Product Modularity and Its Impact on Competitive Performance: An Investigation of the Mediating Effects of Integration Strategies

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Abstract

The purpose of this research is to study the effect of product modularity on performance outcomes. The mediating effects of supplier, design, and manufacturing integrations are also examined. This study is based on a survey of 381 manufacturing firms in Saudi Arabia. Using empirical research, this study analyses the direct and indirect effects of product modularity on performance outcomes. Results indicate a direct, positive relationship between product modularity and performance outcomes and found mixed support on the effects of product modularity on mediation strategies. This research tests theories that have been primarily applied in western country settings. The value of this paper is that, it is one of the first of this kind, conducted in the Middle East region, and adds empirical support, which was previously lacking in extant literature.

**Keywords:** product design, product modularity, performance outcomes, integration, Saudi Arabia manufacturing

Introduction

Innovation in product development technology coupled with an increasing demand for customized products has seen many firms looking to implementing a product modularity (PM) strategy for gaining a comparative advantage. Since the pioneering work on modular design theory by Ulrich and Tung (1991), a stream of research has emerged on this topic. Modular design approach has been an important perspective in product innovation research with the idea of PM having been adopted from product manufacturing (Dray et al., 2000; Lau et al., 2011). Recent research in the domain of modularity in use has identified various advantages of modularity, for example, in providing opportunities to manufacturers on mass customization (Bask et al., 2011); in improving competitive capabilities (Antonio, 2010); in bringing economic efficiencies (Böttcher and Klingner, 2011); in exerting an influence on value
perception (Rahikka et al., 2011); and studying consumers’ responses to PM (Seo-Woong et al., 2012).

Much of extant literature on product modularity deals with features of product components and 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; and cost saving benefits of PM (Baldwin and Clark, 2000; Schilling, 2000). This study is a response to suggestions in the literature that modularity and its relationship with performance outcomes should be studied empirically (Carmeli and Tishler, 2004; Song et al., 2005).

Extant literature has also considered PM to be an effective approach for enabling manufacturers to improve strategic flexibility (Worren et al., 2002; Sanchez, 1995). Numerous studies have reported on the benefits of PM at a firm level (Sanchez and Mahoney, 1996). Yet, existing literature contains surprisingly few studies of how modularization actually should be accomplished from a business perspective. The impact of PM beyond the firm in strategic terms such as external integration and their impact on competitive capabilities have only recently begun to be explored (Antonio 2010; Howard and Squire, 2007).

A vast majority of previous studies have been conducted in the context of US, Europe or other industrialized countries. As a result, present understanding on this topic has remained context-specific limiting our knowledge of marketing phenomena to research conducted in industrialized countries (Burgess and Steenkamp, 2006). Research in the area of international marketing and manufacturing have highlighted the fundamental differences between a developed nation and a developing nation on issues such as marketing strategy formulation, business environment, labor market, industrial competitiveness and others (Sohail, 2009; Kulviwat et al., 2009; Zhou and Li, 2010). This evidence suggests that studying the contextual nuances in different national settings brings forth hitherto unexplored perspectives. Developing and emerging nations present significant departures from the assumptions of theories developed in the West and different results could be expected from studies conducted. In this respect, this study is modelled on and is an extension of earlier work on PM in a developed country setting by Jacobs et al. (2007).

The aim of this study is to test theories that have been primarily applied in Western country settings. Empirically examining extant theories from one region to another will help in accumulating knowledge useful for developing appropriate strategies (Singh et al., 2003). The objective of this study is to assess the impact of PM on performance outcomes. The study explores recent literature related to the relationship between PM, performance outcomes and the mediation effect of integration strategies. The study uses data from the manufacturing industry in Saudi Arabia, considered an emerging powerhouse from the Persian Gulf region.

The Saudi government’s industrial policy has been to reduce the dependence on the crude oil sector by diversifying the productive base of the economy and propelling the growth of the manufacturing sector. Consequently, the manufacturing sector in Saudi Arabia has undergone rapid transformation. Since 2006, the year in which Saudi Arabia gained accession to the World Trade Organization (WTO), several policy measures and reforms have been undertaken to encourage the growth of
manufacturing industries in the private sector, to diversify the industrial base and to increase industrial competitiveness. In the following section, we review the literature on PM outcomes and develop a research model and hypotheses that are tested with data gathered from manufacturing firms in Saudi Arabia.

**Theoretical Framework**

**Product Modularity**

Due to global competition, manufacturers have to deal with more product variations, rising development costs and shorter product life cycles. A growing body of literature has suggested that PM can be used as a strategy to deal with this situation (for example, Garud et al 2003; Baldwin and Clark, 2000). As for the definition of PM itself, a review of literature reveals that little consensus emerges amongst researchers on its terminology. In general, modularity as a theory can be defined as the degree to which the components of a system can be separated and recombined to create a variety of configurations without losing in functionality (Schilling, 2000). Baldwin and Clark (2000), consider modularity as a design strategy that avoids creating strong interdependencies among specific components (modules) within the product. Firms having the ability to develop modular products are reported to have an improvement in their performance (Pil and Cohen, 2006). The theoretical framework, construct development and measurement items are a further extension of preliminary work undertaken by authors reported in a previous study (Sohail, and Al-Shuridah, 2010).

**Performance Outcomes**

Given the competitive nature of industries, performance outcome implies that a firm must have an ability to create products that have a competitive advantage. Existing literature identifies a number of domains for enhancement of a firm’s performance in a competitive environment. These are cost reductions; product quality; manufacturing (Meybodi, 2003; Chesbrough, 2003; Vickery et al., 2003; Calantone et al., 2002; Rundh, 2011) and cycle time reduction (Sherman et al. 2000). Studies have found that a firm’s ability to develop modular products has positive relations with its performance outcome (Pil and Cohen, 2006; Gershenson et al., 2003). A discussion of these performance outcomes and their relationships with PM is discussed in the following sub-sections.

**Potential Linkage between PM and cost reduction**

PM leads to cost reduction 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, which enables quick delivery with short lead time (Hargadon and Eisenhardt, 2000; Ernst and Kamrad, 2000).

Another study reports cost benefit arising from engineering and operational efficiencies attributable to modularization (Collier, 1981). Firms can also benefit
through a reduction in investment costs (Fisher et al., 1999). PM enables a standardized production process. As a consequence of this, costs associated with tooling, engineering, testing, and support services are reduced by using standardized components and sub-assemblies (Fisher et al., 1999).

In contrast to the general consensus, one study reports a contrary finding indicating that PM does not necessarily lead to cost reductions and concludes that the PM process actually leads to an increase in spare parts costs due to higher failure rates of modules vis-à-vis components (Kutner et al., 2005). However, a limitation of their study is that there is no comparison between the cost of spare parts required by modular products and that of integrated products.

Based on above discussion, the following hypothesis is postulated:

H1: PM has a positive influence in reducing costs

**Potential Linkage between PM and product quality**

Studies focusing on specific usage of modular design and its associated standardization have concluded that these practices have led to increases in product quality (Suzik, 1999). Further exploring these relationships, Fisher et al. (1999) concluded that the increase in quality brought about by standardization was attributable to learning curve effects and design improvements. This learning curve effect results from increased production volumes of similar components or subassemblies.

PM improves product quality as it requires companies to specify the module interfaces at an early stage (Hargadon and Eisenhardt, 2000), which in turn helps to detect quality problems early and improve the reliability of each module (Mikkola and Gassmann, 2003; Primo and Amundson, 2002; Ulrich and Tung, 1991). Feitzinger and Lee (1997) concluded that quality is improved in PM because problems, if any, can be isolated to specific modules facilitating targeted corrective action. Considering all of these, the following hypothesis is postulated:

H2: PM will positively correlate with product quality.

**Potential Linkage between PM and flexibility performance**

Flexibility during the production process can lead to improving performance outcomes (Jacobs et al., 2010; Yusuf et al., 2004). Because of advantages of flexibility, firms try to set up manufacturing systems that are flexible. But a system’s ability to be flexible and handle variety is ultimately determined by the product architecture (Ulrich, 1995).

There is a linkage between PM and flexibility in two ways. Firstly, flexibility during the production process increases with the use of PM (Lorenzi and Lello, 2001). This leads to reduced setup times and a corresponding decrease in switching time (Worren et al., 2002). Secondly, PM also increases the flexibility of work-in-process inventory (Lee and Tang, 1997). A major advantage accrues as a result of the ability to store modules in a variety of geographic regions and then assemble them as and when
orders are placed. This arrangement offers a wide variety of end products with very responsive delivery times (Worren et al., 2002)

Further, modular product architecture provides room for design flexibility, enabling firms to attempt product improvements, modification or even innovation by using a relatively small number of independent modules in different permutations. Thus, firms with modular architecture can either launch new products or widen the product ranges by exchanging a few product modules (Ro et al., 2007). Modular products have higher independence among its individual modules, which isolates frequently changing modules from the core design. This scales down the frequency of communication across different module designs and the rate of change of the core design. A modular product design tolerates a higher risk of design changes, allows for late product changes, which leads to better design solutions and avoids the need for entire product changes. This improves the design and manufacturing flexibility for market change (Ro et al., 2007).

Studies have found that PM directly correlates with some manufacturing capabilities such as flexibility and customer service (Vickery et al., 2003). Modular product design standardizes the interfaces between components that allow a variety of components to be substituted into a product system. Thus, firms can flexibly assemble components to develop new products with greater variety (Ro et al., 2007). Therefore, we hypothesize,

H3: PM has a positive influence on improving flexibility in manufacturing.

Potential Linkage between PM and Cycle Time Reduction

PM leads to reducing cycle time (Sherman et al., 2000; Lorenzi and Lello, 2001). As PM enables manufacture of modules in parallel and assembles them based on order requirements, cycle time is reduced (Novak and Eppinger, 2001; van Hoek and Weken, 1998). Improved component availability also reduces cycle time (Jacobs et al., 2007). Lee and Tang (1997) report that system service levels improve with modular architectures and contribute to cycle time reduction. Modular product design is considered to be an effective approach for mass customization and cycle time reduction (Ro et al., 2007). Therefore, we postulate that

H4: Positive relationships exist between PM and cycle time reduction.

Mediating Variables

To be successful in increasingly competitive environments, there is a need for the integration of firm’s capabilities (Hult et al., 2003). Integration leads a firm to make superior offerings (Piercy, 2010). The mediation effect of integrating variables is explored in this section.

Supplier integration

The concept of integrating suppliers has received attention since the initial surge in exploring Japanese manufacturing practices. Early studies focused on finding the
competitive advantage that Japanese manufacturers enjoyed over their U.S. and European counterparts (Clark and Fujimoto, 1991).

Jacobs et al. (2007) identify three facets of supplier integration from the perspective of the buying organization, namely, supplier development; just in time purchasing; and supplier partnering. Antonio et al. (2010) specifically identify three organizational processes that integrate supply chain with PM, namely, information sharing, product co-development and organizational co-ordination. Past studies indicate that PM has a positive influence on supplier integration as it builds a cooperative relationship by increasing the level of trust through the improved forecasts brought about by PM (Petersen et al., 2005). Supplier integration is also enhanced by reducing communication barriers through the creation of a common language (Lorenzi and Lello, 2007; Galvin and Morkel, 2007).

Studies have also indicated that supplier integration has a positive effect on firm performance (Antonio et al., 2007); cost, quality, and cycle time, (Carr and Pearson, 1999); increase in innovation and a decrease in cost and cycle time (Lewis, 1995). For this study, we propose that:

H5a. Supplier integration positively impacts the relationship between PM and cost reduction.

H5b. Supplier integration positively impacts the relationship between PM and product quality improvements.

H5c. Supplier integration positively impacts the relationship between PM and flexibility improvements.

H5d. Supplier integration positively impacts the relationship between PM and cycle time reduction.

**Design integration**

Research on PM and design integration address a variety of concerns that include assembly line design (He and Kusiak, 1998); decomposition of manufacturing systems (Kusiak et al, 1991; Kim and Chhajed, 2000); modular work cell design (Chen et al., 1999) product platform and family design (Erens and Verhulst, 1997; Gonzalez-Zugasti et al., 2000; Sanderson and Uzumeri, 1995) and assembly line design (He and Kusiak, 1998). Besides the effect of PM on key elements of design integration, an effect of design integration has been found to affect performance outcomes (Jacobs et al., 2007). Design integration was also reported to reduce product cost (Sharma, 2004). Another study based on a case analysis found that design integration enables faster production thereby giving more time to market products (Mabert et al., 1992). Reduction in production cost, improved reliability of product leading to better financial performance of firm was reported as benefits through design integration (Parker, 1997; Prabhaker et al., 1995).

Thus, there is support in the literature that PM has a positive effect on design integration, and this in turn makes an impact on performance outcome. We therefore offer the following research hypothesis:
H6a Design integration positively impacts the relationship between PM and cost reduction.

H6b Design integration positively impacts the relationship between PM and product quality improvements.

H6c Design integration positively impacts the relationship between PM and flexibility improvements.

H6d Design integration positively impacts the relationship between PM and design integration.

Manufacturing integration

PM is positively related to manufacturing integration. Past studies have shown that PM will have a positive effect on performance outcomes through the mediating effect of manufacturing integration (Jacobs et al., 2007). Manufacturing integration has a positive impact on performance in a variety of settings and using a variety of research methods.

Research on PM has shown the positive impact of manufacturing integration have shown a positive impact on performance. Sohal et al. (2001) report that manufacturing integration techniques resulted in overall improvements for the study firm, aside from other contributory factors. In a different setting and employing a different methodology, a case study of a manufacturing firm concluded that PM and integration techniques were found to reduce costs (Collett and Spicer, 1995). Another work, based on a simulation study comparing cellular manufacturing and job shop layouts, concluded that the cellular approach decreased work-in-process and cycle-time (Shafer and Charnes, 1993). Thus, we propose:

H7a Manufacturing integration positively impacts the relationship between PM and cost reduction.

H7b Manufacturing integration positively impacts the relationship between PM and product quality improvements.

H7c Manufacturing integration positively impacts the relationship between PM and flexibility improvements.

H7d Manufacturing integration positively impacts the relationship between PM and cycle time reduction.

Research Model

Based on the above hypotheses, which were substantiated by the reviewed literature, the theoretical model for the study was conceptualized and depicted in Figure 1.
Methods

Survey Instrument

A survey instrument was developed specifically for this study. For the operational definition of the concept of PM, measurement items from the works of Lin (2003), Schilling (2000) and Sanchez and Mahoney (1996) were adopted. The items for measuring performance measures and integration strategies were initially adopted from the work of Jacob et al. (2007) and Worren et al. (2002). The items for PM, supplier integration, design integration and manufacturing integration were measured on a scale ranging from 1 (extremely low use) to 5 (extremely high use). The items for performance measures ranged from 1 (poor) to 5 (excellent).

After developing the instrument, a pre-test was conducted on five senior managers from randomly selected manufacturing firms. This was done to ensure clarity and content validity of the survey instrument. Based on the feedback, some revisions were made and it was decided to modify the wordings of some questions as they were found to be lacking clarity in meaning. Overall, there were 17 statements to capture
information across the four performance measures: cost, quality, flexibility and cycle-time (See Appendix A for measurement items, factor loadings and alphas).

**Data Collection**

The target respondents were senior managers in charge of product development of manufacturing firms of all types operating in Saudi Arabia. The population of the present study included all manufacturing companies operating in the three major cities of Jeddah, Riyadh and Dammam-Khobar that are spread across the three major province of Saudi Arabia that is Western, Central and Eastern respectively.

Due to the absence of reliable sampling frames in Saudi Arabia, samples were randomly chosen from the targeted industrial cities. As there is a preference for formality, research assistants were engaged to make personal visits. Research assistants working under the direct supervision of the researchers visited these targeted industrial cities, soliciting the participation of product development managers. A manager who agreed to voluntarily participate was provided with the questionnaire. A total of 1600 questionnaires were distributed in this manner. All these efforts yielded 381 completed questionnaires, for a response rate of 24 per cent, which compares very well with response rates from other studies in Saudi Arabia, for example Sohail and Alashban (2009).

Of the 318 respondent firms, 199 firms (52 per cent) were categorized as manufacturers of industrial products, 148 firms (39 per cent) as consumer products, while the remaining 34 (9 per cent) were engaged in manufacture of industrial and consumer products. Just about half of all firms had introduced modular production in the last 4-7 years. There was an almost even distribution of firms in remaining groups of less than 3 years and 4-7 years. As for size of the firms based on number of employees, the largest percentage of employees, that is 34 were in the range of 1000-1400.

**Results**

**Evaluating the Measurement Model**

Structural equation modeling (SEM) using EQS 6.1 was employed to test the proposed mediation model. The data were analyzed using a two-step structural equation modeling approach described by Anderson and Philips (1981) and widely recommended and used in research (e.g. Hair et al., 1998). First, a confirmatory factor analysis was used to develop a measurement model with an acceptable fit with the data then the structural model was tested. The maximum-likelihood robust method in the EQS software was used to evaluate both the measurement and the structural models. The overall model fit was evaluated using conventional fit indices including the $\chi^2$/df ratio CFI, NFI, NNFI and RMSEA. The goodness of fit indices for the measurement model were above the conventional threshold values ($\chi^2$/df ratio = 1.2, CFI = .984, NFI = .911, NNFI = .980 and RMSEA = .023). The CFI, the NFI and the NNFI were all above 0.90. The RMSEA (0.023) indicated a close model fit. The Chi square ration of 1.2 (356.5/296) also indicated a very good model fit. In summary, these five fit indices collectively indicate a very good model fit.
Content validity of the instrument is assured as the measures were adopted from well-established empirical research studies. All standardized factor loadings were highly significant with a value over 0.5, which indicates good convergent validity.

Using the average variance extracted (AVE) as suggested by Fornell and Larcker (1981) discriminant validity was ensured. As shown in Table 1, the AVE for each construct was greater that the squared correlations between the construct and all other constructs in the model indicating good discriminant validity. In addition, reliability was demonstrated through composite reliability where values were above 0.80.

**Table 1: Test for construct validity using AVE**

<table>
<thead>
<tr>
<th></th>
<th>PM</th>
<th>CR</th>
<th>PQ</th>
<th>FP</th>
<th>CTR</th>
<th>SI</th>
<th>DI</th>
<th>MI</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM</td>
<td>0.670</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CR</td>
<td>0.614</td>
<td>0.620</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PQ</td>
<td>0.542</td>
<td>0.495</td>
<td>0.570</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FP</td>
<td>0.461</td>
<td>0.448</td>
<td>0.460</td>
<td>0.625</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTR</td>
<td>0.537</td>
<td>0.535</td>
<td>0.460</td>
<td>0.449</td>
<td>0.715</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SI</td>
<td>0.565</td>
<td>0.549</td>
<td>0.485</td>
<td>0.513</td>
<td>0.567</td>
<td>0.690</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI</td>
<td>0.515</td>
<td>0.487</td>
<td>0.451</td>
<td>0.422</td>
<td>0.430</td>
<td>0.451</td>
<td>0.664</td>
<td></td>
</tr>
<tr>
<td>MI</td>
<td>0.508</td>
<td>0.477</td>
<td>0.475</td>
<td>0.387</td>
<td>0.508</td>
<td>0.528</td>
<td>0.448</td>
<td>0.695</td>
</tr>
</tbody>
</table>

PM = Product Modularity, CR = Cost Reduction, PQ = Product Quality, FP = Flexibility Performance, CTR = Cycle Time Reduction, SI = Supplier Integration, DI = Design Integration, MI = Manufacturing Integration.

Diagonal elements (bold) represent the average variance extracted for each construct. Other entries represent the squares of the correlations (shared variance) among the constructs. Diagonals should be greater than off-diagonal to demonstrate discriminant validity.

**Research Model and hypotheses testing**

The hypotheses were tested using the structural model. Two tests were performed; the first one was to test the direct relationship between the PM construct and the four performance outcomes (cost, quality, flexibility and cycle time). The second test was conducted to test the mediation hypotheses of three integration strategies (supply, design and manufacturing integrations) between the PM construct and each of the competitive performance outcomes.

**Product modularity’s direct effect on competitive performance outcomes**

Before testing the direct relationships between the PM construct and the performance outcomes constructs, the overall model fit was assessed using multiple fit indices. The chi-square/degrees of freedom ratio ($\chi^2/df = 1.384$) was below the cut-off point of 3, indicating a good model fit. CFI, NNFI, and RMSEA were all within the acceptable recommended thresholds (CFI = 0.979; NFI = 0.928; NNFI = 0.975; and RMSEA = 0.032). Considering all of this, it can be concluded that this direct model provided an excellent fit.
For evaluating the hypothesized model and testing hypotheses all significant path coefficients were first tested to check if they were in the hypothesized direction. All four coefficients were significant and in the hypothesized direction. Standardized path coefficients and t-values were used to test the four hypotheses. Table 2 summarizes the hypotheses and their corresponding standardized path coefficients and t-values. The sign of the coefficients indicates directionality.

H1 to H4 are related to the direct relationship between the PM construct and the four performance outcomes constructs. The standardized coefficients showed that PM significantly influences the cost performance ($\gamma = 0.669$, $p < 0.001$), the quality performance ($\gamma = 0.636$, $p < 0.001$), the flexibility performance ($\gamma = 0.629$, $p < 0.001$), and the cycle time performance ($\gamma = 0.772$, $p < 0.001$). All of the relationships were on the hypothesized direction. Thus all of the four hypotheses were supported.

**Mediating Effects**

In testing the mediating effects, this study applied techniques suggested by Baron and Kenny (1986) and widely used in the literature. Because SEM was used in this study, we employed a procedure widely used in the literature (Holmbeck, 1997). For each hypothesis two models were tested. The first model, shown in Figure 2 panel I, shows the indirect effect of PM by positioning integration in a fully mediating role between the PM and the competitive performance measures. The second model (Figure 2 panel II) shows both the direct relationship between PM and performance measure and the indirect relationship (partial mediation) through the integration constructs. Chi-square tests were performed to test whether integration strategy constructs (supply integration, design integration and manufacturing integration) fully or only partially mediates the relationship between the PM and the competitive performance measures.

**Table 2: Standardized Path Coefficients and t-values for the direct relationship**

<table>
<thead>
<tr>
<th>Path</th>
<th>Hypotheses</th>
<th>Standardized Path Coefficients</th>
<th>t-values</th>
<th>Hypothesis Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H1: PM □ CR</td>
<td>0.669</td>
<td>15.837***</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>H2: PM □ PQ</td>
<td>0.636</td>
<td>12.626***</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>H3: PM □ FP</td>
<td>0.629</td>
<td>12.092***</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>H4: PM □ CTR</td>
<td>0.772</td>
<td>15.425***</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*** $p < .001$.

To assess the existence of mediation effect, the significance of the chi-square difference was first evaluated. The procedure employed was to first check for chi-square differences and if these were not significant, the significance of the coefficients (A, B, C and D) was checked. Full mediation is assumed, in cases where both the A and B coefficients are significant and the D coefficient is not found to be significant. However, if only either A or B coefficients are not significant, we assume there is no mediating effect. Partial mediation is assumed when the chi-square differences between the two models are significant, and the coefficients for A, B and D are all significant (indirect and direct model).

Based on the above procedures, results are reported in Table 3. The first part of the Table 3 shows the results of the SEM analysis for direct and indirect effects with
supply integration mediating the relationship between PM and competitive performance measures (H5a – H5d). The results show that supply integration partially mediates the relationship between PM and cost performance. Thus, hypothesis H5a is supported. There is no mediating role of supply integration between the PM and quality performance (H5b is not supported). Other results reveal that supply integration fully mediates the relationship between PM and both the flexibility performance and the time cycle performances. (H5c and H5d are supported).

Table 3: Role of mediation on competitive performance

| Mediator: Supply Integration and outcomes are Competitive Performance Measures |
|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Model           | χ²     | df     | Δχ²    | Δ df   | p      | NNFI   | CFI    | IFI    | RMSEA  | A      | B      | C      | D      | Mediation |
| Outcome= Cost Reduction | Indirect | 67.39  | 42     | .98    | .98   | .98    | .040   | .72*** | .87*   | .71*** | .37*   | .67*** | .38*   | Partial |
| Outcome= Product Quality | Indirect | 53.46  | 42     | .99    | .99   | .99    | .03    | .72*** | .80*   | .70*** | .33    | .64*** | .35*   | None   |
| Outcome= Flexibility Performance | Indirect | 38.83  | 33     | .99    | .99   | .99    | .02    | .70*** | .80*   | .91**  | .629** | -      | .081   | Full   |
| Outcome= Cycle Time Reduction | Indirect | 47.25  | 33     | .99    | .99   | .99    | .034   | .70*** | 1.**   | .93**  | .77*** | .085   |        |        |

| Mediator: Design Integration and outcomes of Competitive Performance Measures |
|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Outcome= Cost Reduction | Indirect | 75.34  | 42     | <0.01  | .98    | .98    | .042   | .61*** | .26    | .67*** | .48*   |        | None   |
| Outcome= Product Quality | Indirect | 58.95  | 42     | <0.01  | .98    | .99    | .033   | .62*** | .93**  | .64*** | .37*   |        | Partial |
| Outcome= Flexibility Performance | Indirect | 43.68  | 33     | <0.01  | .99    | .99    | .029   | .60*** | .96**  | .63*** | .24    |        | Full   |
| Outcome= Cycle Time Reduction | Indirect | 42.02  | 32     | 1.66   | .988   | .99    | .029   | .59*** | .57*   | .77*** | .57*   |        | None   |

| Mediator: Manufacturing Integration and outcomes of Competitive Performance Measures |
|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Outcome= Cost Reduction | Indirect | 81.02  | 42     | .96    | .97   | .97    | .050   | .64*** | .95**  |        | None   |        |        |        |

98
The second part of Table 3 reports the results of the mediating role of design integration. Hypotheses H6a – H6d are tested. These results show that design integration does not mediate the relationship between PM and cost performance. H6a is not supported. Design integration partially mediates the relationship between PM and quality performance (H6b is supported). Also, the results show that design integration fully mediates the relationship between PM and flexibility performance (H6c is supported). For the mediating role of design integration between PM and time cycle performance, results do not indicate any mediating effect. Thus, H6d is not supported.

Finally, the last part of Table 3 shows the results of the mediating role that manufacturing integration plays in the relationship between PM and competitive performance measures (H7a – H7d). These results indicate that manufacturing integration does not mediate the relationship between PM and cost performance. Thus, H7a is not supported, while H7b, H7c and H7d are all supported. These results indicate that manufacturing integration partially mediates the relationship between PM and each of remaining competitive performance measures (quality performance, flexibility performance, and time cycle performance).

### Discussion

The findings of this study lend support to existing ideas and relationships. The results of this study have implications for management and sets directions for future research. Results of the present study are discussed in the following two sections.

### PM’s direct effect on performance outcomes

Consistent with empirical evidence, findings of this study indicate a direct, positive relationship between PM and performance outcomes, cost reduction, product quality improvements, flexibility improvements and reduction in order cycle time. Very few studies of this nature have been conducted to empirically test the effect of mediation. Our study is empirically supported by another study conducted with a sample drawn from the automotive industry in the U. S (Jacobs et al., 2007). This confirms that despite fundamental differences in the industry dynamics, market structures and

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Indirect &amp; Direct</th>
<th>PM Effect on Outcome</th>
<th>p-Value</th>
<th>Significant</th>
<th>p &lt; .05</th>
<th>p &lt; .01</th>
<th>p &lt; .001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Indirect</td>
<td>64.41</td>
<td>41</td>
<td>16.61</td>
<td>1</td>
<td>&lt;0.00</td>
<td>1</td>
<td>.98</td>
</tr>
<tr>
<td>Direct</td>
<td>61.21</td>
<td>42</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Partial</td>
<td></td>
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<tr>
<td>Flexibility Performance</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indirect</td>
<td>52.91</td>
<td>41</td>
<td>8.3</td>
<td>1</td>
<td>&lt;0.0</td>
<td>1</td>
<td>.99</td>
</tr>
<tr>
<td>Direct</td>
<td>47.72</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Partial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycle Time Reduction</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indirect</td>
<td>42.46</td>
<td>32</td>
<td>6.53</td>
<td>1</td>
<td>&lt;0.0</td>
<td>5</td>
<td>.99</td>
</tr>
<tr>
<td>Direct</td>
<td>48.99</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
customer needs between a developed and an emerging nation, there is an influence of PM on performance outcomes. To this extent, this study lends further research support to the generalization of theory.

Manufacturing firms in Saudi Arabia are facing increasing competitive pressure since the recent accession of the Kingdom to the World Trade Organization (WTO). Reforms are also in place to remove protectionist barriers given to local manufacturers. Given the growing competitiveness, PM must be seen as a strategy to gain multiple benefits on performance outcomes. Further research may be needed to examine the benefits at the process level in the light of observation that managers may attempt to change the manufacturing environment of modular production (Schilling, 2000).

**Mediation effect of integration strategies on performance outcomes**

The study finds mixed support for the mediating role of the integration strategies on performance outcomes. PM has both a direct and indirect effect on performance outcomes and the mediation effect operates through supplier integration, design integration and manufacturing integration. Looking more closely, results indicate a strong support to the effect of supplier integration on reducing cycle time and flexibility, while there is no additional effect of supplier integration on quality improvements in the manufacturing industry of Saudi Arabia. This means that more benefits of PM on flexibility performance and cycle time reduction can be realized through supplier integration strategies. The findings of the present study finds support from other studies investigating modularization and role of suppliers, which have reported benefits through cost reductions and improved performances (Mikkola, 2003).

The study also finds a strong indirect effect of design integration as a mediator on flexibility enhancement. These findings suggest that a firm can achieve additional flexibility in performance through design integration.

The additional effect of design integration on flexibility is not surprising as conceptually PM aims to provide flexibility that enables product variations and technology development without changes to the overall design (Ericsson and Erixon, 1999). The managerial implications of these results are clear: manufacturing firms in Saudi Arabia can obtain improved performance by integrating design procedures to improve flexibility. These procedures in PM include (1) determining interface complexities, (2) identifying critical interfaces, and (3) defining module boundaries (Hölttä, 2005).

The importance of design in product development has long been recognized (Bendell, 1988). Given the indirect effect of design integration on quality improvement, due emphasis must be placed on design for quality to ensure that (1) design of a product meets customer requirements, (2) design that can counter or minimize the effects of potential variation in manufacture of the product and the product's environment, and (3) design, such that it continuously improve aims to improve product reliability, performance, and technology to exceed customer expectations and offer supervisor value (O'Connor, 1998; O'Connor and Veryzer, 2001).
As for the mediation effect of manufacturing integration, the study findings reveal an indirect (indirect effect) effect on flexibility in performance, quality improvements and reducing cycle-time. Again this suggests that besides the direct effect of PM on cost reduction, quality improvement, flexibility enhancement and reducing cycle-time, a firm can achieve additional flexibility in performance and quality improvements and reduction in cycle-time by integrating manufacturing integration. There is no additional effect of manufacturing integration on cost reduction. Our results do not substantiate this claim, which has been touted in literature. Manufacturing firms in Saudi Arabia will have to look at supplier integration to get any additional advantage of cost reductions. The indirect effect of manufacturing strategy on three dimensions suggests that competitive performance of PM can be further enhanced by adopting strategy of lean production. Thus, results of the present study suggests that firms implementing lean production have additional effect of further quality improvements, additional flexibility and enhanced cycle time reductions from a simultaneous application of PM strategy.

Conclusion

The implementation of PM for enhancing performance outcome has been identified in a number of previous research studies (Ro et al., 2007; Hargadon and Eisenhardt, 2000; Baldwin and Clark, 2000; Gershenson et al., 2003). Most of these studies have examined the direct effect of PM from a product manufacturing perspective. This study examines the effect of PM and integration initiatives on competitive performance. Most importantly, this study found that deploying a PM strategy in combination with integration initiatives in design, manufacturing, and supply management, will enable the firm to improve its competitive performance on multiple dimensions.

This study establishes the effects of PM on various performance dimensions and investigates the mediation effects of integration strategies on performance by drawing samples from Saudi Arabia, thereby providing empirical facts previously lacking in existing literature. Consistent with the literature, our empirical findings suggest that manufacturing firms in Saudi Arabia achieve a direct and multiple competitive performance benefits from application of PM. Results indicate that firms achieve multiple benefits through cost reductions, quality improvements, enhanced flexibility and reduced order cycle time.

Our empirical findings suggest that manufacturing firms in Saudi Arabia can further improve performances through the mediation effect of integration strategies on competitive performance outcomes. In particular there is a strong effect of supply integration on enhancing flexibility and reducing order cycle-time. There is also a strong effect of design integration on flexibility enhancement of firms. The indirect effect of mediation strategies is not found in some performance outcomes. Overall, the indirect benefits of integration on performance outcomes are still mixed. Future studies can focus on how to achieve superior competitive performance from modular design.

Two major limitations need to be underlined for future studies. The first limitation is the industrial characteristic of Saudi Arabia’s manufacturing industry, which is scantily diversified and geographically concentrated. Future studies replicating this
research across diverse industries and other nations in the regions can increase our understanding of the impact of PM modularity on competitive performances. This will help in generalizing findings, as different strategies may be prevalent in different regions (Frohlich and Dixon, 2001). Such studies will also enable to identify the elements of Western strategies that have been either absorbed or rejected by manufacturing firms in the Arabian Gulf region. Second, this study suffers from a limitation of the sample size. While the analyses are statistically valid and methodology appropriate, there remains the issue of generalizability of findings. Nevertheless, the sample size is larger than and comparable to a similar previous studies undertaken in Western settings.

Acknowledgment:

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Reference


Seh-Woong Chung, Jin K. Han, Yong SeokSohn (2012).“Technological expectation and consumer preferences for product form” *Journal of Business Research*, Vol. 65, No. 9, pp 1290–1294


## Appendix A: Measurement items, means, item loadings and alphas

<table>
<thead>
<tr>
<th>Construct</th>
<th>Questionnaire Items</th>
<th>Item Loadings</th>
<th>Std. Dev.</th>
<th>Composite Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Modularity</strong></td>
<td>The use of standardized and interchangeable components</td>
<td>0.877</td>
<td>1.329</td>
<td>.890</td>
</tr>
<tr>
<td></td>
<td>Configuration of wide variety of products</td>
<td>0.812</td>
<td>1.063</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The extent of independence from other products</td>
<td>0.812</td>
<td>1.186</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Components can be disaggregated and recombined into new configuration.</td>
<td>0.767</td>
<td>1.149</td>
<td></td>
</tr>
<tr>
<td><strong>Cost Reduction</strong></td>
<td>The ability to reduce cost of production through efficient operations</td>
<td>0.772</td>
<td>1.075</td>
<td>.867</td>
</tr>
<tr>
<td></td>
<td>The ability to reduce cost of production through improvement in process technology</td>
<td>0.791</td>
<td>1.083</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The ability to reduce cost of production through economies of scale.</td>
<td>0.787</td>
<td>1.121</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The overall performance in comparison to competitors on cost reduction.</td>
<td>0.798</td>
<td>1.138</td>
<td></td>
</tr>
<tr>
<td><strong>Product Quality</strong></td>
<td>The overall performance in comparison to competitors on product quality.</td>
<td>0.750</td>
<td>1.082</td>
<td>.841</td>
</tr>
<tr>
<td></td>
<td>The ability to maximize time to product failure/malfunction.</td>
<td>0.757</td>
<td>1.025</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The ability to maximize time to product replacement.</td>
<td>0.743</td>
<td>1.063</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The ability to manufacture a product whose operating characteristics meet established standards.</td>
<td>0.768</td>
<td>1.057</td>
<td></td>
</tr>
<tr>
<td><strong>Flexibility Performance</strong></td>
<td>The overall performance compared to competitors on flexibility.</td>
<td>0.794</td>
<td>1.077</td>
<td>.833</td>
</tr>
<tr>
<td></td>
<td>The ability to increase/decrease total production in response to customers’ needs.</td>
<td>0.801</td>
<td>1.065</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The ability to effectively produce wide variety of products at a given time.</td>
<td>0.777</td>
<td>1.081</td>
<td></td>
</tr>
<tr>
<td><strong>Cycle Time Reduction</strong></td>
<td>The ability to minimize the time from order placement to the delivery of items.</td>
<td>0.869</td>
<td>1.174</td>
<td>.883</td>
</tr>
<tr>
<td></td>
<td>The ability to minimize the time from when the order was placed to the time of completion.</td>
<td>0.862</td>
<td>0.991</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The ability to reduce time from customer order to final delivery.</td>
<td>0.805</td>
<td>1.163</td>
<td></td>
</tr>
<tr>
<td><strong>Supplier Integration</strong></td>
<td>Policies and procedures for assessing supplier capability and performance</td>
<td>0.840</td>
<td>1.128</td>
<td>.869</td>
</tr>
<tr>
<td></td>
<td>Bringing suppliers to participate and provide input in the product life cycle process</td>
<td>0.864</td>
<td>1.048</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Requiring just-in-time delivery from suppliers.</td>
<td>0.787</td>
<td>1.058</td>
<td></td>
</tr>
<tr>
<td><strong>Design</strong></td>
<td>Overlapping activities in product and</td>
<td>0.815</td>
<td>1.031</td>
<td>.844</td>
</tr>
<tr>
<td>Integration</td>
<td>process development to ensure a fit between design requirements and process capabilities.</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>A systematic investigation of manufacturing process to see if design can be changed to improve product performance</td>
<td>0.808</td>
<td>1.052</td>
<td></td>
</tr>
<tr>
<td></td>
<td>An approach to design such that products can be effectively manufactured.</td>
<td>0.821</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Manufacturing Integration</td>
<td>A manufacturing process that produces family of parts within a single line.</td>
<td>0.853</td>
<td>1.076</td>
<td>.872</td>
</tr>
<tr>
<td></td>
<td>Grouping of products that have similar manufacturing properties or design characteristics</td>
<td>0.820</td>
<td>0.999</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A work culture promoting elimination of waste and reducing setup times</td>
<td>0.827</td>
<td>1.195</td>
<td></td>
</tr>
</tbody>
</table>