World Academy of Science, Engineering and Technology
International Journal of Industrial and Manufacturing Engineering
Vol:3, No:5, 2009

Towards External Varieties to Internal Varieties − Modular Perspective

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***Abstract*—**Product customization is an essential requirement for manufacturing firms to achieve higher customers' satisfaction and fulfill business target. In order to achieve these objectives, firms need to handle both external varieties such as customer preference, government regulations, cultural considerations etc and internal varieties such as functional requirements of product, production efficiency, quality etc. Both of the varieties need to be accumulated and integrated together for the purpose of producing customized product. These varieties are presented and discussed in this paper along with the perspectives of modular product design and development process. Other development strategies such as modularity, component commonality, product family design and product platform are presented with a view to achieve product variety quickly and economically. A case example both for the concept of modular design and platform based product development process is also presented with the help of design structure matrix (DSM) tool. This paper is concluded with several managerial implications and future research direction.

***Keywords*—**Customization modular design, platform development, product variety.

I. Introduction

IN present business environment, firms are looking forward to meet up highest customers' satisfaction in order to survive in competition. This trend pushes firms to understand potential customers' desires or affections effectively and transfer those desires and needs with technical specifications. Anecdotal evidence suggests that failing to understand with customers dynamic needs hinders firms' effort to strengthen customer loyalty, lower customer acquisition costs and increase long term customer profitability, all of which are key factors that influence financial performance [1]. In response to this challenge, firms need to understand how customers' perceptions are changing and what the consequences of those changes on market demands are [2]. There is however, little indication that firms have formal processes to tackle this activity or allocate proper resources into anticipating shifts in value perceptions [3].

Along with customers' perceptions and needs, firms are also facing challenges from technological innovation such as newer technology, different design changes and adaptability of changes within exiting product development environment. There may be different available techniques or strategies to adopt these changes but it is commonly difficult to choose for the best option. Rigorous research is needed before implementing any suitable strategy for a firm in order to integrate the new technologies with the existing ones. Technology needs to be adjustment and refined by understanding how customers value perceptions change according to market demands and how suppliers can directly observe the seeds of change and project their impact into future corporate strategies. However, there are little observations that firms have formal processes for allocating significant activities or resources into anticipating major changes in the global marketplace.

Customization which is growing continuously aims at providing customers with individualized goods and services. Manufacturing enterprises strive for customizing their products by taking into account a high level of product variety, which increase the internal complexity in operations and manufacturing related tasks. Complexities evolve both from internal varieties such as operational changes, technologies obsolesces and from external varieties such as government's regulations, market demand etc need to be considered carefully for business success. The effects of complexity generally arise from production program complexity, high configuration complexity for customers and increasing planning and scheduling complexity [4]. The success of customization can only be achieved if these complexities are managed adequately and an optimal understanding of customers who should be considered as partners in the value creation process.

To achieve better customers' satisfactions and gaining business target, firms are taking initiation to produce as many product varieties as possible. Although there are several constraints and limitations in developing product varieties and diversifying market segment but it can not avoided in order to gain business success. Different methodologies such as modularity, commonality, standardization etc could be adopted to ease the variety management. Organizational systems are said to be becoming increasingly modular instead of tightly integrated and hierarchical structure. This structure encompasses of loose coupling components which enables firms to achieve greater scope flexibility and scale flexibility [5]. As this flexibility gains come with a price, firms must assess their flexibility gains through accompanying loss of performance and evaluating contract manufacturing rather than in-house manufacturing.

This paper is organized as follows: Section II analyses various factors of both external and internal varieties related

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with product development process, while Section III outlines general concept and usability of modular phenomenon. Section IV illustrates an example taken from a case company, whereas Section V discusses various strategies to manage product varieties suitable for customization. Several managerial implications are stated in Section VI and the paper is concluded with future research directions in Section VII.

II. Factors for Varieties: External versus Internal

Various issues are needed to be considering before implementing any architectural change of exiting products or developing new product within an organization. These issues could be named as varieties and can be divided in internal and external varieties. Most of the exiting industries are facing both external and internal varieties in their product development sites. External varieties evolve from customers' specifications, market uncertainties, government regulations, etc whereas internal varieties initiate from technical specifications, products efficiencies, qualities etc. Both the varieties are need be scaled out carefully before proceed towards any extension or improvement of the existing product architecture.

In order to control both external and internal varieties, firms need to adopt certain strategic decisions. For instance, external varieties can be controlled and minimized through applying certain development phenomenon such as; configuration process, implementation of web-based technology and tool, customers involvement in the early design process and so on, whereas internal varieties may be controlled through modular product architecture, component commonality, platform-based design and development, standardization etc. Through controlling these varieties properly, firms' managers could facilities customers' preferences and gaining market share by offering many varieties of products. Various factors affecting customized product development process can be displayed as in Figure 1 below.

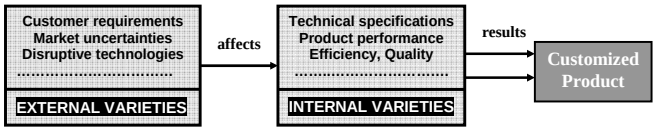

Fig. 1 Factors affecting customized product development

To be competitive with cost effective products, firms need to ensure right type of products and at the right time to the market with right prices. To achieve market share, firms are forced to move forward in order to create as many product variants as possible without measuring the efficiencies and effectiveness. This turns firms into business failure which is not expected for any circumstances. Before proceed towards product variants, it is crucial to analyze its architectural issues along with different factors such as components functionalities and their interfacing, design rules etc. Various production strategies such as; modularization, standardization, component commonality, outsourcing parts etc. are the ways of managing product varieties cost effectively and efficiently.

Due to increasing rate of customization, firms need to look for state-of-the-art technologies or methodologies to generate optimal numbers of product variants that satisfies most of their customers within projected budgets and scopes. It is therefore, a crucial issue for the firms to investigate a way out for developing optimal numbers of product variants in a cost effective manner. In this article, modular architecture is taken into account for creating product variants where product architecture and components functionalities are the key issues for the variants development. Different modules which are formed through interdependencies amount components structure required for variants management through addition, substitution, replacement etc.

III. Modularity Phenomenon: The Perspectives

Modularity which can be treated as a system of independent parts or modules integrated with logical units [6]. Therefore decomposition is the main concerns of modularity as the interaction between-modules are low whereas it is high among intra-modules [7]. Depending on its applicability in product development, modularity can be divided in three types as; functional, technical and physical [8]. In functional modularity, different modules are assembled together based on their functions according to customers' desires or intuition whereas, technical modularity based on technological performances of modules for specific solutions. Physical modularity concerns with the manufacturing feasibilities and interfacing congruencies.

Modularity which generally considered as a strategy with the greatest potential to reduce lead times need to be analyzed before its implementation. Within this strategy, suppliers need to deliver not single components but the entire modules. In such consequences, close partnership is required between the company and module supplier. In modular design, company does not need to cope up with a large number of suppliers but only with a few number of module suppliers. It ensures closer innovativeness towards both sides. Companies could concentrate their own innovation with in house components whereas, module suppliers innovate different functionalities among supplied modules. This makes every type of cooperative improvement and innovation much easier within industrial firms.

Modular design facilitates component commonality and component family which enables company to reduce the number of setups on the shop floor, thereby decreasing production lead times. The interactions among similar modules initiate groupings which characterize as commonality, whereas modularity performs decomposition of product structures. Product structure can be defined in terms of modularity through which various module types are specified. Different product instances or variants are introduced through sharing similar module structures with specific functionalities. Two kinds of approaches are considered generally in firms to develop modular product namely; bottom up approach and top down approach [9], which are discussed as follows.

A. Bottom-up Modular Approach

In this approach modular products are formed on specific functionalities and requirements. The modules which are formed separately are not common with each other but characterize unique characteristics or features. In general, the functionalities of different components and/or parts are analyzed for commonality among them which in turn to form different modules finally. Individual modules are then combined / assembled together to achieve the end products. In this approach there is a possibility of partial modularity as all the requirements may not be transfer to modules but stay with integrated architecture side by side. This would then be the formation of integral-modular product architecture. Bottom up modular approach can be displayed as in Fig. 2 below.

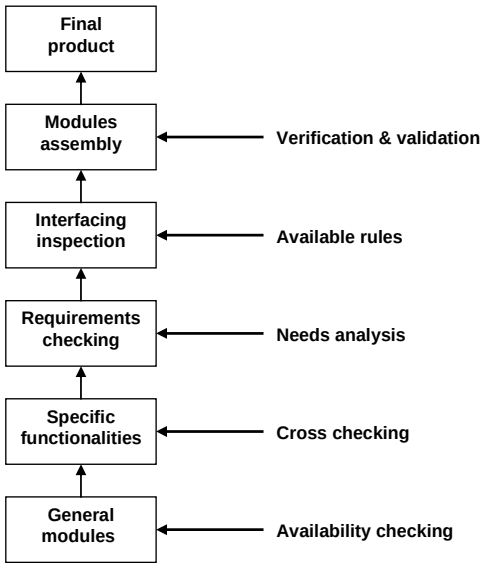

Fig. 2 Bottom-up modular approach

B. Top-down Approach

This approach starts from the basic requirements of a product or product family. All the requirements are gathered, screened out and formulated within the product architecture. This available architecture is studied and critically analyzed for its suitability for high level design which forwarded to detail design phase. At this stage, commonality among design elements are sorted out for the formation of expected modules. These developed modules are used to form a modular product. This approach is especially fruitful for creating product variants, where various modules can be changed or replaced each other for the expected varieties. It is quite cumbersome to improve existing design of a product as all the modules are produced according to the requirements of new system design. Fig. 3 below shows the top down approach of module's formation.

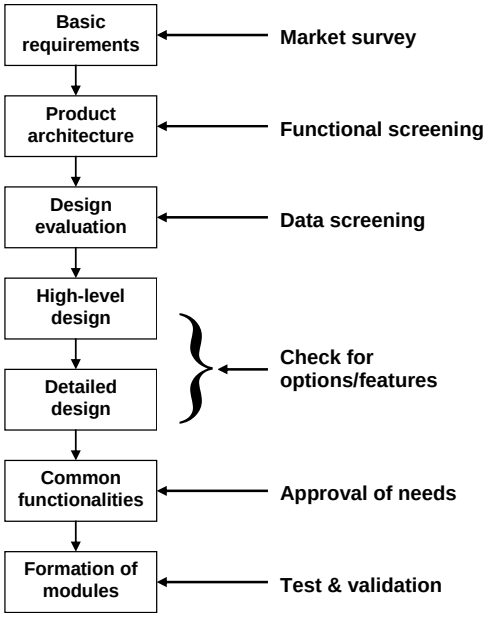

Fig. 3 Top-down modular approach

IV. Modular Phenomenon: A Case Example

As explained above, modularity enhances functional coincidence within product development process. Various designs constrains/functions and modules could be displayed in a matrix format in order to better visualize the interactions among product developments participants. Figure 4 below shows the common interactions among various constraints with modules and the interactions are presented by the mark 'X'. For instance, the constrain 'Engine speed' is related with the modules of 'Power train', 'Valve train', 'Injection equipment', 'Pumps', 'Water pumps', 'Control system', 'Governor' and 'Software' where the interactions are presented by marks 'X' respectively. This matrix display is originated from Steward [10] and applied different industrial arena for its suitability and usefulness.

Module versus Constrains / Functions	Engine block	Power train	Valve train	Pump cover	Mainframe	Injection equipments	Low pressure fuel system	Fuel system	Pumps	Water pump	Oil module (cooler)	Piping	Starting air	Pipes	Starter motor	Valve train	LT system	HT system	Air cooler	Charge air system	Cleaning device for turbo	Control system	Cooling water system	Insulation	Turbocharger	Turbocharger bracket	Control air system	Booster	Governor	Software for control air system	Connectingbox	Sensors	Cablechtail	PTO shaft	Common base + equipments	Tools	Software
bW * cylinder	x	x	x	x	x	x	x	x			x							x	x	x			x		x	x												x
Engine speed		x			x		x		x							x						x							x									x
Prelubrication pump on/off engine				x									x																									
Environment conditions											x								x																			x
TC 1/2 stage																x		x	x	x			x	x	x	x						x	x					x
TC cleaning option																							x		x	x												x
Classification	x	x				x		x	x		x					x								x							x	x					
Engine mounting (CBF + Resilient)	x									x		x						x	x																x		
CAC type 1/2 stage	x															x	x	x	x	x							x										
TC location	x			x							x	x						x	x	x			x	x			x										
Sea water pump (cooler for small bore)	x			x																																	
Direction of rotation				x	x	x				x		x				x	x												x			x	x					
Stand by connections				x				x				x						x	x																		
Engine driven fuel pump & filter				x				x																													
Single or multiple installation (gearbox type)											x									x	x					x	x								x	x	x
Deep sump									x			x																				x	x		x		
Thermostatic valve on/off engine																	x																				
Extra cooling water pump capacity																	x	x																			
Charge air shutoff valve																				x												x	x				x
Suction air connection																				x							x										
Exhaust pipe system (spex/pulse)																																x	x				
Exhaust connection degree (angle)																											x										
Maintenance space	x		x	x	x				x	x		x		x		x			x							x	x					x	x	x	x	x	
PTO for crankshaft bolts		x		x																														x			
Emmission regulation		x	x		x														x				x			x											x
Fuel type		x	x		x		x	x	x									x	x							x			x			x					x
FI system type (conventional /CR)					x		x	x	x																													x
Governor type																													x				x					x
Automation type																														x	x	x	x					x

Fig. 4 Presentation of design constrains/functions versus modules (before partitioning)

After placing all the interactions among constraints and modules within a matrix, we can rearrange the rows and

corresponding columns in order to bring the interdependencies together. This operation is known as partitioning [11]. This partitioning process triggers the clustering operation which is formed according to the tightness or closeness of the dependencies. For instance, from Fig. 5 we can observe that four clusters are formed namely 'Engine module', 'Fuel system', 'Exhaust system' and 'Bus module' after partitioning. These clusters can be focused and processed separately while minimizes the other interactions within the whole development process.

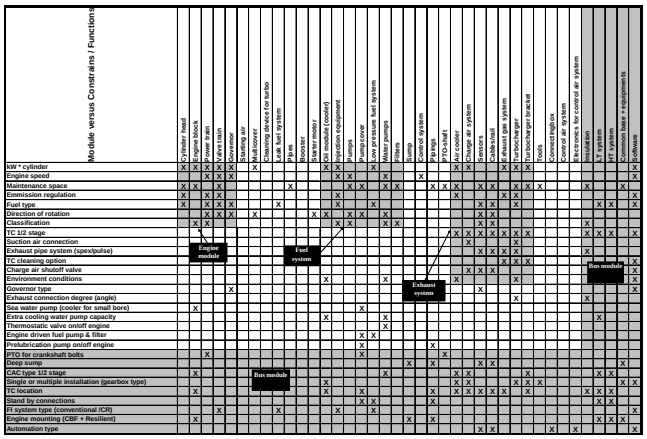

Fig. 5 Presentation of design constrains/functions versus modules (after partitioning)

This clustering process enhances assembly operations and developing platforms within production process. For example, there is 'Bus module' in Fig. 4 which can be considered as a platform upon which all other clusters and interactions could be schedules for the complete product. This way of platform development reduces the costly time and resources which saves money for the firms. Critical investigation among platform participants can be visualized and required amendments also could be performed where necessary. After analyzing the developed platform, its applicability needs to be tested and validated with the customers' satisfaction and firms' business target.

V. Management of Variety Strategies for Customization

Today's mass customization induces a high level of product variety, which creates internal complexities in product architectures, operations and production processes. Complexities also arise from configuration process for customers, planning and scheduling of various development tasks. There are direct relationships among the complexities, costs and efficiencies. These complexities need to be managed adequately in order to be successful in mass customization. Mass customization not only increases complexities, but it has several potentials to reduce complexities too. For instance, it reduces the complexities in order processing, inventory management and production scheduling.

Customization is a way of optimal understanding of customers' desires or preferences that should be considered as partners in value creation process. Customers are directly participating in the designing process of different functionalities among their products of choice. This could evolve new idea generation and/or improvements in the existing design architecture.

Variety management basically deals with the controlling of variety proliferation. This controlling means to offer optimal numbers of variants to the customers depending on the design capability, resource availability and economical consideration within a firm. Although offering many variants of products to the customers are the baseline for increasing firms' sales and gaining market volume, but without critical analysis of this strategy could exaggerate firms' business success. Organizational managers therefore need to be careful to considering variety strategy if it triggers a profit and rejected if it incurs a loss. However, very often variety could be unavoidable, especially if individual customer requirements should be fulfilled.

Such varieties which can be avoided or reduced need to be controlled for companies' betterments [12]. Several strategies such as; component commonality, modularity, platform-based product development, design of product family could be tested for the applicability of specific situation for certain firms. All these strategies may not be suitable for a firm in certain situation but can be applied individually depending on the market demands and firm's capacity or capability. Various strategies for variety management can be illustrated as follows:

A. Component Commonality

This strategic decision encourages firms to bring commonality among their components or parts depending on functionalities and specifications. The principle of commonality is to design and develop as many common components as possible which can be used repeatedly for many other products at the same time. Although, often it is not easy and cost effective to design and produce common component but due to maintain variability and better control and utilization of inventory, firms always look for it.

The usability of common components leads to fewer step up cost and changeover in the production floor which triggers to reduce lead time and resource utilization [13]. Commonality brings economic of scale as many products or product family uses the same component again and again along with other components that minimizes the variety costs and increases the demand volumes. Too much common components reduce the credibility of customers' preference which may negatively affects on reduced sales.

B. Modular Design

The module-based product design and development is a burning issue in today's modern firms. It is a strategy of developing independent and interchangeable building blocks which mix and match with standardized interfaces. The objective of modular design is to minimize production complexity by developing individual modules clustered with highly dependent components or functionalities. All the developed modules are assembled together in order to have the end products after following specific design rules.

Modular design can be based on the reasons of manufacturing, maintenance and logistics [9]. Complexity in manufacturing process is reduced substantially through applying modular architecture in product development. Different modules can be easily interchanged in order to create product variety. The maintenance of modular product is easier in comparison to the product with integral architecture. Modular products also helpful for logistics purpose as different modules are transported easily from one place to another.

C. Product Platform

In order to develop product variety, platform strategy could be an effective and efficient solution for manufacturing firms. In this strategy, the basic platform is design and develops to match most of the parts or components within a product or product family. Platform-based product development is especially beneficial for higher demand level and may not be suitable or cost efficient in lower demand volume. This strategy enables firms to cope with the conflict between customization and efficiency [14].

The platform development is cost-intensive and need to serve for a longer period of time. Therefore, optimum usability of platform needs to be ensured in order to achieve competitive advantage. This strategy reduces the number of setups on the shop floor due to high level of commonality among product families. Different varieties of products with similar functionalities can be developed by applying single or limited number of platforms economically and efficiently. The main benefit of platform-based product design and development is that it allows designers to tradeoffs between market demands with firms' potential.

D. Product Family

The development of product family structuring influences the variety management for customers' satisfaction. This concept relates with the customization of products with similar functionalities and offers multiple of benefits including economies of scale, reduction in development risks and system complexity. Firms are investing money in this strategy in order to provide sufficient variety to the market while maintaining their manufacturing capabilities and diverse market niches [15]. It enhances firms' ability to upgrade products and increases flexibility and responsiveness of manufacturing processes [16].

The architecture of product family initiates' modular design based configuration processes which interact with the customers directly. This design of product family needs to incorporate more front-end issues in product development such as explicit customer modeling and integration, product demand and market segmentation. Along with front-end issues, family design also needs to include more back-end issues including manufacturing, production and the supply chain. Successful product family incorporates the requirements of alignment of the customer, product, process and supply chain decisions [8].

VI. Managerial Implications

Before considering any new product development or to improve an exiting product or product family, organizational managers need to consider both internal and external varieties which directly affects on its production phases. In order to develop customer specific product, firms have to identify intrinsic customers' desires, wishes and requirements, which finally transformed into functional elements within the end product. Designers corporate these functional elements in the product design phase that needs screening before implementation. External factors such as market uncertainties, disruptive technologies and production risks also need to be considered during designing functional specifications of a product.

In product development phase, all the external and internal varieties are accumulated and displayed with the help of DSM tool which visualizes the basic interdependencies among them. These interdependencies are minimized through several internal operations such as clustering, partitioning and grouped the coupled relationships together in order to develop the modules. The formation of modules triggers to facilitate assembly operation, which in turn contributes to minimizing development lead time. These modules also help to control firms supply chain management and keeping low inventory level. Modular product development support firms for the development of customized products with higher customers' satisfaction and lower production cost.

To survive today's competitive business world, firms are forced to consider product varieties in their production lines. Before adopting available strategies for product varieties such as; component commonality, modularization, development of product family, platform-based approach, managers need to evaluate each of them separately. With modularity, organizational managers could consider platform-based product development which triggers the generation and management of varieties among product families. This strategy where components and subsystems are shared across a product family, enable firms to better leverage investments in product design and development. Platform offers greater flexibility among globalization process of firms and the possibility of transferring production from one plant to another. This facilitates reduction of the number of platforms as a result of their use on a world wide basis which contributes cost reduction achieved by using resources on a world wide scale.

In product development process, there is always a conflict between functional elements of a product and customers requirements. Successful product development process requires a specific methodology to transfer and communication process between customers' preferences and functional capabilities. Before entering the design process of concepts, components and parts, organization managers have to ensure the proper methodology to identify the actual voice of the customers and possible solution aspects of the designed product. This paper presents an integral approach by using design structure matrix tool in order to formulate the design requirements according to various solutions strategies. This approach supports transferring the voice of the customer to a

function-oriented product structure as the basis for a customer oriented product design and development.

VII. Conclusion

Each of the business entity should have major focus to develop product and services that satisfy the market demands. Obviously this focus is the customers and their satisfactions. Each firm sells products or services to customers so from a quality assurance point of view it is crucial to develop products in reference to market needs or customer needs respectively. A specific guideline should be developed in order to produce an efficient product development process with the overall objective to customer centric product development with an improved internal workflow. So it is important that a firm is able to help customers understand the superior value of the products or service offered.

In today's global business environment, it is important for firms to reduce cost, improve product quality and minimizing product development lead time. Overall product development strategy needs to be reassigned with a view to achieve synchronizing between design engineering and market demands. External elements in developmental activities such as; government regulations, changing customers attitudes and desires, disruptive technologies etc needs to be carefully adjusted with the firms internal constraints such as; production efficiency, resource limitations, quality assurances etc. Although it is very much challenging to ensure the adjustments of these internal and external variables but firms need to consider generic strategy to tackle these uncertainties and cope up with business target.

An effective production management process will allow firms to increase their credibility of choice by freeing up valuable engineering time, minimize product inventory and improve time-to-market by minimizing downtime. Specific production strategy such as; modular design, standardized component, product platform etc can be implemented, evaluated and documented for the purpose of effective product variety management which is crucial for any business success. Targeted principle needs to be continued if it is profitable and redundant if it is economically not viable. In firm, specific production strategy requires to be implemented at the very early stage of the new product development process, which is especially intuitive, dynamic and very flexible in nature.

The strength of the new development strategy basically based on the concept that all design ideas, documents, structure of the information flow among development participants are needs to be collected and managed by appropriate methodology or tool. In this paper, we have presented a tool named DSM to manage the information flows between different design elements and their functionalities or constraints. This information flow can be organized and presented properly through rearranging each row and column of the designed matrix known as partitioning in order to clustering the elements according to their tightness or dependencies of each other. This clustering operation facilitates firms to keep the track with the specific modules and components to fabricate the end products.

Developed modules can further be investigated to find out the possibility of platform creation which is the base for producing product varieties with reduced lead time and economically. This platform based product development process ease firms for managing the production complexities. The adoption of platform oriented product development provides organizational managers the required agility in their product development process. A well-organized platform is essential to satisfy customer needs and to achieve the economies of scale through sharing tools, knowledge and other resources. Future research can be carried on to investigate the economical feasibility of combining both the modular production process along with the platform-oriented design structure.

Acknowledgment

The authors would like to thank the anonymous reviewers for their encouraging and constructive comments.

References

[1] K. Grieve, and E. Ortiz, "Customer value management sins can be costly," *DM Review*, vol. 13, no.11, pp.38-40, 2003.

[2] L. Fuld, "Be prepared", *Harvard Business Review*, vol. 81, no.11, pp.20-21, 2003.

[3] C.P. Blocker, and D.J. Flint, "Exploring the dynamics of customer value in cross-cultural business relationships," *Journal of Business and Industrial Marketing*, vol. 22, no. 4, pp. 249-259, 2007.

[4] T. Blecker, G. Friedrich, B. Kaluza, N. Abdelkafi, and G. Kreutler, "Integrated series in information systems," in *Information and Management Systems for Product Customizatio*n, Part III, Springer publisher, US, 2005, pp. 243-248.

[5] M.A. Schilling, and K. Steensma, "The use of modular organizational forms: an industry level analysis," *Academy of Management Journal*, vol. 44, no. 6, pp. 1149-1169, 2001.

[6] P.J. Newcomb, B.Bras, and D.W. Rosen, "Implications of modularity on product design for the life cycle," in *Proc. ASME design engineering technical conferences*, DETC96/DTM-1516, Irvine, CA, 1996.

[7] K. Ulrich, "The role of product architecture in the manufacturing firm," *Research Policy,* vol. 24, no. 3, pp. 419–440, 1995.

[8] J. Jiao, T.W. Simpson, and Z. Siddique, "Product family design and platform-based product development: a state-of-the-art review," *Journal of Intelligent Manufacturing*, vol. 18, no. 1, pp. 5-29, 2007.

[9] T. Lehtonen, "Designing modular product architecture in the new product development," Doctoral Dissertation, Tampere University of Technology, Tampere, Finland, 2007.

[10] D.V. Steward, *System Analysis and Management: Structure, Strategy and Design*, Petrocelli Books Inc., New York, 1981.

[11] D.V. Steward, "Partitioning and tearing systems of equations," *SIAM Journal of Numerical Analysis, Series B,* vol. 2, no. 2, pp. 345-365, 1965.

[12] T. Blecker, and N. Abdelkafi,"Complexity and variety in mass customization systems: analysis and recommendations," *Management Science*, vol. 44, no. 7, pp. 908-929, 2006.

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

[14] J. Efstathiou, and T. Zhang, "Future direction on mass customization research and practices: a research agenda," in: Charu Chandra / Ali Kamrani (Eds.): *Mass Customization – A Supply Chain Approach*, New York et al.: Kluwer Academic, 2004, pp. 237-259.

[15] D. Robertson, and K. Ulrich, "Planning product platforms," *Sloan Management Review,* vol. 39, no. 4, pp.19–31, 1998.

[16] M.S. Sawhney, "Leveraged high-variety strategies: from portfolio thinking to platform thinking," *Journal of the Academy of Marketing Science,* vol. 26, no. 1, pp. 54–61, 1998.

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