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Effects of Demand, Manufacturing Flexibility, Cost and Supply Chain on Product Modularity: A Study in Malaysia

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Abstract

The objective of this study was to investigate the effect of customer demand, manufacturing flexibility, cost, and supply chain on product modularity. This study employed a cross-sectional design and a proportionate random sampling procedure was used to select 150 manufacturers from a list of 250 manufacturing companies in Malaysia, which are registered in Federation of Malaysian Manufacturers (FMM) and Association of Proton vendors. Data was collected from the middle and top management from these selected manufacturing organizations. Findings of this study noted that customer demand, manufacturing flexibility and supply chain has a significant positive effect on product modularity, whereas cost has a negative association with product modularity. Manufacturers, therefore, need to develop customer demand, manufacturing flexibility, cost, and supply chains to ensure the success in developing modularity product manufacturing. This study shows strong association for customer demand, manufacturing flexibility, cost, and supply chain to develop modularity product manufacturing.

Keywords: demand, manufacturing flexibility, cost, supply chain, product modularity, Malaysia

1. Introduction

In order to sustain themselves in today's competitive business environment, manufacturing industries are rapidly implementing product modularity strategy to take advantage of increasing demand for customized products (Sohail & Al-Shuridah, 2010). In Malaysia, product modularity practices have been carried out at the infancy stage, where modular product has been carried out on the smaller scale. Malaysia is fast becoming an emerging developed country, however the constraint is the ability to develop mass production with high quality assurance. The need for industry to deliver high quality products at low cost has long been recognized as a crucial factor for survival. However, in Malaysia, the increasing demand for customized products and rapid changes of technology make these requirements ordinary. The further requirements to becoming clear of high variety and rapid product development are gradually dominating quality and cost requirements. Hence, another requirement describing the need for overcoming complexity arises. This involves the stage modularization process which is designed from three different perspectives consisting of customer based, function based and structure based design which include the steps given. Firstly, the manufacturing is focused on reducing costs to increase customer acceptance for quick delivery. Secondly, the need for industry to deliver high quality products at low cost has long been recognized. So, the increasing demand of customized products and rapid change of technology make these requirements ordinary. Thirdly, to overcome the inability and shortcomings in meeting challenging market demands among manufacturing firms with process modularization.

The modular product design allows manufacturers to distribute products more broadly. As different geographical regions have different government regulations, firms can modularize their products by separating fewer modules, which fit different regulations such as power supply and regulated dangerous materials. Otherwise, when the consumer costs of knowing and deciding how to combine the modules are low, and producers gain economies of scale in assembling prepackaged modules, a modular network arises, as stated by Fujimoto et al. (2001). The combination of demand costs and benefits must be finally considered in connection with the life cycle stage of the product, as noted by Kotler, (2003). The modularity also can reduce inventory costs while quickly meeting client orders, as argued by Ulrich et al. (2000). In addition, modular products facilitate the creation of high quality products by combining quality modules. Hargadon et al. (2000) argued that product quality can be ensured if the qualified modules are reused or incrementally improved. According to Mikkola et al. (2003) modular product design may improve the reliability of the product because product modules can be reused in many product variants and frequent reuse of the modules increases the firm's experience of how to produce the modules. Products are now manufactured module by module to increase delivery due to fast changing design and customer demand and quicker response to customer demand. In relation to that, this study aimed to explain the factors that are related to the product architecture activities in manufacturing industries, especially in modularization. On top of that, this study tries to reveal the effects of customer demand and cost toward product modularity while trying to understand the linkage between the flexibility in manufacturing and product modularity. This study is relevant as it gives the manufacturing firms the edge on how to survive in the current economic situation.

2. Literature Review

2.1 The Concept of Modularity

Modular design divides a system into physical and functional modules that can be arranged to facilitate design and servicing. Product design architecture can be categorized into integral design and modular design. Modular architecture differs from integral architecture in terms of the former product's functional element that is performed by one physical block. Thus, the advantages of modular architecture enable design improvements to be conducted on a particular block (Ulrich et al., 2004). The aim of modular design architecture is to allow independence and interchangeability between units in fulfilling the various functions of the product. As mentioned by Huang et al. (1998) and Phuluwa et al. (2013), modularity enables modification to several product functional elements separately without affecting the design of the other elements. Modularity emphasized product module expansion with minimum dependency on other components for maintenance (Dzuraidah et al., 2008). Each components of the same module should have maximum similarity while maintaining minimum similarity with components outside the module. Maximum similarity in the module helps to facilitate servicing on the components of a certain module since each component is more or less similar in its physical and function. Furthermore, an important consideration when defining modularity is the choice on the level of servicing, as argued by Gershenson et al. (1997) and Zirpoli et al. (2011). According to Ullman, (2003) servicing reflects ease of diagnosis and repair on a product. A product may be modular from the perspective of design but may be otherwise from the perspective of servicing operation. For example, the design architecture of an electric coffee maker was reviewed and service modularity was applied, which form the basis for design improvements to the electric coffee maker in view of improving maintenance (Dzuraidah et al., 2008).

2.2 Customer Demand and Modularity

Managing modular architectures is an area of intense interest both to scholars and practitioners, as argued by (Ethiraj et al., 2004; Karim, 2006; Pil et al., 2006). In increasingly dynamic markets modularity of products enables managers to exploit economies of scale and scope and to enhance product variety to meet heterogeneous customer needs, as stated by (Helfat et al., 2004; Tu et al., 2004). Worren et al. (2002) found that internal product modularity had an impact on enhancing the number of variants of a product, but did not influence the pace of innovation. While, Schilling (2000) and Baldwin (2012) noted that modularity as the degree to which a system's components can be separated and recombined. Modularity refers not only to the extent of coupling components, but also to the existence of architectural rules, which define how components are combined in an overall system. In addition, Baldwin et al. (2000) and McDermott et al. (2013) argued that modularity is a structural means of achieving functional integration in complex systems. Reading the articles, it was found that the researcher discusses about three features of modularity in which the modules are distinct parts of a larger system, independent of one another, and modules function as an integrated, seamless whole.

High customer dynamics and competitive intensity make it beneficial for firms to adopt modular strategies, this was found consistently across all the accumulated research findings (Worren et al., 2002; Tu et al., 2004; Phuluwa et al., 2013). Conversely, Sorenson, (2003) found that several research contributions show that some aspects of the technological dynamics may actually counteract the drive to modular strategies in some situations. Thereafter, as stated by Ernst (2005), in the fast moving environment of the semi-conductor industry, firms are reluctant to adopt a single modular architecture, because of the threat of disruptive technological architectures from their competitors. The stabilization of interfaces and parameters may limit the ability of the firm to react to the moves of the competitors with the high dynamics of markets. Indeed, firms which use modular architectures in markets with emerging technologies may fall in modularity traps. According to Chesbrough et al. (1999), firms must switch modularity and integration to answer shifts in the market dynamics from the settings of emerging technology to the settings of dominant designs and vice versa in order to avoid modularity traps. In the emerging technologies, the market dynamics are higher and the threat of emergence of a disruptive technology in a competitive firm is higher. The integration of the components of a complex product risk a competency trap if from outsourcing they lose the systems integration capability (Zirpoli et al., 2011).Thus, in the settings with industry standards and low opportunities for disruptive technological change firms are more likely to adopt modularity (Chesbrough, 2003). Therefore, based on the articles, it was found that firms will adopt increasing modular strategies in markets with opportunities for technological breakthroughs and will reduce their modularity in markets with dominant design and opportunities for only minor technological changes.

Furthermore, Tu et al. (2004) investigated the impact of market dynamics on organizational structures and organizational process modularity. In the markets with consumer and technology uncertainty, the firms which adopt modular manufacturing practices, are able to cope better with the increasing demands for individually customized products. While, Schilling et al. (2001) noted that the market context in terms of consumer heterogeneity, competitive intensity and speed of technological change increases the level of the external product modularity of a firm. Thus, to stay competitive in dynamic markets, firms outsource not only components of their products, but also components of their knowledge (Quinn, 2000; Whitford et al., 2012). Knowledge integration of the different internal and external knowledge components into a smoothly functioning knowledge system determines the success of the firm in developing new products in an innovation-based competition. Market dynamics increase the efforts of the firm to use, develop and integrate different knowledge components (Grant, 1996; Zahra et al., 2002). In addition, market dynamics motivates firms to adopt internal product modularity, external product modularity, organizational process modularity, organizational structure modularity and knowledge modularity.

2.3 Manufacturing Flexibility and Modularity

Flexibility is the organization's ability to meet an increasing variety of customer expectations without excessive costs, time, organizational disruptions, or performance losses (Jacobs et al., 2007). Manufacturing flexibility is the ability of the organization to manage production resources and uncertainty to meet various customer requests (Antonio et al., 2007). Flexibility is a complex and multidimensional capability that requires a company's wide effort to increase a firm's responsiveness and reduce waste and delays (White, 1996). Nevertheless, Zhang et al. (2002) and Dreyer et al. (2004) suggested that a general definition of flexibility which is an order to verify the whole effects of product modularity on numerous competitive capabilities. Hence, flexibility is defined as the firm's ability to provide rapid design change, a wider product range, greater order size flexibility and a greater number of new products (Frohlich et al., 2001; Chase et al., 2001).

According to Thomke et al. *(*1998) and McDuffie (2013), flexibility is achieved if manufacturers can provide many prototypes for rapid design changes. Meanwhile, Kotha et al. (1989) noted that flexibility is achieved in rapidly changing product volumes, product mix and schedules to meet customer needs. Hayes et al. (1984) mentioned that flexibility takes the lead in introducing new products. In this essence, product modularity and flexibility are related, and the flexibility is mainly built up with product architecture, but not with the flexible equipment in the factory. Sanchez (1995) and Baldwin (2012) mentioned that the development of a complex product with high modularity is similar to the development of a set of less complex product modules, which can be flexibly designed and tested. When product modules are fully specified and separated, firms can experiment with each module independently and the pros and cons of the module design can be identified piece by piece which improves the design flexibility. Thus, Sanchez (1999) and Jacobs et al. (2011) noted that firms can also substitute a range of component variations into the product architecture to improve manufacturing flexibility.

In addition, modular product architecture can make many new products by using a relatively small number of independent modules in different permutations. Thus, firms with modular architecture can quickly launch new products and widen the product ranges by exchanging a few product modules (Baldwin et al., 2000; Jacobs et al., 2011). Modular products have higher independence among its individual modules which isolate frequently changing modules from the core design. This reduces the frequency of communication across different module designs and the rate of change of the core design (Sanchez, 2003). For example, a telecommunication switch design includes both the core design call processing systems and frequently changing modules as management information systems. In the process of modularizing the telecommunication switch design, the designers can separate the design of critical call processing, which needs to be highly optimized and cannot be changed frequently, from the management information systems which can be frequently changed. In this way, designers can respond to client requests for different management information systems without interfering in critical call processing software (Thomke et al., 1998). A modular product design thus tolerates a higher risk of design changes, allows for late product changes that lead to better design solutions, and avoids the need for entire product changes. This improves the design and manufacturing flexibility for market change (Antonio et al., 2007). Flexibility and modularity is important because it can lead to a competitive advantage, which is considered the flexibility facilitated by product modularity, such as modular designs and the ensuing flexibility may not be easily imitated (Worren et al., 2002).

2.4 Cost and Modularity

There is broad consensus that product modularity reduces product cost and researchers have proposed a variety of reasons for this relationship. One source of cost reduction is an increase in economies of scale, as noted by Pine et al. (1993). Since modular designs have fewer unique components or subassemblies, the production volume is distributed across a smaller number of unique part numbers (Sanchez, 2002; Baldwins, 2012). Learning curve theory also predicts a reduction in cost, since production volumes are higher on a per part basis, productivity accelerates. Hence, learning curve theory predicts a lower unit cost (Jacobs et al., 2007). Furthermore, inventory is a significant component of unit cost. According to Meyer et al. (2001), product modularity provides a vehicle for parts rationalization. This reduction in the number of unit parts results in inventory reductions from risk pooling, reduced set-ups, and increased economies of scale (Tu et al., 2004; Mirchandani et al., 2002). While, as mentioned by Kim et al. (2000) reductions in forecast errors and consequently, excess inventory. The reduction in inventory levels can be associated with a corresponding reduction in carrying costs and consequently total cost (Collier, 1981).

Several researchers have touted the organizational benefits associated with product modularity, thus, both engineering and operational efficiencies are attributable to the standardization. Engineering efficiency is partly related to a reduction in design effort through the reuse of designs. Operationally, there are improvements through reductions in the numbers of set-ups (Tu et al., 2004; McDermott et al., 2013). There is also a reduction in the product variety versus operational performance tension which should lead to cost advantages, for example product modularity allows for a significant variety of end items and yet enables a standardized production process (Salvador et al., 2002; Jacobs et al., 2011). According to Galvin et al. (2001), organizations can benefit from the coordination improvements facilitated by the loose coupling between components created by modular product architectures. The result should reduce coordination costs (Danese et al., 2004; Galvin et al., 2001). Then, the firm benefits through a reduction in investment costs. While, tooling, engineering, testing and support are all reduced by using standardized components and sub-assemblies, as stated by Fisher et al. (1999). Several researchers agree that product modularity leads to cost reductions. According to Karmarkar et al. (1987) spare parts costs rise from the higher failure rates of modules vis-à-vis components and the result is an increase in spare parts inventory from the deployment of modular products.

2.5 Supply Chain in Modularity

Supply chain integration is defined as business processes to integrate suppliers, customers and internal functional units in order to optimize the total performance of all partners in the supply chain (Frohlich et al., 2001; Stevens, 1989). Supply chain integration involves three dimensions, consisting of integration with suppliers, integration with customers and integration within the company which includes many business processes that cut across these three dimensions, as noted by (Rosenzweig et al., 2003; Vickery et al., 2003). Supply chain integration reflects multiple business activities or processes across suppliers, internal functional units and customers. According to Frohlich et al. (2001) the positive effects of supply chain integration on performance include supplier and customer integration, while ignoring internal integration. While, Rosenzweig et al. (2003) noted a new supply chain integration intensity construct, measuring supplier, customer and internal integration. Thus, Vickery et al. (2003) conceptualized supply chain integration as three business processes including supplier partnership, close customer relationship and cross functional teams. Supply chain integration also includes other business processes across the supply chain (Vickery et al., 2003; Han et al., 2002; Droge et al., 2012). In addition, as stated by Lau Antonio et al. (2007) the supply chain integration processes will affect product design and development, including supplier co-development, customer co-development and internal co-development.

Modular product design is considered to be an effective approach for mass customization and cycle time reduction (Duray et al., 2000). While, Worren et al. (2002) and Sanchez (1995) argued that modular product would improve strategic flexibility for manufacturers. Similarity, Duray et al. (2000) also argued that the decision to implement product modularity is an important aspect in modular product design because different levels of modularity require different product design processes. There is a continuum describing a product system's degree of separateness, specificity and transferability of product components, based on whether the product systems are loosely or tightly coupled (Schilling, 2000; Sanchez, 1995; Bruyn et al., 2012). Thereafter, Parker et al. (2002) and Fine et al. (2005) pointed out that manufacturers need to determine the level of product modularity within a framework of supply chain design otherwise they may lose their value adding activities to their suppliers. According to Sako (2002) and Parente et al. (2011), modular product design is critical to product, process and supply chain design, and usually requires the integration of designers, producers and consumers. Several researchers found that supply chain integration can directly improve company performance (Lee, 2000; Frohlich et al., 2001; Droge et al., 2012).

Modular product design is created by separating a product system into relatively independent components and by specifying the interfaces of the product system across interacting components (Schilling, 2000; Sanchez, 1995; Zirpoli et al., 2011). The decision to implement product modularity is an important aspect in modular product design because different levels of modularity require different product design processes (Duray et al., 2000; Ulrich, 1995). Product modularity deals with a number of features of product components, including the extent to which modules are independent or separate, the extent to which components are specific, the extent to which modules are transferable or reusable within the production process (Baldwin et al., 2000; Schilling, 2000). While, Schilling (2000) and Phuluwa et al. (2013) defined that product modularity as a continuum, describing separateness, specificity and transferability of product components in a product system. Separateness refers to the degree to which a product can be disassembled and recombined into new product configurations without loss of functionality.

3. Research Methodology

This study used a cross-sectional design to investigate the relationship between customer demand, manufacturing flexibility, cost, and supply chain towards modularity. The study was conducted in a two phases, phase 1 was a pilot study to examine the re-ability of the instrument and phase 2 was main study using the revised instrument to examine the relationship among the variables. A survey method using questionnaires was chosen for data collection.

Item measures that were identified and variously developed are included in the study. Most item measures were based on previous research instruments whether following the prior design, or with several adjustments. Some measures were specifically developed for this research. The items of product modularity were measured by the questionnaire prepared and tested by Lau Antonio et al. (2007) and Parente (2003). Through a focused literature search, six items were deemed vital across these studies which were identified customer demand in modularity product manufacturing sectors. The new items were also developed in order to operate with several factors. This study measured eight items of manufacturing flexibility. For each item, the measurement was identified and developed using eight elements to ensure an adequate coverage of the manufacturing flexibility. In this study, it measures six items of cost. All the items were identified and developed to make sure they would cover the cost measurement. All items for each item were developed following Parente (2003). There are five item of supply chain, which will cover all the factors in supply chain and each of the items was identified. All items for each factor were developed following Lau Antonio et al. (2007).

The research focused on the manufacturing industries in Malaysia. In an attempt to complete the research, manufacturing companies across a large range of industries such as electrical and electronic, steel production, engineering supporting, machinery and equipment and others were studied. The classification of this industry was followed by Federation of Malaysian Manufacturers (FMM) directory in 2009. The list contained 250 manufacturing companies in Malaysia, which are registered in Federation of Malaysian Manufacturers (FMM) and Association of Proton vendors. From the listed 250 companies, this study selected 150 companies using proportionate random sampling procedure. As Lau et al. (2001) stated generalization can only be drawn when random samples are used. Therefore, the samples were drawn by using a simple random sampling procedure which assures each company has equal chance of being chosen as the sample.

4. Summary of Findings

Summary of findings starts with the background of the respondents, such as gender, race, education, position, and working experience; as well as the background of company including nature, type of company, age, and size. A total of 150 respondents participate in this study. As noted in Table 1, the majority of them are male (88.7%). Out of them, 77.3 percent are Malay, 19.3 percent are Chinese and only 3.3 percent are Indian. Most of the respondents have at least obtained a bachelor degree (66.0%), followed by diploma (17.3%) and Master's degree (16.7%).

The survey questionnaire was addressed to Director, General Manager, Manager or equivalent. Thus, the respondents hold a variety of positions such as Manager, General Manager, Senior Manager, Director, and other positions. All the respondents were knowledgeable in modularity processes or they have a common understanding of the concept of product modularity. Each group represents personnel, who understand about product modularity process of their respective facilities. Respondent positions, as noted in Table 1, out of 150 respondents, 30 or 20.0% respondents are Managers, 112 or 74.7% are from other positions in the company. The rest of the respondents are from the positions at the same percentage are General Manager (2.7%) and Senior Manager (2.7%). This indicates that the questionnaires were completed by the proper individuals. Respondents were grouped into four categories, based on their years of working experience. The majority of the respondents who are made up 52.0% (78) have work experience between six and ten years in the current position. Table 1 also shows 53 (35.3%) respondents employed between one and five years. About 8.0% have worked more than ten years. While, only 7 out of 150 respondents have worked less than one year.

About the background of the companies, as noted in Table 1, this shows that the 'others' types were the dominant industry representing 62.0%. The next largest companies were the electric and electronic (22.0%), followed by machinery and equipment (16.0%). Table 1 also shows the five types of companies representing 150 respondents. This includes Malaysian owned, Multi-National companies, joint venture, foreign owned and others. More than 70 percent were Malaysian companies, while 10.0 percent were the 'others' type of company. The next type of company were foreign companies representing 8.0 percent. Then, 6.7 percent are Multi-National Company and 2.0 percent are joint venture companies. It was also found that majority of the companies were aged more than 10 years and 8.7 percent of the companies were over 20 years. The minor aged (1.3%) is between 0 to 5 years in the company responses. About the companies' sizes, the respondents were asked to indicate the number of people employed in their companies. Their responses, classified into four groups, are shown in table 8.0. It can be seen, 52 companies (34.7%) had employed 101 to 250, 50 companies (33.3%) had employed more than 251, and 44 companies (29.3%) had employed 50 to 100. The remaining companies surveyed had employed less than 50. No case missing in number of employees data.

Table 1. Background of the respondents and companies

Background of the Respondents					
	N	%		N	%
Gender			*Race*		
			Malay	116	77.3
Male	133	88.7	Chinese	29	19.3
Female	17	11.3	Indian	5	3.3
Education			*Position*		
Master	25	16.7	General Manager	4	2.7
Bachelor	99	66.0	Senior Manager	4	2.7
Diploma	26	17.3	Manager	30	20.0
			Others	112	74.7
Working Experience					
Less than 1 year	7	4.7			
1-5 years	53	35.3			
6-10 years	78	52.0			
More than 10 years	12	8.0			
Background of the Companies					
	N	%		N	%
Nature			*Type of Company*		
Electric and electronics	33	22.0	Malaysia owned	110	73.3
Machinery and equipment	24	16.0	Multi-National company	10	6.7
Others	93	62.0	Joint venture	3	2.0
			Foreign owned	12	8.0
			Others	15	10.0
Years			*Sized*		
0-5 years	2	1.3	Less than 50	4	2.7
6-10 years	57	38.0	50-100	44	29.3
11-15 years	46	30.7	101-250	52	34.7
16-20 years	32	21.3	More than 251	50	33.3
Over 20 years	13	8.7			

4.1 Testing Validity and Reliability

Before conducting the main analysis, a validity test was performed with all the items tapping in the independent variables and dependent variables that were included in the study. The validity test was conducted based on the data collected from 150 cases which found no respondents as outliers among the respondents. Therefore, established statistical tools such as factor analysis helped determine the construct adequacy of measuring device, as mentioned by Cooper et al. (1998). The statistical test result (KMO = 0.866, Bartlett Test of Sphericity = 1154.526, *p* value of 0.000) indicated that the value of Kaiser-Meyer-Olkin (KMO) was found to be acceptable. Finding that this value is more than 0.5, it can be suggested that the factor analysis test had proceeded correctly, and the sample used was adequate, as noted by Hair, (2006).

Factor 1, which was labeled as *Product Modularity*, was composed of seven items and accounted for 40.01 per cent of the variance. The items in this factor were similar to the original dimension. Factor 2 comprised of six items that are related to the *Customer Demand* of the industries and accounted for an additional 8.01 percent of the variance. Factor 3 was labeled *Manufacturing Flexibility* and comprised eight items. It accounted for an additional 6.38 percent of the variance. Factor 4 was a *Cost* factor that contained six items. It accounted for the additional 9.68 percent of the variance. Factor 5 was interpreted as a *Supply Chain*. It accounted additional 4.94 percent of the variance and contained five factors.

Table 2. Validity and internal consistency

Variables/Factor	No of Items	KMO	Cronbach's Alpha (∂)
Product Modularity	7	0.866	0.833
Customer Demand	6	0.866	0.861
Manufacturing Flexibility	8	0.866	0.862
Cost	6	0.866	0.837
Supply Chain	5	0.866	0.812

Reliability is an assessment of the degree of consistency between multiple measurements of variables. The reliability test was performed with all the items tapping in the independent variables and dependent variables included in the study. The Cronbach Alpha value ranged from 0.730 to 0.932 indicating that all scales are acceptable. Alpha values greater than 0.60 are suggested as being adequate for testing the reliability of factors, as noted by Sekaran (1992). From the results obtained, it can be concluded that this instrument has high internal consistency and is therefore reliable.

4.2 Descriptive Analysis

Descriptive analysis examines statistical description of variables in the study. Statistics such as mean and standard deviation are used as descriptive statistics in this study by calculating independent variables and dependent variables. These scores highlight the respondents' feedback obtained from the data collected through the questionnaires. The result obtained show that some effort need to be focused on developing the companies' ability to incorporate the important factors in their practice to ensure the success of practicing the product modularity in manufacturing. Therefore, correlation analysis and regression analysis were carried out to emphasize this successful implementing of modularity product.

Respondents were asked to indicate their agreement towards the statements of the variables, using the five points Likert scale. Means score for each variable were then computed to determine to level of their agreement.

Table 3. Descriptive statistic of variable

Variables/Factor	Mean	Standard Deviation
Product Modularity	3.8419	0.55714
Customer Demand	4.1089	0.56461
Manufacturing Flexibility	4.3308	0.37378
Cost	4.2589	0.50962
Supply Chain	4.1493	0.44763

Table 4. Modularity, demand, flexibility, cost and supply chain

	Mean	SD	Level
Product Modularity	3.84	0.56	*High*
Your product can be decomposed into separate modules	3.89	0.84	High
Your product components can be reused in various products	3.08	1.47	Moderate
The interfaces among the components of the product are standard	3.91	0.81	High
Your company using modularity as a general set of principles for managing complexity	3.96	0.69	High
Your products are difficult for competitors to imitate	3.88	0.93	High
Your company adopts a high degree of modularity in production	4.07	0.78	High
Your product used modularity concept that can achieve higher variety	4.11	0.73	High
Customer Demand	*4.11*	*0.56*	*High*
Your customers are increasingly demanding more product modularity variety	4.09	0.74	High
Your customers demand that you offer different product modularity configurations of the same model	4.11	0.88	High
Your competitors have been increasing their product modularity variety consistently in the last few years	4.09	0.81	High
Frequently change all or part of the line of products modularity offered, in order to satisfy customer needs	4.09	0.79	High
Within the product modularity, components with different quality and specifications can be used	4.06	0.88	High
Your company has experience in serving local markets with your products modularity	4.21	0.68	High
Manufacturing Flexibility	*4.33*	*0.37*	*High*
Your company can build different products in the same plants at the same time	4.27	0.68	High
There is a need for variety inputs in order to meet various needs of the customers	4.32	0.59	High
Your business is prepared to quickly develop new products to meet challenge with your competitors	4.39	0.57	High
Your business is prepared to quickly make adjustments in production to satisfy new customer’s demand	4.36	0.63	High
Your company support to develop or produce different components for the product available to the market	4.40	0.61	High
Your company is prepared to make adjustments in production to adapt to new technological standards	4.35	0.61	High
Your company has produced the variety amount of differential models or variants	4.27	0.62	High
There is a high level of inter-dependency between the components and parts that make up your products	4.28	0.70	High
Cost	*4.26*	*0.51*	*High*
Reducing costs is a key priority for your company	4.23	0.64	High
Lower selling prices are the main criteria to win orders from customers	4.19	0.82	High
The competitive pricing is important issue in setting product modularity price as compare to the competitor	4.27	0.69	High

	Mean	SD	Level
The cost reduction is important factor to remain competitive in product modularity	4.35	0.74	High
The prices will be determined by customers who are satisfied with your product	4.30	0.77	High
Your major suppliers have a good estimate of the cost of the products that you manufactured.	4.21	0.75	High
Supply Chain	*4.15*	*0.45*	*High*
Frequently cooperate with your major suppliers in order to resolve problems whenever and unexpected situations arise	4.17	0.64	High
Your major suppliers are highly committed to the whole assembly process with regards to quality and reliability	4.19	0.65	High
Your organizations integrate or coordinate activities by sharing technological information with your suppliers	4.06	0.71	High
Your organizations integrate or coordinate activities by mutual business systems design with your suppliers	4.15	0.69	High
Your major suppliers have the ability to quickly adjust their production schedule accordingly to the speed of your production line	4.17	0.63	High

The descriptive analysis results for product modularity are shown in Table 4. All 150 companies were found to implement modularity process in their activities. The agreement and commitment level among the companies towards product modularity is high (mean=3.84, sd=0.56). Most of the respondents agreed that products using modularity concepts can achieve higher variety (mean=4.11, sd=0.73) and their company adopts a high degree of modularity in production (mean=4.07, sd=0.78). However, respondents' commitments are moderate in the statement "Your product components can be reused in various products" (Mean=3.08, sd=1.47).

About customer demand, it is found that respondents' agreements towards customer demand are high (mean=4.11, sd=0.56). Their agreements are high for each statement about customer demand. The highest mean score can be found in the statement "Your company has experience in serving local markets with your products modularity" (mean=4.21, sd=0.68).

In regard to the level of agreement towards manufacturing flexibility is high at mean=4.33 and sd=0.37. Respondents also showed a high agreement towards all items in this variable, with the lowest score 4.27 ("Your company can build different products in the same plants at the same time" and "Your company has produced the variety amount of differential models or variants") to highest score 4.40 ("Your company support to develop or produce different components for the product available to the market").

About the cost, it was found that respondents' agreement towards cost is also high (mean=4.26, sd=0.51). Respondents highly agreed that cost reduction is an important factor to remain competitive in product modularity (mean=4.35, sd=0.74). They also agreed that prices will be determined by customers who are satisfied with your product (mean=4.20, sd=0.77).

In regard to the Supply Chain, as noted in Table 4, respondents perception towards supply chain were also high (mean=4.15, sd=0.45). This can be referred to in Table 19.0. Overall, they highly agreed that major suppliers are highly committed to the whole assembly process with regards to quality and reliability (mean=4.19, sd=0.65). Respondents also highly agreed with the need to frequently cooperate with the major suppliers in order to resolve problems whenever unexpected situations arise (mean=0.417, sd=0.64).

4.3 Testing the Association

Four hypotheses were developed and tested in this study. A summary of the hypotheses testing is illustrated in Table 5 below. Product modularity was found to have a significant relationship with customer demand, manufacturing flexibility, cost and supply chain. Customer demand has the strongest relationship with product modularity, compared to other variables. This finding suggests that to implement product modularity, companies are relying on customer demand. The higher demand from customer will lead to an increase in implementing product modularity in Malaysia.

Table 5. Summary of hypotheses test

Hypothesis	Method of Analysis	Results	Summary
There is a positive association between customer demand and product modularity	Pearson Correlation	r=0.694 p<0.01	Supported
There is a positive association between manufacturing flexibility and product modularity.	Pearson Correlation	r=0.519 p<0.01	Supported
There is a positive association between cost and product modularity.	Pearson Correlation	r=0.418 p<0.01	Supported
There is a positive association between supply chain and product modularity	Pearson Correlation	r=0.516 p<0.01	Supported

4.4 Multiple Regression Analysis

Multiple regression analysis was used to examine the effect of customer demand, manufacturing flexibility, cost, and supply chain on product modularity. The analysis was done using the regression model as below:

$$Y = \partial + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + e \quad (1)$$

Where, Y = Product Modularity; X_1=Customer Demand; X_2=Manufacturing Modularity; X_3=Cost; X_4=Supply Chain; ∂=Constant; β=coeffecient; e=standar error

Table 6. Model summary

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
.739[a]	0.546	0.534	0.38047	1.388

Table 6, below, presents the summary of the model. The multiple correlation coefficient (*r*) is 0.739. The R-squared (r^2) value shows the proportion of variation in dependent variables explained by the independent variables. In this model, the four independent variables, i.e., customer demand, manufacturing flexibility, cost, and supply chain explain 54.6% of the total variation in product modularity.

Table 7. ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	25.261	4	6.315	43.628	.000[a]
	Residual	20.989	145	0.145		
	Total	46.251	149			

As noted in Table 7 and 8, the results suggest that only three variables can be used to predict product modularity, these are customer demand (β =0.523, t=7.150, p<0.01); manufacturing flexibility (β =0.313, t=3.170, p<0.01) and Supply Chain (β =0.199, t=2.278, p<0.05). Customer demand, manufacturing flexibility and supply chain were found to have a significant positive effect towards product modularity. This overall model shows that cost is not a predictor of product modularity.

Table 8. Regression coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-0.343	0.400		-0.859	0.392
Customer Demand	0.523	0.073	0.530	7.150	0.000
Manufacturing Flexibility	0.313	0.099	0.210	3.170	0.002
Cost	-0.033	0.077	-0.030	-0.434	0.665
Supply Chain	0.199	0.087	0.160	2.278	0.024

5. Conclusion and Recommendations

The objective of this study was to investigate the effect of customer demand, manufacturing flexibility, cost, and supply chain on product modularity. Findings of this study noted that customer demand, manufacturing flexibility and supply chain has a significant positive effect on product modularity, whereas, cost has a negative association with product modularity.

The results from the study offer several implications in developing firms' modularity product manufacturing. Firstly, this study focuses on independent variables to bridge the gap in predicting and developing the modularity product manufacturing in the Malaysia context. The findings suggests that manufacturers with higher efforts of manufacturing flexibility, cost, supply chain, and customer demand are more likely to report more success in developing the modularity product manufacturing. The results also highlight the importance of having strong factors for modularity product manufacturing. From the managerial point of view, the findings from this research suggest that companies need to be concerned with modularity product manufacturing in terms of customer demand, manufacturing flexibility, cost, and supply chain. This requires the companies' efforts to adopt related customer demand, manufacturing flexibility, cost, and supply chains into their organization to enhance the modularity product manufacturing and develop the high degree of modularity product manufacturing in driving their companies to compete with other competitors. In terms of customer demand, manufacturing flexibility, cost, and supply chain this study found that the companies must consider this independent variable to develop the high degree of modular product manufacturing. Besides, this study also points out that multiple relationships help to focus and assess the important factors that must be focused on in developing manufacturing capabilities. For instance, the companies should focus on customer demand, manufacturing flexibility, cost, and supply chain in developing the modularity product manufacturing. Customer demand, manufacturing flexibility, cost, and supply chain will assist manufacturers in utilizing at optimum level due to operation attained from diversity of technology. Therefore, companies become more competent and sustainable in any economy recession. This study found evidence to support the hypotheses. This reveals that customer demand, manufacturing flexibility, cost, and supply chain measures are an important function of firm cooperative action. The findings confirmed the studies conducted by Schilling (2000), where they noted that customer demand, manufacturing flexibility, cost, and supply chain characteristic plays the intermediary role and firm should pay more attentions for this part.

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