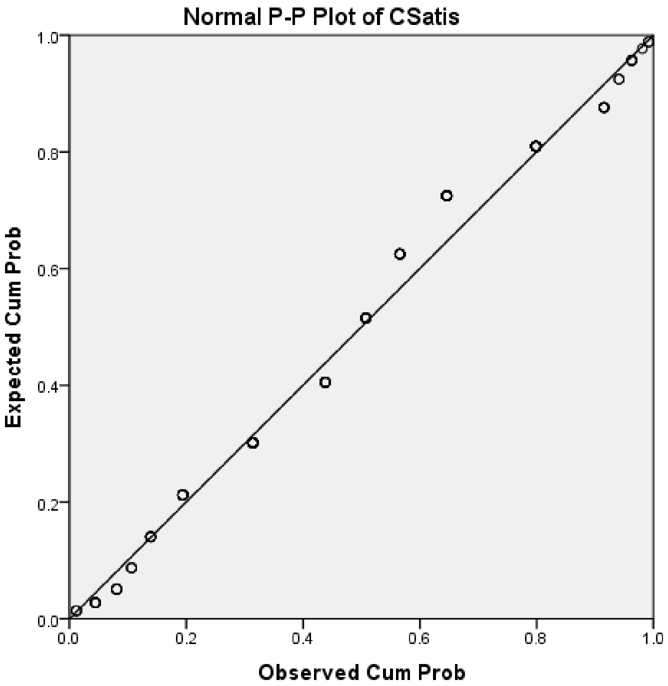

Normal P-P Plot of Lead
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of Prod
Expected Cum Prob
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Observed Cum Prob


Normal P-P Plot of lnMi
Expected Cum Prob
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Observed Cum Prob


Normal P-P Plot of Profit
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of Market
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0


Normal P-P Plot of CSatis
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0

Appendix G: Regression Analysis Manufacturing Flexibility Components on Manufacturing Performance

Quality

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Qua
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.761[a]	.579	.557	.49512

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	43.554	7	6.222	25.381	.000[b]
	Residual	31.624	129	.245		
	Total	75.177	136			

a. Dependent Variable: Qua
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.206	.305		3.961	.000
	Mix	.271	.063	.298	4.334	.000
	New	-.218	.070	-.251	-3.115	.002
	Labor	-.201	.103	-.203	-1.956	.053
	Mach	-.187	.080	-.201	-2.326	.022
	MHan	.558	.105	.538	5.339	.000
	Rou	.314	.081	.332	3.872	.000
	Vol	.254	.093	.274	2.721	.007

a. Dependent Variable: Qua

Cost Reduction

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Cost
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.764[a]	.583	.561	.45894

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	38.010	7	5.430	25.781	.000[b]
	Residual	27.171	129	.211		
	Total	65.181	136			

a. Dependent Variable: Cost

b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.097	.282		3.885	.000
	Mix	.078	.058	.092	1.352	.179
	New	.051	.065	.063	.791	.431
	Labor	.108	.095	.117	1.133	.259
	Mach	-.247	.074	-.285	-3.317	.001
	MHan	.121	.097	.125	1.250	.213
	Rou	.485	.075	.550	6.448	.000
	Vol	.143	.087	.166	1.651	.101

a. Dependent Variable: Cost

Lead Time Reduction

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Lead

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.761[a]	.579	.556	.38361

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	26.067	7	3.724	25.306	.000[b]
	Residual	18.983	129	.147		
	Total	45.051	136			

a. Dependent Variable: Lead

b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.435	.236		6.084	.000
	Mix	.221	.049	.313	4.556	.000
	New	.226	.054	.336	4.168	.000
	Labor	.020	.080	.026	.249	.804
	Mach	-.264	.062	-.368	-4.252	.000
	MHan	.300	.081	.373	3.702	.000
	Rou	.117	.063	.160	1.868	.064
	Vol	.046	.072	.063	.628	.531

a. Dependent Variable: Lead

Productivity

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Prod
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.780[a]	.608	.587	.44591

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	39.786	7	5.684	28.585	.000[b]
	Residual	25.650	129	.199		
	Total	65.436	136			

a. Dependent Variable: Prod
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.682	.274		2.488	.014
	Mix	.112	.056	.131	1.979	.050
	New	.051	.063	.063	.805	.422
	Labor	.057	.093	.062	.616	.539
	Mach	-.034	.072	-.040	-.475	.636
	MHan	.327	.094	.338	3.475	.001
	Rou	.266	.073	.301	3.645	.000
	Vol	.079	.084	.091	.939	.349

a. Dependent Variable: Prod

Inventory Minimization

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: InMi
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.710[a]	.504	.477	.46166

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	27.883	7	3.983	18.690	.000[b]
	Residual	27.494	129	.213		
	Total	55.377	136			

a. Dependent Variable: InMi
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.141	.284		4.018	.000
	Mix	.216	.058	.276	3.702	.000
	New	.061	.065	.082	.933	.352
	Labor	.145	.096	.171	1.516	.132
	Mach	-.031	.075	-.038	-.409	.683
	MHan	-.100	.097	-.112	-1.023	.308
	Rou	.204	.076	.251	2.701	.008
	Vol	.205	.087	.257	2.349	.020

a. Dependent Variable: InMi

Appendix H: Regression Analysis Manufacturing Flexibility Components on Business Performance

Profitability

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Profit

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.825[a]	.681	.663	.46042

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	58.306	7	8.329	39.292	.000[b]
	Residual	27.346	129	.212		
	Total	85.652	136			

a. Dependent Variable: Profit

b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.240	.283		-.848	.398
	Mix	.409	.058	.420	7.020	.000
	New	.070	.065	.076	1.077	.283
	Labor	.096	.096	.091	1.008	.315
	Mach	-.213	.075	-.215	-2.860	.005
	MHan	.283	.097	.256	2.913	.004
	Rou	.350	.075	.346	4.641	.000
	Vol	.056	.087	.056	.639	.524

a. Dependent Variable: Profit

Product Market Performance

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Market
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.792[a]	.627	.607	.49703

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	53.661	7	7.666	31.030	.000[b]
	Residual	31.869	129	.247		
	Total	85.529	136			

a. Dependent Variable: Market
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.106	.306		.347	.729
	Mix	.532	.063	.547	8.458	.000
	New	.081	.070	.087	1.151	.252
	Labor	-.034	.103	-.032	-.328	.743
	Mach	-.384	.081	-.388	-4.771	.000
	MHan	.216	.105	.195	2.058	.042
	Rou	.567	.081	.562	6.971	.000
	Vol	-.058	.094	-.058	-.614	.540

a. Dependent Variable: Market

Customer Satisfaction

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: CSatis
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.746[a]	.557	.533	.48994

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	38.890	7	5.556	23.145	.000[b]
	Residual	30.965	129	.240		
	Total	69.855	136			

a. Dependent Variable: CSatis
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.677	.301		2.246	.026
	Mix	.228	.062	.259	3.677	.000
	New	-.004	.069	-.005	-.059	.953
	Labor	-.074	.102	-.077	-.726	.469
	Mach	.134	.079	.149	1.682	.095
	MHan	.289	.103	.289	2.798	.006
	Rou	.210	.080	.230	2.617	.010
	Vol	.082	.092	.092	.885	.378

a. Dependent Variable: CSatis

Appendix I: Regression Analysis Manufacturing Performance Indicators on Business Performance

Profitability

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	InMi, Qua, Lead, Cost, Prod[b]	.	Enter

a. Dependent Variable: Profit
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.874[a]	.763	.754	.39329

a. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	65.389	5	13.078	84.548	.000[b]
	Residual	20.263	131	.155		
	Total	85.652	136			

a. Dependent Variable: Profit
b. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.122	.281		-3.994	.000
	Qua	.141	.068	.132	2.080	.039
	Cost	.059	.078	.052	.762	.448
	Lead	.494	.091	.359	5.424	.000
	Prod	.185	.104	.162	1.781	.077
	InMi	.376	.088	.302	4.264	.000

a. Dependent Variable: Profit

Product Market Performance

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	InMi, Qua, Lead, Cost, Prod[b]	.	Enter

a. Dependent Variable: Market
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.682[a]	.466	.445	.59064

a. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	39.829	5	7.966	22.834	.000[b]
	Residual	45.700	131	.349		
	Total	85.529	136			

a. Dependent Variable: Market
b. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.354	.422		-.838	.403
	Qua	.186	.102	.174	1.822	.071
	Cost	.269	.117	.235	2.299	.023
	Lead	.490	.137	.356	3.580	.000
	Prod	-.220	.156	-.192	-1.411	.161
	InMi	.293	.133	.236	2.213	.029

a. Dependent Variable: Market

Customer Satisfaction

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	InMi, Qua, Lead, Cost, Prod[b]	.	Enter

a. Dependent Variable: CSatis
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.830[a]	.689	.677	.40742

a. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	48.110	5	9.622	57.969	.000[b]
	Residual	21.744	131	.166		
	Total	69.855	136			

a. Dependent Variable: CSatis
b. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.011	.291		.037	.971
	Qua	.381	.070	.395	5.421	.000
	Cost	-.120	.081	-.116	-1.491	.138
	Lead	.076	.094	.061	.808	.420
	Prod	.278	.108	.269	2.584	.011
	InMi	.368	.091	.327	4.022	.000

a. Dependent Variable: CSatis

Appendix J: Multicollinearity Diagnostics Results

Coefficients[a]

Model		Collinearity Statistics	
		Tolerance	VIF
1	Mix	.691	1.448
	New	.502	1.991
	Labor	.303	3.303
	Mach	.436	2.291
	MHan	.321	3.111
	Rou	.445	2.248
	Vol	.321	3.117

a. Dependent Variable: Qua

Coefficients[a]

Model		Collinearity Statistics	
		Tolerance	VIF
1	Qua	.447	2.238
	Cost	.392	2.554
	Lead	.413	2.420
	Prod	.219	4.556
	InMi	.359	2.787

a. Dependent Variable: Market

Appendix K: Results of Principal Components Analysis

Principal Components Analysis of Manufacturing Flexibility

Data variables:
- Mix
- New
- Labor
- Mach
- MHan
- Rou
- Vol

Data input: observations
Number of complete cases: 137
Missing value treatment: listwise
Standardized: yes

Number of components extracted: 7

Principal Components Analysis

Component Number	*Eigenvalue*	*Percent of Variance*	*Cumulative Percentage*
1	4.46171	63.739	63.739
2	0.788695	11.267	75.006
3	0.548527	7.836	82.842
4	0.405489	5.793	88.635
5	0.326711	4.667	93.302
6	0.263627	3.766	97.068
7	0.205243	2.932	100.000

The StatAdvisor
This procedure performs a principal components analysis. The purpose of the analysis is to obtain a small number of linear combinations of the 7 variables which account for most of the variability in the data. In this case, 7 components have been extracted, since 7 components had eigenvalues greater than or equal to 0.0. Together they account for 100.0% of the variability in the original data.

Table of Component Weights

	Component 1	*Component* 2	*Component* 3	*Component* 4	*Component* 5	*Component* 6	*Component* 7
Mix	0.274282	-0.885963	0.0308343	-0.0567852	-0.34986	-0.111975	0.026886
New	0.36042	0.292941	0.598943	-0.534735	-0.232957	-0.285662	-0.0611344
Labor	0.407085	0.0884496	-0.488175	-0.0876286	0.0533565	-0.138789	-0.747231
Mach	0.383092	-0.17282	0.44768	0.349118	0.698941	0.0433734	-0.103316
MHan	0.405207	0.068114	-0.443198	-0.206783	0.295296	-0.335866	0.626081
Rou	0.380641	0.28491	0.0268525	0.710501	-0.48248	-0.13585	0.131011
Vol	0.416304	0.0758391	-0.066624	-0.183575	-0.109442	0.868017	0.131792

The StatAdvisor
This table shows the equations of the principal components. For example, the first principal component has the equation

0.274282*Mix + 0.36042*New + 0.407085*Labor + 0.383092*Mach + 0.405207*MHan + 0.380641*Rou + 0.416304*Vol

where the values of the variables in the equation are standardized by subtracting their means and dividing by their standard deviations.

Principal Components Analysis of Manufacturing Performance

Data variables:
Qua
Cost
Lead
Prod
InMi

Data input: observations
Number of complete cases: 137
Missing value treatment: listwise
Standardized: yes

Number of components extracted: 5

Principal Components Analysis

Component Number	*Eigenvalue*	*Percent of Variance*	*Cumulative Percentage*
1	3.64856	72.971	72.971
2	0.571364	11.427	84.398
3	0.325271	6.505	90.904
4	0.287547	5.751	96.655
5	0.167261	3.345	100.000

The StatAdvisor
This procedure performs a principal components analysis. The purpose of the analysis is to obtain a small number of linear combinations of the 5 variables which account for most of the variability in the data. In this case, 5 components have been extracted, since 5 components had eigenvalues greater than or equal to 0.0. Together they account for 100.0% of the variability in the original data.

Table of Component Weights

	Component 1	*Component* 2	*Component* 3	*Component* 4	*Component* 5
Qua	0.418651	-0.660038	0.423611	0.38872	-0.241934
Cost	0.445647	-0.364399	-0.493501	-0.639597	-0.126434
Lead	0.434078	0.503688	0.591726	-0.396731	-0.224365
Prod	0.48788	0.0702091	-0.00294378	0.132211	0.859974
InMi	0.446855	0.415851	-0.476301	0.514722	-0.368223

The StatAdvisor
This table shows the equations of the principal components. For example, the first principal component has the equation

0.418651*Qua + 0.445647*Cost + 0.434078*Lead + 0.48788*Prod + 0.446855*InMi

where the values of the variables in the equation are standardized by subtracting their means and dividing by their standard deviations.

Principal Components Analysis of Business Performance

Data variables:
Profit
Market
CSatis

Data input: observations
Number of complete cases: 137
Missing value treatment: listwise
Standardized: yes

Number of components extracted: 3

Principal Components Analysis

Component Number	*Eigenvalue*	*Percent of Variance*	*Cumulative Percentage*
1	2.33383	77.794	77.794
2	0.436927	14.564	92.359
3	0.229244	7.641	100.000

The StatAdvisor
This procedure performs a principal components analysis. The purpose of the analysis is to obtain a small number of linear combinations of the 3 variables which account for most of the variability in the data. In this case, 3 components have been extracted, since 3 components had eigenvalues greater than or equal to 0.0. Together they account for 100.0% of the variability in the original data.

Table of Component Weights

	Component 1	*Component* 2	*Component* 3
Profit	0.604776	-0.069262	0.793378
Market	0.568537	-0.660059	-0.491007
CSatis	0.557685	0.748014	-0.35981

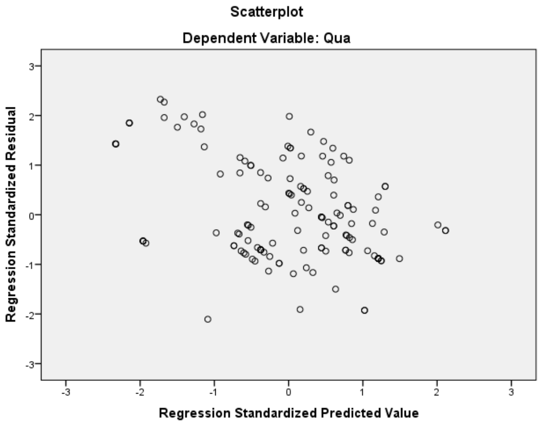
The StatAdvisor
This table shows the equations of the principal components. For example, the first principal component has the equation

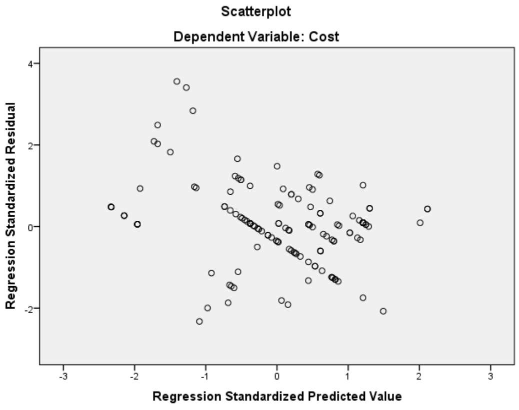
0.604776*Profit + 0.568537*Market + 0.557685*CSatis

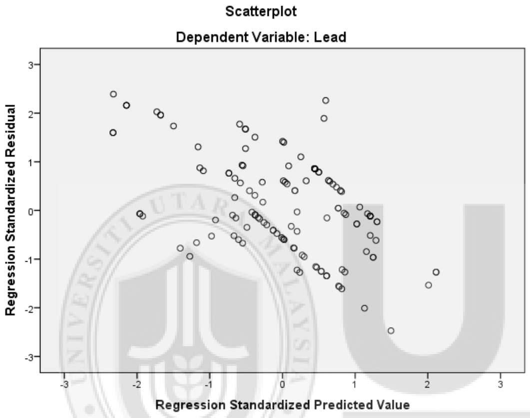
where the values of the variables in the equation are standardized by subtracting their means and dividing by their standard deviations.

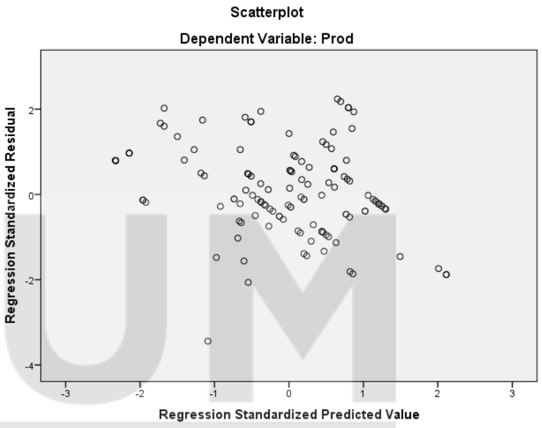
Appendix L: Standardized Residual Scatterplots

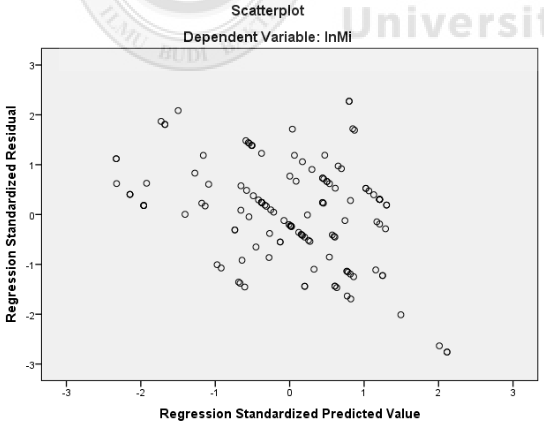
MF on MP measures



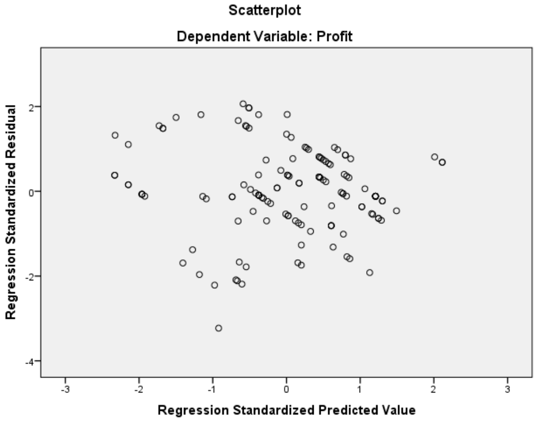


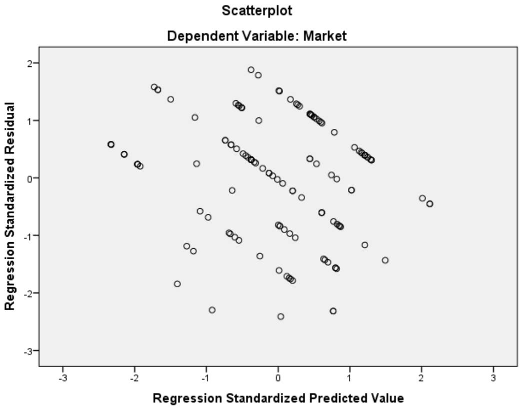


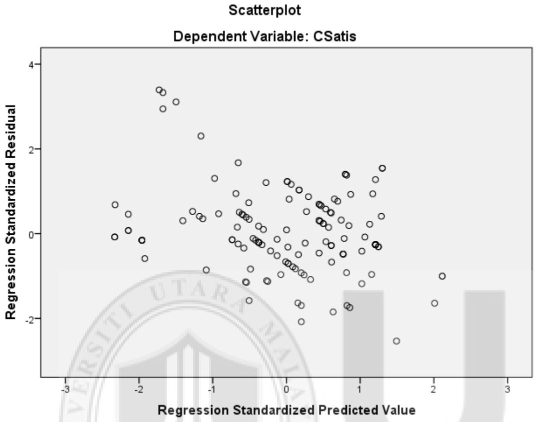




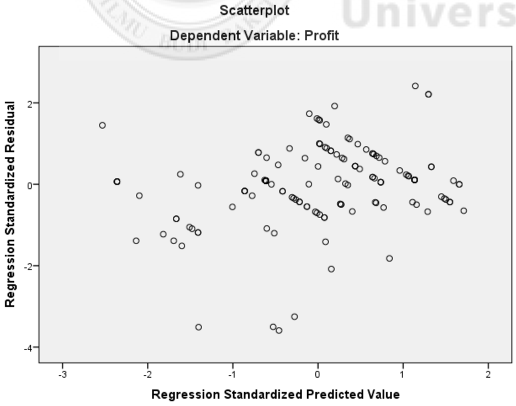
MF on BP measures

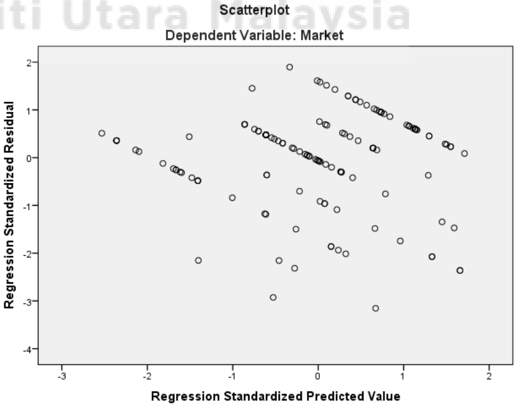


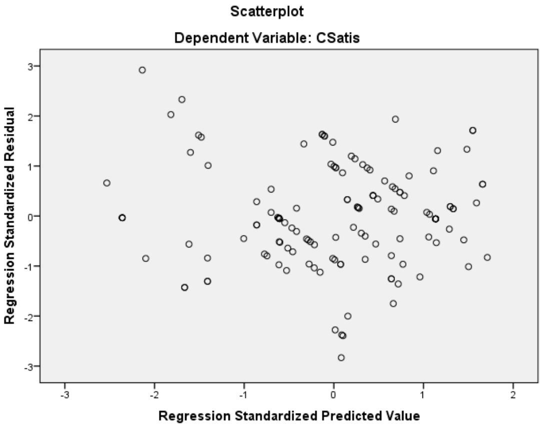




MP on BP measures






Scatterplot
Dependent Variable: CSatis
Regression Standardized Residual
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
Regression Standardized Predicted Value

Appendix M: Regression Analysis for Mediation Test

Regression - MF on MP

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	PCAMF[b]	.	Enter

a. Dependent Variable: PCAMP

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.788[a]	.621	.618	.7896442

a. Predictors: (Constant), PCAMF

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	137.963	1	137.963	221.259	.000[b]
	Residual	84.178	135	.624		
	Total	222.141	136			

a. Dependent Variable: PCAMP

b. Predictors: (Constant), PCAMF

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.953	.460		6.426	.000
	PCAMF	.607	.041	.788	14.875	.000

a. Dependent Variable: PCAMP

Regression – MF and MP on BP

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	PCAMP, PCAMF[b]	.	Enter

a. Dependent Variable: PCABP

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.883[a]	.781	.777	.5549226

a. Predictors: (Constant), PCAMP, PCAMF

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	146.743	2	73.371	238.266	.000[b]
	Residual	41.264	134	.308		
	Total	188.007	136			

a. Dependent Variable: PCABP

b. Predictors: (Constant), PCAMP, PCAMF

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.654	.369		-1.772	.079
	PCAMF	.181	.047	.256	3.888	.000
	PCAMP	.614	.060	.668	10.159	.000

a. Dependent Variable: PCABP

Appendix N: PROCESS Results with Standardized Beta Weight

```
Run MATRIX procedure:

**************** PROCESS Procedure for SPSS Release 2.13.2 **************

         Written by Andrew F. Hayes, Ph.D.       www.afhayes.com
    Documentation available in Hayes (2013). www.guilford.com/p/hayes3

**************************************************************************

Model = 4
    Y = StdBP
    X = StdMF
    M = StdMP

Sample size
       137

**************************************************************************

Outcome: StdMP

Model Summary
          R       R-sq        MSE          F        df1        df2          p
      .7881      .6211      .3817   221.2585     1.0000   135.0000      .0000

Model
              coeff         se          t          p       LLCI       ULCI
constant      .0000      .0528      .0000     1.0000     -.1044      .1044
StdMF         .7881      .0530    14.8748      .0000      .6833      .8929

**************************************************************************

Outcome: StdBP

Model Summary
          R       R-sq        MSE          F        df1        df2          p
      .8835      .7805      .2228   238.2662     2.0000
134.0000      .0000

Model
              coeff         se          t          p       LLCI       ULCI
constant      .0000      .0403      .0000     1.0000     -.0798      .0798
StdMP         .6679      .0657    10.1592      .0000      .5379      .7979
StdMF         .2556      .0657     3.8877      .0002      .1256      .3856

************************** TOTAL EFFECT MODEL ****************************
Outcome: StdBP

Model Summary
          R       R-sq        MSE          F        df1        df2          p
      .7820      .6115      .3914   212.4632     1.0000   135.0000      .0000

Model
              coeff         se          t          p       LLCI       ULCI
constant      .0000      .0535      .0000     1.0000     -.1057      .1057
StdMF         .7820      .0536    14.5761      .0000      .6759      .8881
```

```
***************** TOTAL, DIRECT, AND INDIRECT EFFECTS ******************

Total effect of X on Y
    Effect         SE          t          p       LLCI       ULCI
     .7820      .0536    14.5761      .0000      .6759      .8881

Direct effect of X on Y
    Effect         SE          t          p       LLCI       ULCI
     .2556      .0657     3.8877      .0002      .1256      .3856

Indirect effect of X on Y
        Effect    Boot SE   BootLLCI   BootULCI
StdMP     .5264      .0493      .4327      .6225

******************** ANALYSIS NOTES AND WARNINGS ***********************

Number of bootstrap samples for bias corrected bootstrap confidence
intervals:
    5000

Level of confidence for all confidence intervals in output:
   95.00

------ END MATRIX -----
```