شبكة المعلومات الجامعية

بسم الله الرحمن الرحيم

شبكة المعلومات الجامعية

التوثيق الالكتروني والميكروفيلم

شبكة المعلومات الجامعية

جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

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بالرسالة صفحات لم ترد بالأصل

AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Design and Production Engineering

Effect of products' architectural modularity on supply chain performance

A Thesis submitted in partial fulfilment of the requirements of the degree of

Doctor of Philosophy in Mechanical Engineering

(Design and Production Engineering)

by

Eman Alaa Eldin Mohammed Khalil Omar Heikal

Master of Science in Mechanical Engineering

Faculty of Engineering, AUC, July 2015

Supervised By

Prof. Amin K. El-Kharbotly

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Cairo - (January 2020)

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Statement

This thesis is submitted as a partial fulfilment of Doctor of Philosophy in Mechanical Engineering Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Thesis Summary

Nowadays, consumers' demands are frequently changing seeking wider varieties of products at lower prices. The manufacturers faced the challenge of satisfying wide range of customers' needs at lowest possible cost. Researchers recognized the need for the integrated product and supply Chain design considering modularity and commonality in design to provide variety in products at lower total supply chain cost compared with considering no commonality and modularity within the design.

The integrated design of product and supply chain enhances the SC performance because the parameters of both design and supply chain perspectives are taken into consideration while seeing the other side. Hence, design is made that result into best Supply chain performance than that just designing in blinding eye from its associated cost. It makes no sense to design extra ordinary design that may be very costly to implement it or un-applicable.

Also, it is inefficient for supply Chain manager to optimize the supply chain performance at different parameters at a predetermined commonality based on his expectation without optimizing both product design and supply chain one ahead. Sequential and simultaneous approaches are used for the integrated design of product and supply chain.

Many works for integrated design considering the two approaches are conducted, however, many of the crucial problem parameters are not considered in the model formulation before. These parameter include: 1) material discount, 2) discount threshold, 3) discount range, 4) Extra feature of the High end module to tackle the cannibalization thread of commonization 5) Multi-period different inventories types and

Compromising between materials, modules, products inventory levels decision.

Many of the previous works seldom investigated the optimum level of commonization at different SC parameters. Also, the effect of extra features of common modules at different SC and design parameters, and by virtue the dependency of product design and SC decision on product parameters, SC parameters, or on both.

The objective of the present research is to develop a mathematical model that enables the decision maker to make necessary compromises between commonality decisions and supply chain performance. The mathematical model has to optimize both product commonality decisions and supply chain decisions simultaneously. Also, to study the effect of supply chain parameters such as material discounts, ability to keep inventory and available production capacity on commonality decision is investigated. In addition, the effect of commonizing product family variants of similar functional modules to high end variant instead of low end variant is investigated.

A mixed integer nonlinear programming mathematical model is developed to optimize both the products decision and supply chain decision simultaneously at one step. Each of either components of the optimized design (e.g. product design or supply chain design) is dependent on the other. Furthermore, the developed model included a developed index that assesses the commonization of High end module at end of all planning periods. LINGO optimization software is used to conduct the needed runs.

The objective function formulated to minimize supply chain total cost. The deliverables of the model should be: 1) The selection of variant modules for each product, 2) Specification of optimum level of commonization within the

family at end of all periods, 3) The amount of materials acquired in each period, 4) Deciding to take the discount or not. 5) Specifying amount of inventory kept in each period from materials, modules, products, 6) Technology section for common module on an operational level.

In order to examine the benefits and behavior of proposed integrated product design and supply chain design. Three main groups of instances are designed addressing three different problem perspectives. The three perspectives are designer perspective, supply chain perspective and integrated design and supply chain perspective. However, emphases are made to determine the advantage of considering the integrated perspectives.

In the first group, the commonization decisions made by Product Designer dis-considering main SC characteristics such as: material discount, inventory and the processing facility capacity constraint are designed. It is only objective to investigate of the effect of two main parameters, namely High-end module cost and Product Family Structure, on supply chain performance and commonality decision when it is taken by product designer

In the second group, optimizing supply chain performance by the supply chain mangers at two input levels of commonality either no commonality or maximum commonality is designed. It is only objective to investigate of the effect of different high-end module cost ratio, inventory allowance and disallowance and discount allowance and disallowance.

In the last and third group, the integrated simultaneous decisions that optimize module commonization and supply chain performance are designed. In this group of instances, the parameters affecting the simultaneous supply chain and commonality decisions are studied. The parameters investigated are the product structure, High-end module cost, and

the interchangeability of high-end modules to variant modules, and variant module changing weight. As for the supply chain parameters the purchase discount rate and discount threshold, in addition to keeping inventory or not. The fixed and variable costs of technology used in addition to the technology capacity are also investigated.

It was concluded that the commonization decision targeting lowest total supply chain cost is mainly decided by the trade-off formula which is the material and inventory cost increase due to commonization with respect to the production cost decrease due to commonization. It was evident that each of the studied parameter including discount range, discount threshold, inventory cost and allowance, fixed and variable processing cost of High technology and its capacity, high end module cost, product structure has integrated critical effect on the trade-off formula, on the integrated decisions and on SC performance.

Certain level of commonization is only decided if its associated material and inventory cost due to the commonalizing of variant modules by high end module is compensated by the associated production cost decrease due to the processing of higher end modules by the low processing cost of high technology. In the contrary to the debate that suggest that full commonization should always achieved due to economics of scale. It was proven that maximum, partial, zero commonization is optimized according to different product design and SC parameters. This proves that commonization is not always the most economic decision.

It was proven that the parameters like as discount, threshold has controlling impact on the integrated decision because it effect the actual material purchase cost, hence, it controlling the stated trade off formula. After

investigating the impact of increasing the extra feature of high-end module on the integrated decision, the following could be concluded:

If the total quantity of the material of any High end module doesn't merit quantity discount and the increase in cost of the High end module is high and the total quantity produced does not justify the use of high technology, the supply chain will consider no commonization.

If the total quantity of the material of any High end module doesn't merit quantity discount while the increase in cost of the High end module is Low and the total quantity produced does justify the use of high technology, the supply chain will consider Full commonization.

In the contrary, discounts can be achieved due to high quantities that exceed the threshold quantity specified by the supplier and the increase in material cost of High end module is compensated by the discount cost savings and the production cost savings due to the use of High technology, the supply chain may favor maximum possible commonization.

If the total quantity of the material of any High end module does merit quantity discount and the increase in cost of the High end module is intermediate (between high and low) and the total quantity produced does justify the use of high technology, the supply chain will consider partial commonization.

Key words:

Product Modularity, Product commonality, Commonality decisions, Commonality Index, Supply Chain optimization, integrated commonality and supply chain optimization