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Investigating the Relationship between the Outcomes of Manufacturing Performance and Product Modularity

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Abstract
The paper seeks to test empirically a variety of hypotheses related to four outcomes of manufacturing performance in terms of cost reduction, product quality, manufacturing flexibility, and cycle time reduction, and investigates its relationship with product modularity (PM) within some industrial companies in Egypt. The data collection instrument used was a questionnaire which was administrated to a total sample of 230 Egyptian managers. Sample selection was based on convenience sampling. Total 192 valid questionnaires were filled by the respondents representing a response rate of 83.48%. The hypotheses were tested using correlation analysis and stepwise regression to ascertain the validity of the hypotheses. All hypotheses were partially accepted. These findings show that the relationship between the dimensions of the four constructs of cost reduction, product quality, manufacturing flexibility, cycle time reduction and the construct of product modularity was not proved as suggested by the existing literature review.

Key words: Manufacturing Performance, Product modularity, Cost reduction, Product quality, Manufacturing flexibility, Cycle time reduction

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INTRODUCTION

With increasing the heterogeneous markets, manufacturing becomes more complex. Where it faces several challenges due to the ever-greater need for flexibility, and the need of companies to provide great of product variety as a result of increasing the shortness of the product life cycle while maintaining excellent product quality at low costs (Brettel and Friederichsen, 2015). Managing innovation is a challenge for companies because they have to cope with the complexity of todays' market. Improving a systematic process for such a management strategy is considared as a goal of many companies and enumerates as a factor for competitive advantages to reduce the costs of products, to decrease cycle time, to improve product quality and to flexible the manufacturing (Ahmadi, 2015). According to (Lehtovaara, Kokkonen, Rousku, and Kässimodularity, 2011) modularity has several advantages which have been widely discussed in previous research (e.g., Kusiak, 2002; Jose and Tollenaere, 2005), such as increasing the economies of scale, increasing the product variety, reducing the time to market, saving the cost in inventory, shortening the product life cycle, and improving quality.

Campagnolo and Camuffo (2010) reported that the studies on product modularity often postulate a perfect uniformity between product modules, knowledge partitioning, and economic actors within and across organizations (e.g., Brusoni et al., 2001; Takeishi, 2002; Brusoni and Prencipe, 2006). As well, the literature review has so far not fully investigated the economics of product modularization (Thyssen et al, 2006) and the relationship between product modularity and performance (Lau, Yam, and Tang, 2007).

As mentioned by (Chung, 2012) modular products may be defined as products that can create product variants to fulfill various overall functions through the combination of distinct building modules. According to (Todorova and Durisin, 2009) theories on modular management of products separated between increasing flexibility through manufacturing multiple products from few components and gaining flexibility through faster component innovation. In addition, with increasing the dynamic markets, modularity of products has different types of advantages that enables managers to exploit economies of scale and scope, to enhance product variety to meet heterogeneous customer needs, to improve the ability to introduce a higher number of product variants and component innovation (e.g., Wheelwright and Clark, 1992; Garud and Kumaraswamy, 1993; Gawer and Cusumano, 2002; Tu, Vonderembse, Ragu-Nathan, and Ragu-Nathan, 2004). Product modularity can improve competitive

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performance of a firm in different ways such as product costs, quality, flexibility, manufacturing cycle time and customer service (Danese and Filippini, 2010).

In many of the aforementioned studies, product modularity was measured by using operational and financial performance dimensions which has been introduced in several mass-customization industries. Still, empirical investigations on the performance impacts of modularity have only recently evolved after a long period of conceptualization and theory building within the management literature. Few scholars in the domain of manufacturing performance outcomes have examined empirically the relationship between cost reduction, product quality, manufacturing flexibility, and cycle time reduction and product modularity. Furthermore, much of the literature focuses on the developed world but not concentrated on developing countries such as Egypt. This particular study addresses the most four important constructs that have impact on product modularity.

The objective of this study

- To investigate the impact of cost reduction, product quality, manufacturing flexibility, and cycle time reduction on product modularity in some of Egyptian industrial companies.
- To support the proposed relationship for the conceptual model provided by (Sohail et al, 2010) and retested by (Sohail et al, 2015) between cost, quality, flexibility, and cycle time and product modularity.

The importance of this study

- Based on (Chung, 2012; Rocha , Formoso, and Tzortzopoulos, 2015) there is no clear consensus on the definition of product modularity and the traditional measures are not enough to measure it; there is no common or standard way of assessing the product modularity (e.g; Gershenson, Prasad, and Zhang, 2003,2004; Fixsen, 2005; Salvador, 2007). Therefore, it is necessary for testing and building the theory in the area of product modularity.
- According to (Lau, 2011) the extensive literature such as (Nobelius and Sundgren, 2002; Sullivan, 2003; Persson and Ahlstrom, 2006) has highlighted the technical side of modular product design only. In addition, Campagnolo et al (2010) revealed that the literature has so far not fully investigated the relationship between product modularity and cost reduction, product quality, manufacturing flexibility, and cycle time reduction (Worren et al., 2002; Lau et al., 2007) because of, there is some controversies and ambiguities on how modularity should be defined, measured and used in managerially meaningful ways. So, the current research will help to cover this gap.
- To verify the validity of the research framework which proposed and have been examined by (Sohail et al, 2010) and re-examined by (Sohail et al, 2015).
- Few Egyptian studies have empirically linked between the cost reduction, product quality, manufacturing flexibility, and cycle time reduction with the dimensions of product modularity. The current research will provide initial evidence on how some of Egyptian industrial companies can use these factors in order to impact on product modularity.

The Research Question

The research question of this paper is: “How do the manufacturing performance outcomes in terms of cost reduction, product quality, manufacturing flexibility, and cycle time reduction impact on product modularity in some of Egyptian industrial companies?”

There are four questions that derived from it, as the following:

- How does cost reduction impact on product modularity?
- How does product quality impact on product modularity?
- How does manufacturing flexibility impact on product modularity?
- How does cycle time reduction impact on product modularity?

The research is organized as follows: relevant literature is reviewed and synthesized first to develop a conceptual model, followed by research methodology. The results are then presented along with discussion. Conclusion and implication are discussed finally.

LITERATURE REVIEW AND HYPOTHESES

Within the research objectives in this study, there are four concepts that needed to be explored and interpreted, to obtain an understanding of these objectives. The research provides an overview over the development of empirical findings within the management literature framework and elaborate these factors influencing on product modularity.

Cost Reduction

According to (Zainol et al., 2013) there is a broad consensus that product modularity reduces the product cost. Several researchers agree that product modularity leads to cost reductions such as (Karmarkar et al., 1987) who stated that spare parts costs rise from the higher failure rates of modules vis-à-vis components, 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), product modularity provides a vehicle for parts rationalization (Meyer et al., 2001). The reduction in the number of unit parts results in inventory is reduced from risk pooling, reduced set-ups, and increased economies of scale (Tu et al, 2004; Mirchandani et al., 2002). The result of Zainol et al (2013) supported that cost has a negative association with product modularity (β= -0.030, t= -0.434, p< 0.665) and it is not a predictor of product modularity. Jacobs et al (2007), found that there is a significant relationship between product modularity and cost reduction with (β=0.371, P<0.05) in plastics, electronics, and toy companies. However, not all Researchers agree that product modularity leads to cost reductions such as (Karmarkar and Kubat, 1987; Boer, 2014), who reported that spare parts costs rise from the higher failure rates of modules components because there is no comparison between the spares of inventory that required for modular products and that for integrated products. Lau et al (2007) disclosed that Mikkola and Gassmann (2003) clarified that products with high modularity can gain economies of scale through the modular Components shared with other products and also support the standardization of the components that increases product variety without adversely affecting cost. Thatta (2013) found that regarding product modularity, smaller subsystems are designed and manufactured independently in order to improve the system of process technology and can function all the processes together as a whole, and they are better-being integrated designs with providing more value to the customer, and reducing the cost of piece. Kremer, Ma, Chiu and Lin (2015) found that economic and ecological costs are important factors that can be taken into account to optimize the components modules of the products in order to limit the residual waste, to manage the reusable components at the lowest cost for environmental reasons, to cover the remanufacturing activities, and to produce multiple classes of products at a time.

Based on (Sohail et al, 2010) cost reduction in modular product design arises due to increasing economies of scale (Ulrich and Tung, 1991; Pine et al., 1993), inventory cost reduction (Meyer and Mugge, 2001; Weng, 1999), lower repair and development costs (Krikke et al., 2004; Fisher et al., 1999) and reduced set-up times (Tu et al., 2004; Mirchandani and Mishra, 2002). Further, costs are also lowered due to faster assembly of existing modules enabling quick delivery with short lead time comparing with the competitors (Hargadon and Eisenhardt, 2000; Ernst and Kamrad, 2000). Nevertheless, Kutner, Nachtsheim, Neter, and Li (2005) revealed that there is a contrast finding indicating that product modularity does not necessarily lead to cost reductions. The standardized coefficients (γ=0.669, p<0.001) showed that product modularity significantly influences the cost of product performance (Sohail et al., 2015).

Golfmann and Lammers (2015) reported that in most cases, the newly built modules are designed to standardize product components and assembly groups for a product. Standardization of production and assembly equipment are the major opportunity to reduce costs of the products, particularly where the firms have different production facilities. The standardization of production and assembly equipment with universal and sustainable modules could constitute a significant limitation of independence for each

respective factory. Danese et al (2010) stated that product modularity is often considered a useful approach to reduce costs by increasing component standardization, and commonality across different product variants (Sheu and Wacker, 1997; Mikkola and Gassmann, 2003). Kortmann, Gelhard, Zimmermann, and Piller (2014) stated that through enabling modularity, manufacturing firms may indeed be flexible enough to accommodate product variety without significant detrimental effects on costs. This is particularly evident in manufacturing environments that aim to produce at low unit costs in order to maintain the superior level of cost structures as well as in manufacturing systems and in delivery times. The hypothesis related to the discussion in this section is:
H1: There is a positive relationship between cost reduction and product modularity.

Product Quality
Rocha et al (2015) suggested that product modularity is a concept that can contribute to the improvement of product quality and production efficiency in house-building.
Lau et al (2007) found that there is no significant relationship between product modularity and product quality because of the reliability which refers to what extent there is a consistency of performance over time and the rate of failure achieved (e.g., Chase et al., 2001). Whilst Jacobs et al (2007), revealed that there is a significant relationship between product modularity and product quality with (β=0.272, P< 0.05). This result is confirmed with some scholars such as Child et al., (1991), who estimated that the design accounts for 50 percent of the quality of a product; Suzik (1999), who found that the use of a modular design and its associated standardization was to increase product quality; Kusiak (2002), who reported that standardization leads to quality; Fisher *et al.* (1999), who concluded that the increase in quality brought by standardization; Feitzinger and Lee (1997), who proposed that quality is improved by product modularity because problems can be isolated to specific modules facilitating targeted corrective action. Boer (2014) reported that Lau et al (2007; 2009) proved that product modularity has a marginal effect on product quality.
Lau et al (2009) found that product modularity is significantly correlated with product quality with (β=0.271, p=0.000). Modular product design may improve a company's ability to provide high quality conformance when appropriate and reliable modules are reused. Modular design may weaken the quality of the product design if a smaller physical size or mass of products is highly valued by customers (Ulrich and Tung, 1991). In addition, an appropriate level of integration across module teams is crucial if a company is ready to deliver a new product quickly and flexibly and ready to have high respondent rate to the performance level of their product quality standards relative to their competitors (Brusoni and Prencipe, 2001; Sosa et al., 2004). Sohail et al (2010) proposed that product modularity has a positive effect on quality improvements based on some of previous researches (e.g., Child et al, 1991; Suzik, 1999; Hargadon and Eisenhardt, 2000; Fisher, 2009), who estimated that specific usage of modular design which brought by standardization will lead to increase the product quality. Sohail et al (2015), proved that the standardized coefficient showed that product modularity significantly influences the quality performance with (γ = 0.636, p <0.001) based on design and supply integration as two mediator variables. Lau (2011), concluded that modular design improves product variety by mixing and matching a small amount of modules that are standardized and interchangeable, so, manufacturers can improve the conformance of product quality. The module could be mixed and matched with other components without sacrificing the quality of the furniture products and hence, conducting failure mode affects analysis to improve the quality of the product. Product modularization cuts down too much variety in development by simplifying the design that helps to improve the competitive performance and the manufacturing facilitates and design integration (Dube, Muyengwa, and Battle, 2013). Based on the empirical research conducted through (Ahmadi, 2015) the best innovative companies try to improve the reliability of overall product design, to depend on alternative materials and possibilities for component designs and to modify the features of the product quality. Thatta (2013) supported the results of Tu et al. (2004) which found that modularity based practices can enable firms to reconfigure the production teams quickly, without loss of efficiency, and can minimize manufacturing response times without compromising on the quality of product design. The relevant hypothesis is:

H2: There is a positive relationship between product quality and product modularity.

Manufacturing Flexibility

Manufacturing flexibility refers to the quickness and ease with which plants can respond to the changes in market conditions (Ndubisi, Jantan, Hing, and Ayub, 2005). It reflects the ability of the plants to respond in a timely manner to the needs and wants of the company's customers including potential customers (Jacobs et al., 2011). It also means the ability of a firm's manufacturing system to address changes in customer demand, and to rapidly configure or reconfigure assets and operations of a manufacturing system in order to cope with consumer trends. Thatta (2013) stated that responsiveness from a manufacturing standpoint, would be an ability of the manufacturing system to respond rapidly to unexpected events, to swiftly accommodate special or non-routine customer requests, to deliver the product or service in a timely and reliable manner, and finally to satisfy customer demand. Whereas process modularity enables them to handle increasingly complex technology (Tu, 1999). According to (Oke, 2005) the existing literature related to flexibility is very extensive and argued that manufacturing flexibility has the capability to provide organisations with the ability to change levels of production rapidly, to develop new products more quickly, to respond more rapidly to competitive threats, to determine the best solutions for delivering system flexibility and to have highly demand responsive operations. As mentioned by (Dube et al., 2013) manufacturing based modularity is the application of unit standardization or substitution principles to create modular components and processes that can be configured into a wide range of end products to meet specific customer needs. Product modularity provides flexibility and responsiveness that enables firms to serve a variety of customer requirements. It offers many advantages to the manufacturing industry through reducing the number of labour, waste, and inventory besides increasing quality, improved productivity and enhancing cost and quality performance (e.g., Pasquire and Connolly, 2002). The empirical results demonstrated by(Lau et al., 2007), showed that there is a significant relationship between product modularity and flexibility with correlation coefficient (r= 0.20, p< 0.002), This result is matched with previous studies such as (Hargadon and Eisenhardt, 2000; Primo and Amundson, 2002), who found that firms can flexibly assemble the modules to develop new products, to develop independent modules in parallel to speed up delivery, to reuse high quality modules, to quickly test and to replace defective modules. Such integration activities are also found to mediate the relationship between modular design and flexible performance.

Jacobs et al (2007), supported that there is a significant relationship between product modularity and flexibility with (β=0.327, P< 0.05). This result confirmed with some previous studies such as (Lorenzi and Lello, 2001; Worren et al., 2002), who stated that production mix flexibility is increased with the use of product modularity and this may be due to both of the decrease in the number of set-ups required for modular products and a corresponding decrease in switching time; or the constraining of complexity that comes from re-using the modules; Lee and Tang, (1997), who found that product modularity also increases the flexibility of work-in-process (WIP) inventory. Lin and Bush (2010) stated that a modular system has ability to maintain its flexibility by blending part of its components with other components through its pre-defined interface to perform different functions, to produce more variations of products, to adapt to environmental changes by mixing the existing components to form a new manufacturing system without redesigning all components in the system. In addition, flexibility focused on competence, speed responsiveness matching with changing customer demand and dynamic environment that requires the ability to reconfigure not only for manufacturing processes in short-lived opportunities but also for designing modularity of products. Boer (2014) reported that product modularity has a positive impact on flexibility in the work of which confirmed with Lau et al., (2007) and Jacobs et al., (2007). Sohail et al (2010) proposed that product modularity has a positive effect on flexibility performance based on previous studies such as Vickery et al (2003), who found that product modularity is directly correlated with some manufacturing capabilities such as flexibility, so modular product design standardizes the interfaces between components that allow a variety of components to be substituted into a product system. Ro et al (2007) stated that firms can flexibly assemble components to develop new products with greater variety. Gangnes and Van Assche (2011), mentioned that based on (Garud and Kumaraswamy, 1995; Schilling, 2000), product modularity can increase flexibility by allowing the firms in the electronic industry to be more easily substitute certain components of a technological system, to reuse other components and to enable the firms to reduce the costs of trading and communicating.

Zainol et al (2013), mentioned that flexibility flexibility is achieved in rapidly changing product volumes, product mix and schedules to meet customer needs (Kotha et al., 1989); flexibility requires a company's wide effort to increase a firm's responsiveness, to reduce waste in order to meet the various customer requests (White, 1996), flexibility provides rapid design change, wider product range, great order size flexibility and great number of new products (Frohlich et al., 2001; Chase et al., 2001). The result of Zainol et al (2013) found that manufacturing flexibility have a significant positive effect towards product modularity (β=0.313, p<0.01). Sohail et al (2015) found that the standardized coefficient showed that product modularity significantly influences the flexibility performance with (γ = 0.629, p <0.001). According to (Golfmann et al, 2015) standardization of interfaces in modular product architectures creates multiple benefits for achieving flexible manufacturing. These include reduced complexity and increased interchangeability in engineering, a lower rate of production errors and reduced component variety in manufacturing.

Lau et al (2009) proved that product modularity has a marginal significant effect with flexibility (β=0.137, p=0.047) they supported that when product modules are fully specified and separated, companies can experiment with each module independently and the pros and cons of the module design can be identified piece by piece, which improves both of the design flexibility and the manufacturing flexibility. Ndubisi et al (2005) revealed that technology consideration is significantly associated (t=2.331; p=0.022) with launch flexibility and delivery consideration contribute significantly (F=2.788; p=0.031) and predict 11.4 % of the variation in launch flexibility due to being placed on bringing many new products to market as quickly as possible since it provides companies a real competitive advantage to meet the challenges with their competitors. Pil et al (2006) reported that modularity changes not only from the rest of the product, the flexibility in how it self not just in how changes are made to the functional parameters embodied in a component but also in how modules are integrated and combined. Firms can incorporate components that exploit novel technology at a lower cost, since the effects of change are localized (see. Sanchez et al, 1996; Garud, 1997). Modular product allows manufacturers to designate different module design teams to specialize in different technology developments at the modular level. Hence, their experience provides substantial specific technological knowledge for the company.

Todorova et al (2009) found that there is a significant negative relationship between external product modularity and flexibility through innovation of components (β=.-.74; p=.04). In addition, flexibility of product variants and strategic flexibility of components negatively and significantly influencing product modularity (β=-.54; p=.09; β=-1.05; p=.001) respectively. Markarian (2014), mentioned the main determinants that help the companies to meet the uncertainty of market demands such as optimizing the manufacturing capacity, increasing the flexibility for changing both of the capacity and the type of the product, enhancing the flexibility when designing the facilities, and adopting new technologies to provide customers a range of options and to create the market competition. Thus, the relevant hypothesis is:

H3: There is a positive relationship between manufacturing flexibility and product modularity.

Cycle Time Reduction

Danese et al (2010) concluded that customers expect new products even more quickly than before and a company must explore all available opportunities for shortening the time-to-market for new products while numerous authors (Ulrich, 1994; Sanchez et al, 1996) argue that product modularity can be beneficial to reduce the time dedicated to detailed designing and testing of products. Meyer and Utterback (1995) stated that the proponents of time-based competition argue that a firm will be most successful if its development times are shorter and products generated faster than its competitors. When multiple core technologies must be combined, this may lead to slow the speed of the time required to develop and bring new products to market. Reduced cycle time in isolation from underlying organizational and technical foundations may drive the firm out of business. Markarian (2014) reported that the ability to predict the characteristics associated with the engineering aspects of the module, the ability to accelerate the schedule for running the equipment, and the ability to speed up the time to manufacturing the modules are the key benefits of building any modules. Based on (Campagnolo et al., 2010) modularity methods help in reducing cycle time of a manufacturing process. Lau et al (2007) revealed that there is a significant relationship between product modularity and reduced production lead time, and flexibility (r=0.14, p <0:029). This result refers to the link between the rapid design change, the greater order size flexibility and the greater number of new products. Boer (2014) stated that the performance effects that can be expected from achieving component economies of scale include shorter manufacturing lead-time, and higher-throughput time efficiency. Sherman, Souder, and Jenssen (2000) confirmed that the effective R&D integration of knowledge from the past products had the largest contribution to the reduction in cycle time with (β=0.46, t=3.55, P< 0.001). The result found that there is significant relationship between Customer/R&D integration and reduction of cycle time with (β=0.28, t=2.20, P< 0.05). These results were apparent that the industrial companies should address set of factors that positively affect the shortening in cycle time introduced product. These factors consist of eliminating the conflict of the specifications of items or requirements at earlier development stages, increasing of the information flow between R&D and manufacturing during the product design process, greater flexibility in managing changed, and the reducing the need for design changes. Modular product design requires that the target design should involve fewer dependencies between the components and the subsystems which entails significantly less complexity and directly reduces the number of design alternatives. With fewer functions mapped to each component or subsystem, the performance of cycle time will be reduced (Pil et al, 2006). Based on (Jacobs et al., 2007), there is a significant relationship between product modularity and cycle time (β=0.461, P< 0.05), which matched with (van Hoek and Weken, 1998; Lorenzi and Lello, 2001; Novak and Eppinger, 2001), who reported that cycle time is reduced by increasing product modularity and this reduction may be due to the ability to manufacture the modules in parallel and then assemble them quickly based on customer' order requirements.

Sohail et al (2010) proposed that product modularity has a positive effect on reducing order cycle time according to literature review provided by (van Hoek and Weken, 1998; Sherman et al, 2000; Lorenzi and Lello, 2001; Novak and Eppinger, 2001), who stated that product modularity leads to reducing cycle time through enabling to manufacture the modules in parallel and assembles them. The results of Sohail et al (2015) showed that the standardized coefficient of product modularity significantly influences the cycle time performance with (γ=0.772, p <0.001). According to Meyer et al (1995) some researchers found that there is a positive relationship between the average of new product development NPD cycle time at the firm level and the perception of the overall firm performance for the computer industry, not for the automobile industry. Griffin (2002) proved that there is no statistically significant relationship between any dimension of the length of the cycle time and any of the three composite variables: overall success compared to competitors, success compared to the firm's goals and market success because of the high variability across the very broad set of industries in the study. Langerak, Hultink, and Griffin (2008) reported that the emphasis on cycle time reduction is based on the belief that the largest market share is achieved by the firm that first introduces the product in the marketplace. They revealed that the literature has produced divergent evidence with regard to the effects of development cycle time reduction and market entry timing. Several studies (e.g., Chen, Reilly and Lynn, 2005; Langerak and Hultink, 2005) have shown that the faster the firm completes the product development cycle time, the greater is its likelihood of surpassing competitors in the marketplace. Danese et al (2010) confirm that product modularity has a positive impact on the speed of product introduction depends on the new product development NPD cycle time which reflects the total time that runs from product concept generation through to product introduction and meets an assigned schedule on-time performance. In addition, the results found that product modularity has a positive impact on the extent to the plant to compare its speed of product introduction with that of competitors with regards to speed on time new product launch. In accordance with (Hartley et al., 1997; Kessler and Chakrabarti, 1999), it is difficult to compare the short NPD cycle time in different industries, so it is important to compare their speed of product introduction with that of competitors working in the same industry. Therefore:

H4: There is a positive relationship between cycle time reduction and product modularity.

Product Modularity

According to (Bask, Lipponen, Rajahonka, and Tinnilä, 2010) modularityhas been a popular concept especially in operations research and management rhetoric for decades, nevertheless there is no universal definition of modularity seems to exist not even for manufacturing of physical goods. However, Campagnolo et al., 2009) suggests that modularity is a design strategy that avoids creating strong interdependencies among specific components (modules) within the product. It facilitates a wide number of product configurations, rapid product development and helps to increase flexibility. In modularity-based manufacturing units, standardization and substitution principles are applied to create modular components and processes that can be configured into a wide range of end products to meet specific customer needs. Sanchez and Mahoney (2012) modular product is used to generate more product variety targeted, to establish new patterns and levels of competition in which modular design becomes an essential firm competence, to endow firms the strategic flexibility to offer more product variations and more rapid technological upgrading of products, and to increase the firm's ability to design rapid, with lower-cost.

Mcduffie (2013) stated that based on (Utterback, 1996; Langlois, 2002) modularity decomposes the complexity of a product into fully separable components, such that each component can be developed independently without necessary coordination with other components, advancing modularity-as-property. Eventually, a dominant design emerges, allowing standardization and scale which, in turn, reduces costs, channels innovation efforts. Technological change or customer demands for new functionality can redefine module boundaries, may increase interdependencies across modules and Undertaken strategically, as a means to improve product performance. As mentioned by (Thatta, 2013) today's managers face an array of complex challenges toward keeping pace with technological progress in order to generate more flexibility in manufacturing systems to cope with global competition (e.g., Ketchen and Hult, 2002). Besides, computer information technology enables virtual organizations to effectively reallocate production tasks and resources among modular virtual teams to cut costs and throughput time (e.g., Hoogeweegen et al, 1999). The major advantages of modularity are the ability to flexibly derive new derivatives of products on the basis of existing parts, to have a positive impact on product development speed and product variety, to relieve the negative costs effects of product variety, to achieve mass customization (Brettel et al, 2015). In addition, the literature advocates that effective modularity are the ability of organizations to offer a wide variety of products in a short time, to rapidly configure a variety of products as customer demand changes, to share common parts in designing the product, to respond quickly to demand fluctuations, to finish products only based on having accurate information on consumer preferences, to allow not only sharing of modules across product lines, but also reducing the volume of parts delivered to the assembly plant and to allow substitution of a range of components without requiring changes in the design of other components (Thatte, 2013). Jacobs, Vickery and Droge (2007) and Campagnolo et al., 2010) stated that modularity elaborates on Simon's (1962), who was the first to broach the concept of modularity within the academic literature when introduced the topic of nearly decomposable systems and Baldwin and Clark (1997, 2000) also argue that, in a modular system, each module communicates and interacts with the others via standardized interfaces that allow modules' decoupling. According to (Sohail et al., 2010), the term of modularity refers to components that are designed independently but still function as an integrated whole (Baldwin and Clark, 1997). Designing for product modularity attempts to achieve high levels of simplification and standardization in product modularity. Methods used to solve the same modularization problems have different results. Sanchez and Mahoney (1996) explained that to what extent the advanced technology can influence on the fully and standardize the component interfaces that used to specify standard operating procedures, to coordinate the work system to make up a modular product. Lau, Yam, and Tang (2009) stated that the literature on 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, and the extent to which modules are transferable or reusable within the production process (Garud et al., 2003, Baldwin and Clark, 2000, Schilling, 2000, Ulrich and Eppinger, 2000, and Ulrich, 1995). Zainol, Al-Mamun and Permarupan (2013) measuring product modularity depends on seven statements as follows: a product can be decomposed into separate modules, product components can be reused in various products, the interfaces among the components of the product are standard, a company used modularity as a general set of principles for managing complexity, the products are difficult for competitors to imitate, a company can adopt a high degree of modularity in production, and product used modularity concept that can achieve higher variety. In addition, according to (Dzuraidah et al., 2008), modularity has three features of in which the modules are distinct parts of a larger system, independent of one another, and modules function as an integrated, seamless whole. Ozman (2011) stated that the concept of modularity is applicable mostly to assembled products. A growing amount of literature suggests modularity as the one to one mapping between components and the functions of a system (Ulrich, 1995), it is a critical determinant of how the complementary products will fit together (Hill,1997), and all product systems are modular such as all automobiles, airplanes, and consumer electronics (Sanchez and Mahoney, 2003). Measuring the product modularity depends on the process of developing interchangeable parts across products that can be configured into a wide variety of end products (Jacobs, Droge, Vickery, and Calantone, 2011). Chiu and Okudan, (2012) stated that the two key factors of modularity are the degree of independence across modules which results in easily configuring new product variants and the standardization of modular interfaces that enables both substitutability and interchangeability as a product demands maintenance and upgrades. In addition, Fine et al (2005) developed the first quantitative model to investigate the interdependencies among products and processes and to analyze the trade-offs among product architecture alternatives, and assembly processes.

Boer (2014) proposed five measures that used in survey research in the modularity field. The first is decomposability and assimilability which means the ease to which the product can be decomposed and assembled. The second is independence which refers to the ability to make changes to key components without changing others. The third are both commonality and carryover which means the ability to reuse components between products and across product generations. The fourth are combinability and add-on which indicate to the ability to combine and add-on components to create different end products. The fifth are standardization of components and processes which refers to use of modular design and use of a standard base unit or technology. Lau, Yam, and Tang (2007), review some previous studies that provided a definition of product modularity. Fine, 1998 and Ulrich and Eppinger, (2000) defined as the most important part to configure the product architecture, Ulrich and Tung (1991) defined it as the degree of minimization of incidental interaction between physical components and functional product architecture, Sanchez et al (1996) defined it as the independency of the product components, and Schilling (2000) defined it as a continuum describing specificity, separateness, and recombination of the product components.

Lau, Yam, Tang, and Sun (2010) define product modularity in a product system as the degree to which first, a product can be reassembled into new configurations without loss of functionality (separateness), second, a component has a clear, unique and definite function with its system interfaces (specificity), and third, system components can be handed over and reused by another system (transferability). In addition, they stated that based on Ulrich and Tung (1991), when a product described as a set of independent modules, which allows for standardization, it became modularized.

Pil and Cohen (2006) clarified that in a product system a module is a component or group of components which designed to deliver a unique function, and independent of other modules' functions. In addition, some researchers argue that the independent modules do not exchange information, energy, or material to perform their function, nor do they require spatial coordination (Pimmler & Eppinger, 1994) and the goals of a modular product are to cluster components according to similar functional impact and to reduce dependencies between components assigned to different clusters (Gershenson et al., 2003) and how independent those modules' functions are from one another (Gershenson, Prasad, & Zhang, 2004). Rocha et al (2015) defined Product modularity as one of the key elements of mass customisation strategies. It concerns the use of a limited set of modules to create several product variants.

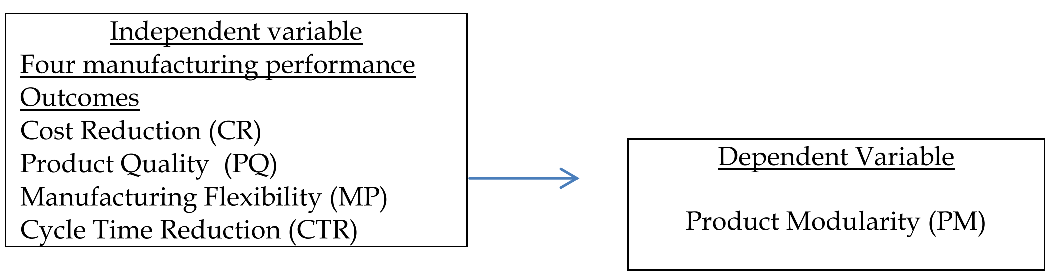
Based on (Boer, 2014), product modularity and manufacturing integration will interact to significantly improve flexibility and it has a marginal effect on costs and cycle time. Phuluwa et al. (2013), modularity enables modification to several products functional elements separately without affecting the design of the other elements. Salvador, Forza, and Rungtusanatham, (2002); Ernst, 2005; Chiu et al., (2012); and Chung, (2012) argue that researches in operations management highlighted that product modularity is categorized into four types based on Ulrich and Tung (1991). First, fabricate to fit modularity due to product variation is associated with physical dimensions so the product can depend one or more standard components with one or more variable additional components. Second, component-swapping modularity due to integrating the different types of components with the same basic component different variants related to the same product family can be produced. Third, component-sharing modularity refers to by combining different modules that sharing the same basic component different varieties belonging to the different product families can be produced. Fourth, bus modularity refers to creating a module of a product that matched with any number of basic components.

Danese et al (2010) defined product modularity as a strategic approach that affects several dimensions of competitive performance, such as product costs, quality, manufacturing flexibility and cycle time (Sanchez et al, 1996; Worren et al., 2002; Danese and Romano, 2004; Lau and Yam, 2005; Jacobs et al., 2007). Sohail et al (2010) proposed that product modularity will have a positive effect on cost, quality, flexibility, and cycle time through design integration. Drawing on the previous literature review, the four constructs which significant to product modularity within the conceptual framework depicted in figure1. This framework is grounded on production processes that emphasizes on the features of product components, the cost savings, the reduction of processing time, and the improvement of the product quality which derived from the benefits of product modularity.

The relevant hypothesis is:

H5: There is a positive relationship between cost reduction, product quality, manufacturing flexibility, cycle time reduction and product modularity.

Figure 1: Conceptual Framework



Source: (Zainol et al., 2013; Sohail et al., 2015)

METHODS

Standard questionnaire adapted from this research included 20 statements covering the four independent variables (cost reduction, product quality, manufacturing flexibility and cycle time reduction) and 7 statements covering the dependent variable (product modularity). The questionnaire divided into five parts. First: cost reduction composed of five items and second: manufacturing flexibility consisted of eight items drawn from (Zainol et al., 2013) which were developed following Parente (2003). Third: product quality composed of four items which derived from (Sohail et al., 2015) who adopted them from (Jacob et al., 2007; Worren et al. (2002). Fourth: cycle time reduction with tree items, the first two items were derived from (Danese et al., 2010) in accordance with several authors (Griffin, 1997; Hartley et al., 1997; Kessler and Chakrabarti, 1999) and the third item taken from (Sohail et al., 2015) who were initially adopted them from the work of Jacob et al. (2007) and Worren et al. (2002). These four parts were measured under-five point Likert scale ranging from “poor” to “excellent”. Fifth: product modularity was measured using seven items derived from (Zainol et al., 2013) who adopted them from the questionnaire prepared and tested by (Parente, 2003; Lau et al., 2007) under-five point Likert scale ranging from "extremely low use" to "extremely high use".

Sample

According to (Boer, 2014), there is a tendency in the literature to generalize the findings from a limited empirical background that have gained from using modular systems that most of them derived only from the automotive and electronics industries.

The sample of the current research will cover another area in furniture and weaving and textile industries. The operations strategy in these two industries and their approaches are concerned on managing the product variety–operational performance to satisfy customers' requirements. The unit of analysis in this study is plant. This research collected 230 questionnaires, but 192 were valid responses which addressed to a variety of positions such as managers, general managers, senior managers, and directors.

Data analysis

The following statistical tests were employed using SPSS software ver.21:

- Descriptive analysis was used to classify, analyze and interpret the four factors in terms of cost reduction, product quality, manufacturing flexibility, and cycle time reduction and product modularity.
- Conbach's alpha coefficients, were applied as the most common internal consistency test in multifactorial scales as suggested by (Nunnally (1978; Cooper and Schindler, 2006).
- Questionnaire items' validity was assessed using confirmatory factor analysis. The eigenvalues will be calculated in order to decide how many factors will be extracted in the overall factor analysis. While, Kaiser-Meyer-Olkin statistics are also examined the sampling adequacy measurement test.
- Pearson correlations were used to test each of the four research hypotheses.
- Stepwise regression was used to determine the extent of the effect of the four variables (CR, PQ, MF, and CTR) on product modularity.

RESULTS

Descriptive and Reliability Results

Table 1 depicts the results of the data collected. Since the Cronbach's alpha for all the constructs was 0.796 exceed the threshold value of 0.7 as suggested by (Nunally, 1978) indicating the theoretical constructs exhibited good psychometric properties, the internal consistency of the questionnaire used was adequate, and therefore it has a reasonable level of reliability.

Table 1. Description and Reliability of the research variables

Variable constructions	Mean	SD	Minimum	Maximum	Scale Mean If Item Delete	Scale Variance If Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Cost Reduction (CR)	3.596	0.559	1.40	4.60	14.657	3.245	0.624	0.744
Product Quality (PQ)	3.698	0.544	1.75	4.75	14.555	3.302	0.615	0.747
Manufacturing Flexibility (MF)	3.736	0.416	1.88	4.63	14.517	3.498	0.736	0.733
Cycle Time Reduction (CTR)	3.572	0.608	2.00	5.00	14.680	3.536	0.398	0.814
Product Modularity (PM)	3.650	0.772	1.14	9.14	14.602	2.614	0.643	0.746
Cronbach's Alpha Based on Standardized Items .796								N of Items 5

Factor Analysis Results

Based on the findings presented in Table 2, the minimum factor loading coefficient was 0.522 for item (PQ2: the ability to maximize time to product failure/malfunction) in the (PQ) construct. With loadings between 0.522 and 0.853 greater than 0.5 as noted by (Cooper et al, 2006), indicate that there is satisfactory convergent validity for all four constructs (CR, PQ, MF, and CTR) in the theoretical model.

The KMO measure of sample adequacy (0.799) is greater than 0.5 indicated a high-shared variance and a relatively low uniqueness in variance (Cooper et al, 2006). Barlett's sphericity test (Chi-square=345.721, df=10, p<0.000) indicated that the distribution is amenable to data reduction (Cooper et al, 2006). Therefore, this result can be suggested that the factor analysis test had proceeded correctly.

Table 2. Summary for factor analysis of CR, PQ, MF, and CTR

		Factor Loading			
Items		CR	PQ	MF	CTR
CR1: The ability to reduce cost of production through efficient operations		.661			
CR2: The ability to reduce cost of production through improvement in process technology		.764			
CR3: The overall performance in comparison to competitors on cost reduction.		.735			
CR4: The ability to reduce cost of production through economics of scale.		.728			
CR5: Reducing costs is a key priority for your company.		.561			
PQ1: The overall performance in comparison to competitors on product quality			.707		
PQ2: The ability to minimize time to product failure/malfunction.			.522		
PQ3: The ability to maximize time to product replacement			.715		
PQ4: The ability to manufacture a product whose operating characteristics meet established standards.			.695		
MF1:Your company can build different products in the same plants at the same time				.794	
MF2: There is a need for variety inputs in order to meet various needs of the customers				.743	
MF3:The company is prepared to quickly develop new products to meet challenge with your competitors				.771	
MF4:The company is prepared to quickly make adjustments in production to satisfy new customer's demand				.853	
MF5:The company is supported to develop or produce different components for the product available to the market				.845	
MF6:The company is prepared to make adjustments in production to adapt to new technological standards				.552	
MF7:The company has produced the variety amount of differential models or variants				.705	
MF8:There is a high level of inter-dependency between the components and parts that make up your products				.582	
CTR1:The ability to minimize the time from order placement to the delivery of items.					.549
CTR2:The ability to minimize the time from when the order was placed to the time of completion.					.656
CTR3:The ability to reduce time from customer order to final delivery.					.728
KMO		.799			
Barlett's Test of sphericity	Approx. Chi-square ($\chi2$)	345.721			
	Df	10			
	Sig.	.000			

Based on Table 3, the minimum factor loading coefficient was 0.549 for item (PM1) in the (PM) construct. Thus, all the factor loading coefficients for the dimensions of (PM) construct are higher than 0.5 as noted by (Cooper et al, 2006) indicate good measures and an acceptable validity level for this construct. The KMO measure of sample adequacy for the dependent variable (Product Modularity) was 0.742 greater than 0.5 indicated a high-shared variance and a relatively low uniqueness in variance (Cooper and Schindler, 2006). Barlett's sphericity test (Chi-square=228.650, df=6, p<0.000) indicated that the distribution is ellipsoid and amenable to data reduction (Cooper et al, 2006). Thus, all the model's constructs have a satisfactory reliability and validity measurements.

Table 3. Summary for factor analysis of Product Modularity (PM)

Items		Factor loadings
PM1: The product can be decomposed into separate modules		.549
PM2: The product components can be reused in various products		.643
PM3: The interfaces among the components of the product are standard		.501
PM4: The company using modularity as a general set of principles for managing complexity		.736
PM5: The products are difficult for competitors to imitate		.787
PM6: The company adopts a high degree of modularity in production		.716
PM7: The product used modularity concept that can achieve higher variety		.648
KMO		.742
Barlett's Test of sphericity	Approx. Chi-square (χ2)	228.650
	Df	6
	Sig.	.000

Correlation Results

The results of the correlation analysis presented in Table 4, showed that there are statistically significant relationship between the fife constructs included in the model (significance level $p < 0.01$).

Manufacturing flexibility is a significant and strong positive correlation with product modularity ($r=0.617$). This means that the manufacturing flexibility is more important for product modularity. This result corroborates with prior research (e.g. Oke, 2005; Jacobs et al, 2007; Lau et al, 2oo7, 2009; Gangnes et al, 2011; Zainol et al 2013; Boer, 2014) which revealed that increasing the manufacturing flexibility will lead to decompose the product into separate modules, to standardize the components of the product, and to implement a high degree of modularity in production in order to achieve high variety of products. The results indicate a significant and strong positive correlation between cost reduction and product modularity ($r=0.561$) and means that cost reduction is an important element. Nevertheless, this result was not expected due to the original hypothesized in this case, as cost reduction increases does product modularity. This result didn't support previous studies (e.g. Nevertheless et al, 2005; Zaino et al, 2013; Karmarkar and Kubat, 1987; Boer, 2014) that confirm negative correlation between cost reduction and product modularity. Though, there may be an axiomatic explication. First, the Egyptian furniture companies face many fundamental challenges as a result of a lack of high quality domestic inputs due to many of the local manufacturers depend on importing their needs from the raw materials with low quality in order to minimize production costs, and hence, there is no local standards from the specifications of raw materials (Egypt Furniture Export Council, 2011). Second, the public sector is dominated on the subsidiaries of industrial companies operating in the spinning and weaving sector, which has led to multiple negative repercussions on their factories' performance. They have become burdened by inferior technology, lack of operational efficiency, and low levels of use of capital. Besides, the fabric costs are also relatively higher in Egypt than any of its competitors. These conditions have resulted to high production cost, to low quality of products, and to limited response to changes in customer preferences (El-Haddad, 2012). The correlation results indicated that product quality is positively related with product modularity as shown by a coefficient of $r=0.464$. These results confirmed the findings of previous studies (Jacobs et al, 2007; Lau et al, 2009; Sohail et al, 2010; Lu, 2011; Sohail et al, 2015). They found that the use of a modular design standardization conducive to increase product quality which lead to provide high performance products, to offer consistent, to reliable quality, to improve conformance to design specifications. In addition, the increase in quality brought about by standardization can contribute increasing production volumes of similar components or subassemblies. The results revealed that there is a significant and positive correlation between the cycle time reduction and product modularity ($r=0.358$, $p<0.01$). This result is in the same direction of what was original hypothesized and in this case, as cycle time reduced, so does product modularity. This result corresponds with (Sherman et al, 2002; Jacobs et al, 2007; Campagnolo et al, 2010; Sohail et al, 2010; Boer, 2014; Sohail et al, 2015) who found a significant positive correlation between the cycle time reduction and product modularity. Based on aforementioned, the statistical tests revealed that there is a linear relationship between cost reduction, product quality, manufacturing flexibility, and cycle time reduction and product modularity.

Table 4. Correlation Results

Constructs	Product Modularity	Cost Reduction	Product Quality	Manufacturing Flexibility	Cycle Time Reduction
Product Modularity	1				
Cost Reduction	.561**	1			
Product Quality	.464**	.529**	1		
Manufacturing Flexibility	.617**	.551**	.683**	1	
Cycle Time Reduction	.358**	.286**	.297**	.363**	1

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

Regression Analysis

Results of Regression of Cost reduction on Product Modularity

Regarding *H1,* as shown in Table 5, the value of R2 =.349 indicates that the five dimensions of the cost reduction construct collectively contributed 34.9 % of the variance in the product modularity (PM). A summary of regression coefficients indicates that four out of five dimensions of the construct (CR) have positive and significant effect on the product modularity construct (PM) in the order of ranking from the higher to the lower effect. The first, CR4: the ability to reduce cost of production through economics of scale (β=0.309, t=4.811, p< .05), this result is consistent with (Lau et al, 2007; Sohail et al, 2010; Kremer et al, 2015). The second, CR1: the ability to reduce cost of production through efficient operations (β=0.238, t=3.741, p<.05), this result is consistent with (Danese et al, 2010; Kortmann et al, 2014).The third, CR2: the ability to reduce cost of production through improvement in process technology (β=0.228, t=3.607, p< .05) this result is consistent with (Thatta, 2013; Golfmann et al, 2015). The fourth, CR3: the overall performance in comparison to competitors on cost reduction (β=0.197, t=3.142, p<.05), this result is consistent with Sohail et al (2010) according to (Hargadon and Eisenhardt, 2000; Ernst and Kamrad, 2000). In addition, there is only one dimension of the (CR) construct called CR5: reducing costs is a key priority for your company (β=-0.009, t=-0.143, p>.05). This result has negative but non-significant impact on PM dimensions. This result is consistent with the findings of Zainol et al (2013). However, this result does not mean this dimension (CR5) was unimportant. None the less, there may be an intuitive explanation due to the most inputs of fabrics in the the sample of the Egyptian industrial companies are imported rather than produced internally (El Haddad, 2012). This finding supports the partial acceptance of *H1.*

Table 5. Regression Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	0.866	0.303		2.856	0.005	0.268	1.464
CR1		0.200	0.053	0.238	3.741	0.001	0.094	0.305
CR2		0.176	0.049	0.228	3.607	0.006	0.080	0.272
CR3		0.182	0.058	0.197	3.142	0.002	0.068	0.297
CR4		0.233	0.048	0.309	4.811	0.016	0.137	0.328
CR5		-0.008	0.055	-0.009	-0.143	0.886	-0.117	0.101
R^2 = .349								

A. Dependent Variable: PM
B. Predictors: CR construct (5 Items)

Results of Regression of Product Quality on Product Modularity

Regarding *H2,* the regression analysis in Table 6 revealed that the coefficient of determination for the four dimensions of the product quality construct explained 33.1 % of the total variance in product modularity (PM). A summary of regression coefficients indicates only two out of four dimensions of product quality construct (PQ) have positive and significant effect on the product modularity construct (PM). The findings indicate the dimension which has the most important effect on product modularity is (PQ4): the ability to manufacture a product whose operating characteristics meet established standards (β=0.444, t=6.985, p< .05), followed by (PQ3) dimension: the ability to maximize time to product replacement with (β=0.281, t=4.359, p< .05). The findings disclosed that neither dimension (PQ2) nor dimension (PQ1) are non-significant influenced on product modularity with (β=0.079, t=1.289, p>.05) and (β=-0.033, t=-0.52, p>.05) respectively. This result was expected, there may be an intuitive explanation. El Tobgy and El Masri, (-) reported that the lack of competition for these companies returns to set of factors. The facilities are almost obsolete, the quality and delivery of output are inconsistent, they have limited impact in world markets due to its small size local and international competition is incompatible with the requirements of export activities due to they often lack strategic vision to compete, and the activities of product development are ineffective. According to (El Haddad, 2012) since September 2009, most of the contracts in the Egyptian industrial companies have been cancelled because there is no confirmation between the specifications of their products and the level of quality required, the corruption is deeply ingrained in the system, 17% of the companies have already reduced their investments in the machines and 8 % of the companies have reduced their training costs, three quarters of these companies have reduced the utilization of their capacities, hence increasing in production costs and decreasing their ability to compete. With the exception of PQ1and PQ2, these findings provided a partial support to the hypothesis *H2* due to assertion that the PQ construct of PQ3 and PQ4 influence on PM dimensions.

Table 6. Regression Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.307	0.324		4.039	0.000	0.668	1.945
PQ1		-0.031	0.059	-0.033	-0.52	0.603	-0.148	0.086
PQ2		0.058	0.045	0.079	1.289	0.199	-0.031	0.147
PQ3		0.228	0.052	0.281	4.359	0.000	0.125	0.331
PQ4		0.377	0.054	0.444	6.985	0.000	0.27	0.483
R^2 = .331								

A. Dependent Variable: PM
B. Predictors: PQ1, PQ2, PQ3, PQ4

Results of Regression of Manufacturing Flexibility on Product Modularity

According to *H3*, the regression analysis in Table 7, revealed that the coefficient of determination for the eight dimensions of the manufacturing flexibility construct (MF) collectively contributed 69.2 % of the variance in product modularity construct (PM) although not all the relationships between the eight dimensions of the MF construct and PM construct are significant. A summary of regression coefficients indicate that among the MF construct, MF3 (β=0.456, t=7.667, p=.000) and MF4 (β=0.422, t=6.347, p=.000) were found to be significant and positively influence on PM dimensions and seem to be the most influential dimensions on PM dimensions.

As to the influence of the MF3, the results are consistent with Zainol et al (2013) and Danese et al (2010).

In addition, the findings of the influence of the MF4, are consistent with Todorova et al (2009); mcduffie (2013); Dube et al (2013). These results indicated that the managers of these companies have abilities toward both of the developing new products quickly in order to meet the challenges from their competitors (MF3) and making adjustments in the production to satisfy new customer’s demand (MF4).

Nevertheless, the findings of testing this hypothesis of the influence of the MF1 (β=-0.037, t=-0.546, p=.585) and MF6 (β=-0.051, t=-1.042, p=.299) are negative but non-significant on PM dimensions. Moreover, the findings of testing this hypothesis of the influence of the MF2 (β=0.012, t=0.185, p=.853), MF5 (β=0.027, t=0.474, p=.636), MF7 (β=0.071, t=0.731, p=.466), and MF8 (β=0.029, t=0.678, p=.499) are positive but non-significant on PM dimensions.

These results appear that these dimensions do not play a pivotal role of influencing on PM dimensions which are illogical findings. The finding of MF1 does not support the argument that the capability of the companies to build different products in the same plants at the same time can positively influence on PM dimensions. However, this result is convenient with Sohail et al (2015) who found this dimension has the lowest mean score in the MF construct. As to the influence of the MF2, the result is not consistent with mcduffie (2013) and Todorova et al (2009) who found the need for variety inputs in order to meet various needs of the customers influence PM. As to the influence of the MF5, the result is not coordinated with Ndubisi et al (2005) and Lethovaara et al (2011) who supported the importance of flexibility to develop and to produce different components to present many new products to the market as quickly as possible on the PM dimensions. Also, the findings of the MF6 is not agreement with Sanchez et al (2012); (Boer (2014) who found positive influence of making adjustments in production to adapt to new technological standards on PM dimensions.

The findings related to MF7 are not compatible with Salvador et al (2002); Ernst (2005); Todorova et al (2009); Jacobs et al (2011); Chung (2012); Boer (2014); Rocha et al (2015) who found positive influence of producing variety amount of differential models on PM dimensions. As to the influence of the MF8, the findings are not concordant with Fine et al (2005); Dzuraidah et al (2008); Lau et al (2009, 2010); Sohail et al (2015) who asserted the positive influence of the existing high level of inter-dependency between the components and the parts that make up the products on PM dimensions. With the exception of MF3 and MF4, the findings provide a partial support to the hypothesis *H3* due to assertion that the MF construct of MF1, MF2, MF5, MF6, MF7 and MF8 are not influenced on PM dimensions.

Table 7. Regression Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-0.063	0.308		-0.204	0.839	-0.671	0.545
MF1		-0.033	0.06	-0.037	-0.546	0.585	-0.151	0.086
MF2		0.013	0.069	0.012	0.185	0.853	-0.123	0.148
MF3		0.485	0.063	0.456	7.667	0.000	0.36	0.610
MF4		0.463	0.073	0.422	6.347	0.000	0.319	0.606
MF5		0.037	0.078	0.027	0.474	0.636	-0.116	0.190
MF6		-0.065	0.062	-0.051	-1.042	0.299	-0.187	0.058
MF7		0.095	0.131	0.071	0.731	0.466	-0.162	0.353
MF8		0.022	0.032	0.029	0.678	0.499	-0.042	0.085
R^2 = .692								

A. Dependent Variable: PM

B. Predictors: MF1, MF2, MF3, MF4, MF5, MF6, MF7, MF8

Results of Regression of Cycle Time Reduction on Product Modularity

According to *H4,* the regression analysis in Table 8, revealed that the coefficient of determination for the three dimensions of the cycle time reduction construct (CTR) collectively contributed 29.2 % of the variance in product modularity construct (PM) although not all the relationships between the three dimensions of the (CTR) construct and PM construct are significant. A summary of regression coefficients indicate that among the (CTR) construct, CTR3 only (β=0.527, t=8.531, p=.000) was found to be significant and positively influence on PM dimensions. These results indicated that reducing the time between receiving the customer's order and the final delivery time is a decisive dimension of the (CTR) construct and it seems to be the most influential dimension on PM dimensions. As to the influence of the CTR3, the results are consistent with Sherman et al (2000); Jacobs et al (2007); Danese et al (2010); Sohail et al (2015). Nonetheless, the findings of testing this hypothesis of the influence of the CTR1 (β=0.089, t=1.446, p=.150) and CTR2 (β=0.009, t=0.145, p=0.885) are positive but non-significant on PM dimensions. These results appear that these dimensions do not play an axial role in the sample of Egyptian companies of influencing on PM dimensions which are inconsequent findings.

As to the influence of the CTR1, the result is not harmonious with Ndubisi et al (2005); Pil et al (2006); Lau et al (2007); Sohail et al (2005) who found the key role of minimizing the time from order placement to the delivery of items can positively influence on PM dimensions. Though, there may be self-evident exegesis. Because most of the inputs of these companies are imported rather than being internally produced and with the rising levels of the price internationally. Also, in the light of the political situation, the economic crises that are experienced by the Egyptian government, and the limited access to finance the needs of these companies constitute obstacles to the possibility of minimizing the time between the placement time of orders and the delivery time of items. These companies believe that government must provide them financial subsidies and should reduce the number of taxes levied on their imported inputs (El-Haddad, 2012).

As to the influence of the CTR2, its result is not compatible with Sherman et al (2000); Pil et al (2006); Campagnolo et al (2010); Sohail et al (2010); Markarian (2014); Boer (2014) who found that reducing the time between received the orders from the customers and the completion time of manufacturing these orders can positively influence on PM dimensions. None the less, there may be axiomatic explication. As a result of the state dominance of industrial public sector, the amount of investments were reduced in machinery in this sector for many years and therefore the most available machinery used were for more than 20 years ago. In addition, the subsidiary companies to this sector burdened with the overemployment, the high rate of power outage and the low levels of capital utilization.

These conditions led to the inability of these companies to respond to its customers to reduce the time from when the order was placed to the time of completion (El-Haddad, 2012).

With the exception of CTR1 and CTR2, the findings provide a partial support to the hypothesis *H4* due to assertion that the (CTR3) only influence on PM dimensions.

Table 8. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.675	0.294		5.702	0	1.095	2.254
CTR1		0.066	0.046	0.089	1.446	0.150	-0.024	0.157
CTR2		0.007	0.049	0.009	0.145	0.885	-0.09	0.104
CTR3		0.459	0.054	0.527	8.513	0.000	0.352	0.565
R^2 = .292								

A. Dependent Variable: PM B. Predictors: CTR1, CTR2, CTR3

Results of Regression of CR, PQ, MF and CTR on Product Modularity

The stepwise regression results as shown in Table 9, indicate that the value of (R2 = .464) of the four dimensions (CR, PQ, MF and CTR) jointly explained 46.4 % of the variance in the product modularity construct (PM).

A summary of regression coefficients indicates that three dimensions are positively related and significantly associated with PM in the order MF (β=0.415, t= 5.288, p<.05), CR (β=0.306, t= 4.600, p<.05) and CTR (β=0.125, t=2.158, p<.05). While the statistical tests revealed that a negative but non-significant correlation between product quality (PQ) and product modularity (β=-.019, t= -.247, p>.05) in the sample of Egyptian companies. This result is neither logical nor consistent with the results of prior studies such as (Jacobs et al, 2007; Sohail et al, 2010), which confirmed a positive relationship between product quality and product modularity. A convincing explanation for this result is that the variables such as design integration and supply chain integration may be partially mediate the relationship between the product quality construct (PQ) and the product modularity construct (PM) which is in agreement with Lau et al, (2007); Boer, (2014); Ahmadi, (2015); Sohail, (2015), but they were not included in the current research model .

These findings of testing the research hypothesis (*H5*) of the influence of the four constructs (CR, PQ, MF and CTR) on the PM construct provide a partial support for the acceptance this hypothesis.

Table 9. Regression Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-1.216	.396		-3.071	.002	-1.998	-0.435
CR		.423	.092	.306	4.600	.000	0.241	0.604
PQ		-.027	.107	-.019	-.247	.805	-0.239	0.185
MF		.770	.146	.415	5.288	.000	0.483	1.058
CTR		.159	.073	.125	2.158	.032	0.014	0.304
R^2 = .464								

A. Dependent Variable: PM
B. Predictors: CR, PQ, MF, CTR

CONCLUSION

This research has contributed to the field of product modularity by focusing on four constructs in terms of cost reduction, product quality, manufacturing flexibility, cycle time reduction. Quantitative data was collected to empirically test five hypotheses in some of Egyptian companies in the field of furniture and weaving and textile industries. The results provided partial evidence that certain dimensions of the four constructs showed a positive and statistically significant relationship with the dimensions of product modularity construct.

Furthermore, findings suggest that the construct of manufacturing flexibility is most influenced on product modularity. Nevertheless, this result was, in part, surprising that only two dimensions out of eight of this construct in terms of the ability of the companies' managers to quickly develop new products to meet challenge with the competitors, and to quickly make adjustments in production to satisfy new customer's demand.

These results are also interesting in that they disprove the earlier results of studies about respecting to cost reduction as a key priority dimension influenced on PM dimensions (Jacobs et al, 2007; Danese et al, 2010; Golfmann et al, 2015). These results also recognize that product quality is not used as indicator to compare between the performance of the companies and their competitors' performance or to be an indicator to minimize time to product failure. And therefore it has no significant influence on PM dimensions.

While the findings revealed that there are disappointing results related to the cycle time reduction construct, whereas companies' managers don't have abilities to minimize both of the time from order placement to the delivery of items and the time from the order was placed to the time of completion and thus they do not impact on the PM dimensions.

However, there are several contributions in this research. First, a theoretical framework is provided for empirical study on product modularity. Second, the relationship between the four manufacturing outcomes in terms of cost reduction, product quality, manufacturing flexibility, cycle time reduction and product modularity is addressed. Third, this study attempts to find the relationships between cost reduction, product quality, manufacturing flexibility, cycle time reduction and product modularity in some of Egyptian industrial companies in the area of furniture and weaving and textile where the previous studies never applied yet this model in these fields.

FURTHER RESEARCH

In spite of the interesting implications of this research which has built on past theoretical and empirical studies, it has several limitations, which are described below to be addressed in future research.

- This research can test the model in larger samples, which will make it possible to detect effects with smaller size (Todorova et al, 2009).
- Future researches may expand the current theoretical framework by integrating new constructs related to modularity like technological innovations, operation capability, uneven demand, and competitive environment. Environmental issues including energy usage, reuse, recycle, and disposal has become important on product modularity (Kremer et al, 2015).
- This research is limited to the sample of companies that work in the field of furniture and weaving and textile industries and this could limit the generalizability of its results to other industries types. This research recommends that this research be replicated in different Egyptian industrial sectors such as steel, food, and consumer electronics, automobile industries that attempts to more widespread generalizations to be made.
- Future studies may also test the hypothesized relationships across countries, for identification and comparison of country specific issues in modularity and responsiveness.
- Finally, it is expected that a flow of further researches will arise supplemental confirmation of the results reported in this research and identifies another results of the effectiveness of these four constructs and its influence on the construct of product modularity.

REFERENCE

Ahmadi, A. R. (2015), "The Role of System Theory In New Product Development: An Investigation Focusing on Lean and Simultaneous Engineering", *International Journal of Lean Thinking*, Vol. 6, Issue. 1, pp. 1-20, June.

Bask, A.; Lipponen, M.; Rajahonka, M., and Tinnilä, M. (2010), "The Concept of Modularity: Diffusion from Manufacturing to Service Production", *Journal of Manufacturing Technology Management*, Vol. 21, No.3, pp. 355- 375. Doi.org/10.1108/17410381011024331

Boer, H. E. E. (2014). Product, Organizational and Performance Effects of Product Modularity. *In Proceedings of the 7th World Conference on Mass Customization, Personalization, and Co-Creation* (MCPC), pp. 449-460.
Doi: 10.1007/978-3-319-04271-8_38

Brettel, M and Friederichsen, N. (2015), The modularity-performance link: a literature review, 22nd EurOMA Conference, Operations Management for Sustainable Competitiveness, June 26 - July 1, Neuchâtel, Switzerland.

Campagnolo, D., and Camuffo, A. (2010), "The Concept of Modularity in Management Studies: A Literature Review", *IJMR International Journal of Management Reviews*, Vol. 12, Issue 3, pp. 259-283, September. Doi: 10.1111/j.1468-2370.2009.00260.x

Chiu, M-C. And Okudan, G. (2012), "An Investigation on the Impact of Product Modularity Level on Supply Chain Performance Metrics: An Industrial Case Study", *International Journal of Intelligent Manufacturing,* Vol. 13, No. 7, pp. 1259-1272. DOI 10.1007/s10845-012-0680-3

Chung, W. H. (2012), "A Modular Design Approach to Improve Product Life Cycle Performance Based On Optimized Closed-Loop Supply Chains", *A Dissertation in Industrial Engineering,* Ph.D, Pennsylvania State University.

Cooper, R. C., and Schindler, P. S. (2006), "business Research Methods", 9th ed, Boston, Mass, mcgraw Hill.

Danese, P. And Filippini, R. (2010), "Modularity and the impact on new product development time performance: Investigating the Moderating Effects of Supplier Involvement and Inter-functional

Integration, *International Journal of Operations & Production Management*, Vol. 30, Issue.11, pp.1191–1209. Doi.org/10.1108/01443571011087387

Dube. P., Muyengwa, G., and Battle, K. (2013), T*he Impact of Product Modularization on Supply Chain relationships : a furniture industry perspective*, SAIIE, 25TH Annual Conference of the Southern African Institute for Industrial Engineering, Cape Town, South Africa, July 9-11.

Egypt Furniture Export Council. (2011), Industrial Modernisation Centre, Egyptian Furniture Sector Development Strategy*, Detailed report*, December.

12. El Tobgy, A., and El Masri, M. (-), "Challenges Facing Investment in the Egyptian Cotton Industry", AIT Consulting -Cairo, Egypt. https://www.icac.org/Meetings/Plenary/61cairo/documents/open_1/e_togby.pdf.

El-Haddad, A. (2012), "Effects of the Global Crisis on the Egyptian Textiles and Clothing Sector: A Blessing in Disguise?", *ISRN International Scholarly Research Notices Economics journal,* Vol. 2012. Doi.org/10.5402/2012/941695

Ernst, D. (2005), "Limits to Modularity: Reflections on Recent Developments in Chip Design. *Industry and Innovation*, Vol. 12, No. 3, pp. 303–335, September. Doi: 10.1080/13662710500195918.

Gangnes, B., and Van Assche, A. (2011), "Product Modularity and the Rise of Global Value Chains: Insights from the Electronics Industry", Working Papers, University of Hawaii at Manoa, Department of Economics.

Golfmann, J., and Lammers, T. (2015), "Modular product design: reducing complexity, increasing efficacy", Performance, Volume 7, Issue 1.

Griffin, A. (2002), "Product development cycle time for business-to-business products", *Industrial Marketing Management*", Vol. 31, pp. 291-304.

Jacobs, M., Droge, C., Vickery, S. K., and Colantone, R. (2011). Product & Process Modularity's Effects on Manufacturing Agility and Firm Growth Performance. *Journal of Product Innovation Management,* Vol. 28, No.1, 123-137. Doi.org/10.1111/j.1540-5885.2010.00785.x.

Jacobs, M., Vickery, S, K., and Droge, C. (2007) "The effects of product modularity on competitive performance: Do integration strategies mediate the relationship?" ,*International Journal of Operations & Production Management,* Vol. 27, Issue. 10, pp. 1046 – 1068. Doi.org/10.1108/01443570710820620

Kortmann, S., Gelhard, C., Zimmermann, C., and Piller, F. T. (2014), "Linking strategic flexibility and operational efficiency: The mediating role of ambidextrous operational capabilities", *Journal of Operations Management*, Vol. 32, pp. 475–490. Doi.org/10.1016/j.jom.2014.09.007

Kremer, G. O., Ma, j., Chiu, M. C., and Lin, T. K. (2015), "Green Supply Chain: Challenges and Opportunities: Product Modularity and Implications for the Reverse Supply Chain", *Supply Chain Forum: An International Journal,* Vol. 14, Issue 2. DOI:10.1080/16258312.2013.11517315Gül E. Okudan

Langerak, F., and E. J. Hultink. (2005), "The impact of product innovativeness on the link between development speed and new product profitability", *Journal of Product Innovation Management,* Vol. 23, No. 3, pp. 203–14.

Langerak, F., Hultink, E. J., and Griffin, A. (2008), "Exploring Mediating and Moderating Influences on the Links between Cycle Time, Proficiency in Entry Timing and New Product Profitability", *Journal of Product Innovation Management,* Vol. 25, No. 4, pp. 370-385, May.

Lau, A. K. W. (2011), "Critical success factors in managing modular production design: Six company case studies in Hong Kong, China, and Singapore", *Journal of Engineering and Technology Management*, Vol. 28, pp. 168–183. Doi:10.1016/j.jengtecman.2011.03.004.

Lau, A.K.W., Yam, R.C.M., Tang, E. P.Y. (2007), "The impact of product modularity on competitive capabilities and performance: An empirical study", *International Journal of Production Economics,* Vol. 105, pp. 1–20. Doi:10.1016/j.ijpe.2006.02.002

Lau, A.K.W., Yam, R.C.M., Tang, E. P.Y. (2009), "The complementarity of internal integration and product modularity: An empirical study of their interaction effect on competitive capabilities", *Journal of Engineering and Technology Management*, Vol. 26, Issue 4, pp. 305–326, December. Doi:10.1016/j.jengtecman.2009.10.005

Lau, A.K.W., Yam, R.C.M., Tang, E. P.Y., Sun, H.Y. (2010) "Factors Influencing the Relationship Between Product Modularity and Supply Chain Integration", *International Journal of Operations & Production Management,* Vol. 30, Issue: 9, pp. 951 – 977. Doi.org/10.1108/01443571011075065

Lehtovaara, M., Kokkonen, K., Rousku, P., and Kässi, T. (2011), "Product Modularity Influences on Firm Performance: Evidence from Bioenergy Technology", *MECHANIKA,* Vol. 17, Issue 5, pp. 562-569, September. Doi.org/10.5755/j01.mech.17.5.737

Lin, S. F., and Bush, A. A. (2010), "The Complementary Effect of Manufacturing Process Modularity and IS Flexibility on Agility in Manufacturing", Proceedings of the Sixteenth Americas Conference on Information Systems, Lima, Peru, August 12-15.

Markarian, J. (2014), "Modularity Creates Flexible Manufacturing Systems", *Pharmaceutical Technology,* Vol. 38, Issue 8, Sep.

Mcduffie, J. P. (2013). "Modularity-as-Property, Modularization-as-Process, & Modularity-as-Frame: Lessons from Product Architecture Initiatives in the Global Automotive Industries", *Global Strategy Journal,* Vol. 3, No.1, pp. 8-40. Doi.org/10.1111/j.2042-5805.2012.01048.x

Meyer, M.H, and Utterback, J. M. (1995), "Product Development Cycle Time and Commercial Success", *IEEE Trans. Engrg. Management,* Vol. 42, Issue. 4, pp. 297-304, November.

Ndubisi, N. O., Jantan, M., Hing, L. C., and Ayub, M. S. (2005) "Supplier Selection and Management Strategies and Manufacturing Flexibility", *Journal of Enterprise Information Management,* Vol. 18, Issue. 3, pp. 330-349. Doi.org/10.1108/17410390510592003

Nunnally, J. C. (1978), "*Psychometric Theory*", mcgraw-Hill, New York, NY.

Nunnally, J.C. (1978), *Psychometric Theory,* 2nd ed., mcgraw-Hill, New York, NY.

Oke, A. (2005), "A Framework for Analysing Manufacturing Flexibility", *International Journal of Operations & Production Management*, Vol. 25, No. 10, pp. 973-996. Doi:10.1108/01443570510619482

Ozman, M. (2011), "Modularity, Industry Life Cysle and Open Innovation", Journal of *Technology Management & Innovation,* Vol. 6, Issue. 1, pp. 26-34. Doi.org/10.4067/S0718-27242011000100003

Pil, F. K., and Cohen, S. K. (2006), "Modulatory: Implications for Lmitation, Innovation, and Sustained Advantage", *Academy of Management Review,* Vol. 31, No. 4, pp. 995–1011.

Rocha, C. G. D., Formoso, C. T., and Tzortzopoulos, P. (2015), "Adopting Product Modularity in House Building to Support Mass Customisation", *Sustainability,* Vol. 7, pp. 4919-4937. Doi:10.3390/su7054919

Salvador, F., Forza, C., and Rungtusanatham, M. (2002), "Modularity, Product Variety, Production Volume, and Component Sourcing: Theorizing Beyond Generic Prescriptions", *Journal of Operations Management*, Vol. 20, pp. 549–575.

Sanchez, R and Mahoney, J. T. (2012), "Modularity and Economic Organization: Concepts, Theory, Observations, and Predictions", *Working Paper,* http://www.business.illinois.edu/Working_Paper.

Sanchez, R. And Mahoney, J. T. (1996), "Modularity, Flexibility, and Knowledge Management in Product and Organization Design", *Strategic Management Journal,* Vol. 17, Winter Special Issue, pp. 63-76.

Sherman, J. D., Souder, W. E. And Jenssen, S. A., (2000), "Differential effects of the primary forms of cross functional integration on product development cycle time", *Journal of Product Innovation Management*, Vol. 17, pp. 257-267.

Sohail, M. S., and Al-Shuridah, O. (2010), "Linkages between product modularity and integration strategies: A conceptual framework to determine competitive capabilities", *International Conference on E-business, Management and Economics*, Hong Kong

Sohail, M. S., and Al-Shuridah, O. (2015), "Product Modularity and Its Impact on Competitive Performance: An Investigation of the Mediating Effects of Integration Strategies", *Asian Journal of Business Research,* Special Issue, pp. 86-107. Doi: 10.14707/ajbr.140016

Thatte, A. A. (2013), "Supply Chain Responsiveness through Modularity Based Manufacturing Practices: An Exploratory Study", *The Journal of Applied Business Research,* Vol. 29, No. 3, pp. 743-764, May/June.

Todorova, G., and Durisin, B. (2009), "Do firms innovate through integrated modular designs? Disentangling the effects of types of modularity on types of innovation", Working Paper, kites: Knowledge, Internationalization and Technology Studies, Carnegie Mellon University & Bocconi University, n. 13.

Tu, Q., Vonderembse, M. A., Ragu-Nathan, T. S., and Ragu-Nathan, B. (2004), "Measuring Modularity-Based Manufacturing Practices and Their Impact on Mass Customization Capability: A Customer-Driven Perspective", *Decision Sciences,* Vol. 35, No. 2, pp. 147-168.

Zainol, n. R. B., Al-Mamun, A and Permarupan, P. Y. (2013), "Effects of Demand, Manufacturing Flexibility, Cost and Supply Chain on Product Modularity: A Study in Malaysia", *Asian Social Science;* Vol. 9, No. 17, pp. 167-179. Doi:10.5539/ass.v9n17p167