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Supply Chains Based on Common Platforms: Analysis of Time Savings Gained by Commonality

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Abstract: Sharing common resources is amongst critical factors creating competitive advantages in business and manufacturing. In today's competitive and dynamic environment, application of the resource sharing approach has become the focal point of attention for business managers. By resource sharing and through common platform guidelines, the possibility of producing an extended variety of products using the least variable production elements is provided. Meanwhile, today's manufacturing industries are trying hard to plan and manage an effective foundation for creating a value stream from the point of supplying resources to the stage of delivering the final product to the customer. Standardizing and sharing product components and common platforms is of great assistance to this effort. This study presents a mathematical model to contribute to making the decision of choosing the best combination of common components and analyze the time effects of commonality approach and its possible consequential savings as one of the key performance indicators of a supply chain based on common platform.

Key words: Product architecture, time management, commonality, SCBCP

INTRODUCTION

Tightening competition in world class level has forced the companies to make and develop new competitive advantages to be able to survive. Rapid pace of innovation, variety of products, customer expectations are amongst the main concerns of today's business managers (Chopra and Meindl, 2007). Accordingly, producing diverse products with the least possible variety in parts and components from one hand, as well as design and analysis of the value stream to support the optimal flow of these diverse parts and products on the other hand has become an important challenge for today's manufacturing companies. The two aforementioned challenges address the concepts of common platform (CP) and supply chain management (SCM), respectively.

The platform approach was introduced in the early 90s as the result of attempts in simplifying product design and development and not long after that, in 1994, it was used as a key solution in different industries. Common platform (CP) is known as a component that can be shared amongst several products, apart from differences in outward appearances (Siddique and Rosen, 2001). Simpson (2003) believed that CP is a basis with restructuring abilities so that by adding or removing different modules, it is possible to improve the flexibility in producing new and diverse products. When using a platform, four product characteristics can be shared which are: components, processes, human resources and knowledge (Muffatto and Roveda, 2000).

Supply chain management was also introduced and widely accepted in 1990s when industry managers found out that in order to continue their presence in competitive markets, they need more than improvements in internal processes and flexibility of their companies. They realized that part and material suppliers have to produce components and materials with best qualities and least costs and also the distributors must work consistent to market development policies of the manufacturer (Croom *et al*., 2000). These constitute the main concept of SCM. In the situation where make to order (MTO) has been taken as a dominant approach in manufacturing industries, SCM has gained even more attention. According to Prasad *et al*. (2005), in make to order manufacturing, it is essential that the manufacturer and its suppliers have a closer relationship. They have to be more integrated in order to enhance the ability of producing and delivering products consistent with the needs of customers and in a timely manner. Based on this definition, it can be said that the supply chain encompasses all the activities related to material flow and product transformation from the source of raw materials to the final stage of delivery to end consumers and all the related informational and financial flows

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Table 1: Reviewing the related studies

Year	Author's Name	Description
1997	Sheu and Wacker	With emphasis on the strategy of part and component commonality, they showed that commonality leads to reduction of design and production cycles and causes valuable benefits in the chain
2002	Ulrich and Bradley	Propose a model for analyzing the effects of product variety on supply chain performance. They demonstrate that product variety increases lead time and costs linearly; therefore they recommend optimum variety for products
2002	Ma *et al.*	While implying the effectiveness of commonality approach on supply chain development, they analyzed the effects of process time and supply lead time on commonality decisions and postponement by mathematical modeling
2004	Ghosh *et al.*	Shows the interaction between product platform development and supply chain configuration in a global environment. He developed a comprehensive decision support model to simultaneously determine product strategy and supply chain configuration
2005	Fixson	Discusses a multidimensional framework regarding product architecture considering the common components, product platform and modularity in the supply chain system
2005	Meixell and Gargeya	Studies the effect of start up costs, component commonality and capacity on supply chain scheduling and states that sharing components has an impact on it
2007	Simpson *et al.*	Discuss the redesign of product families in concern with the platform approach by proposing a decision making framework. They demonstrate that using the platform approach, the possibility of cost and time reductions will be provided

(Chopra and Meindl, 2007). It is important to note that amongst several key indicators that characterize the effective management of supply chains, the time factor has always been in the focal point of attention (Gunasekaran *et al.*, 2001).

Although many researchers have studied the interactions between diversity of products and commonality of production elements, the aspects of this problem have scarcely been investigated in the area of supply chain management (Fathollah and Shafia, 2006). Table 1 reviews the related works that have studied the concept of common platform in concern with SCM. Considering the freshness of the subject matter, it has been studied from different viewpoints and attracted different opinions.

Literature review reveals that the causes and effects of CP approach on a supply chain system have not been discussed specially in a comprehensive and quantitative manner (Nobelius and Sundgren, 2002). Concerning the identified deficiency in the literature, different topics can be discussed in strategic and operational level. For example: specifying the characteristics of a supply chain based on common platform, architecture of new products considering the supply chain factors, the best combination of the common components, cost and time management in platform based supply chains, policy making regarding commonality and diversification and so on. It is obvious that providing answers for each of these matters needs separate study and research (Krishnan and Ulrich, 2001).

One of the basic challenges amongst the aforementioned topics is decision making regarding the best combination of components to be shared (Fellini *et al.*, 2004). Besides, measurement of possible cycle time reductions gained by commonality can also be of great importance to the decision making process regarding the CP strategy since time has always been one of the important factors attracting the attention of researchers separately in SC and CP systems. Examples of time factors include lead times, setup times, time to market, design and manufacturing times and so on.

In the following research, besides incorporating and integrating the concepts of SCM and CP, it is tried to analyze and model the time effect of commonality in supply chains based on common platforms. The study calculates the amount of time savings gained by applying the CP strategy through the supply chain and specifies the best combination of possible common components to be shared.

Accordingly, two important questions that are addressed in the following study are:

RQ1: When using the platform approach, what is the best combination of the common components?

RQ2: Based upon commonality approach, how much time savings can be achieved in the supply network?

In order to answer these questions, at first an extensive study has been performed on related published research. Afterwards, based on field observations and semi structured interviews, the impact of utilizing platforms through supply chains in some selected automotive firms has been extracted. Lastly, it is tried to develop a mathematical model for a selected part of the chain and provide a solution for it.

SUPPLY CHAINS BASED ON COMMON PLATFORMS (SCBCP)

The interactions and relationships between product architecture, platform design and supply chain were studied and brought into attention by Salvador *et al.*

(2002). Moreover, there has always been an emphasis that while designing and architecting a family of products, the designers and producers has to consider the product family and supply chain plans at the same time (Lamothe, 2006). Accordingly, a supply chain based on common platform (SCBCP) proposes a decision making and decision building framework based on which the supply network and product architecture plans are developed consistently and therefore cause support and advancement of competitive advantages. One can say that strategic and operational decisions throughout the chain are influenced by the platform approach. For example by assuming the usage of platform, topics like quantity and combination of products, structure of distribution and logistic networks, quantity and combination of suppliers, product architecture approach, decision making about the point of differentiation, making a tradeoff between pull and push policies through the chain, policy making regarding commonality, diversification, standardization and product modularity, new product development, the number and combination of platforms and their development policies, structure and mixture of common/different elements in bill of materials, time and cost management through the chain, resource management and so on are very important and require special attention. Hence, it is important that supply chains are designed and developed in a way that they can support the policies and requirements of platform development (Appelqvist *et al*., 2004; Simpson, 2003). Some of the main advantages of SCBCP are as follows:

- Emergence of mega suppliers due to resource sharing and economics of scale in supply and logistic processes
- Changing the role of suppliers from being operational executives of the build contracts with manufacturer to being associates of production planning and assembly of components and modules
- Simplification of supply and manufacturing processes and single modules along with facilitation of giving responsibilities to suppliers
- Reduction of component variations and simplification of production planning, supply and procurement processes
- Possibility of promoting network structures, combining and tiering the suppliers and distributors consistent with policies regarding commonality and diversification of products and production elements
- Providing the possibility of utilizing common logistic equipments and sharing of hard and soft resources amongst chain members
- Development of agility, quick response capabilities and flexibility in the chain
- Support and development of interactions and relationships between chain members via sharing the resources and consequently gains and risks
- Providing the possibility of developing and promoting competitive advantages in world class level, benefiting from network economy and economy of scope and scale
- Providing the possibility of grading and tiering suppliers based on platform design and product families
- Worldwide development of supply, production and distribution networks due to platform architecture and worldwide product architecture

PRODUCT ARCHITECTURE IN SUPPLY CHAIN BASED ON COMMON PLATFORM

The concept of product architecture was first proposed by Abberathy in 1975. It includes topics such as: designing the assignment of functions to physical parts of a product, integration of physical parts and components and designing the relationships and physical interactions of parts (Simpson *et al*., 2007). Having a closer look, one can realize that subjects like specification and separation of different parts and product sections, individualization and at the same time creation of order and integration and defining the relations between different components, stand out in the above definition. This concept, in the filed of CP, provides the circumstances of meeting the requirements for the development of a platform based family of products. Therefore, in the field of platform based product architecture and supply chain management, topics like specifying and defining family member products, sharing physical parts and components, categorizing products with similar specifications, deciding about combining common elements and the platform that can be used to produce a family of products, plus many other related subjects are discussed by Krishnan and Ulrich (2001). Accordingly, commonality, as a comprehensive aspect discussed in the field of product architecture, may cause problems and disadvantages that require logical and structured decision making (Nobelius and Sundgren, 2002).

Studying the levels and hierarchy of parts and product elements reveals that each platform contains a family of products and in each family there are variable product models. In addition, each product model is comprised of different modules, components and parts

(Zha and Sriram, 2006). It is important to note that in this study, commonality is considered in modular and part level and the model is developed in this level. Of course it is possible to generalize the model or revise it to be used in other levels.

Component commonality and resource sharing: Generally, resource sharing is defined as using common materials, tools, processes, human resource and other possible elements in a family of products. Commonality is explained as having common characteristics and specifications in a series of products or their production processes. In the past, commonality was used as an approach for cost reduction because it reduced inventory expenses. However, lately it has gained more attention due to the fact that using common components can greatly facilitate new product design, development and production process and create competitive advantage. Commonality has many advantages such as: reducing complexities in product line, maintaining economics of scales in production processes, reduction of time and cost, enhancing flexibility, reducing inventory and safety stock costs, reducing time to market, reducing setup times and increasing productivity rates (Sheu and Wacker, 1997). Commonality is one of the effective approaches in CP strategy and by means of it; industries can manufacture diverse products, increase the flexibility of their production processes and therefore reduce their costs and gain competitive advantages. However, one of the main challenges of utilizing commonality approach in product architecture is to choose the best combination of components to be shared (Fellini *et al*., 2004).

Time management in SCBCP: Lead time (LT) has long been a popular key indicator for process performance evaluations. Several production theories and philosophies such as lean, Just in Time and Agile manufacturing have put their focus on LT (Jones and Towill, 1999). On the other hand, Tan (2001) revealed the importance of considering cycle time in supply chains. In order to manage cycle time through supply chains, it is important to consider appropriate strategies and methods. In this regard, commonality approach and platform strategy can be taken into account. Generally speaking, there are difference between lead time and non lead time reduction strategies. The general aim of lead time reduction is to minimize the wait time of different processes, the forecasting horizon will be shortened and therefore errors between plan, forecast and operation will be reduced. Effective methods for managing these sorts of times include structural organization of work processes and quick response. Correspondingly, the main aim of non lead time reduction strategies is to minimize system complexities by reducing component, part and process variations. That is, using strategies such as component and part commonality and postponement of operations, process timings and sequences. Cycle time reduction can lead to several advantages such as: reduction of forecasting errors, reduced length of wait queues, faster recognition of defects and nonconformities in products and processes, effective control of lead time variations and reducing inventory levels. It is important to note that other methods and strategies have also been proposed to reduce cycle times which include reengineering and eliminating non value adding processes, compressing process times, integrating operations, knowledge and information sharing and synchronization of operations (Jones and Towill, 1999).

DEVELOPMENT OF TIME OPTIMIZATION MODEL

According to the aforementioned, one can say that time reduction, is amongst what most companies have declared as their main objectives in utilization of common platform strategy (Simpson, 2003). Time reduction in common platform concept, directly and indirectly, can be achieved from different aspects, including: reduction of supply and logistic times, production line suppression periods, product/part design and engineering times, engineering change times, production customization times and reducing production, assembly and setup times. It is important to remark that in earlier studies, time structures in supply chains are defined and classified in different manners (Otto and Kotzab, 2003). However, in this study, according to field research and case studies performed on Iranian car producers, Iran Khodro and Sapco, it is tried to consider the time factor as one of the most important factors in increasing performance and effectiveness of platform based supply chains and perform the mathematical modeling based upon time factors in automotive industry.

Mathematical modeling: Here, the details of the mathematical model will be defined. The goal of modeling is to discover the best combination of parts to be shared and calculate the amount of time savings gained by using common components in the supply chain. Considering a three level network consisting of suppliers, warehouses and manufacturer as shown in Fig. 1, the model is purposed to answer two main questions: (1) in the

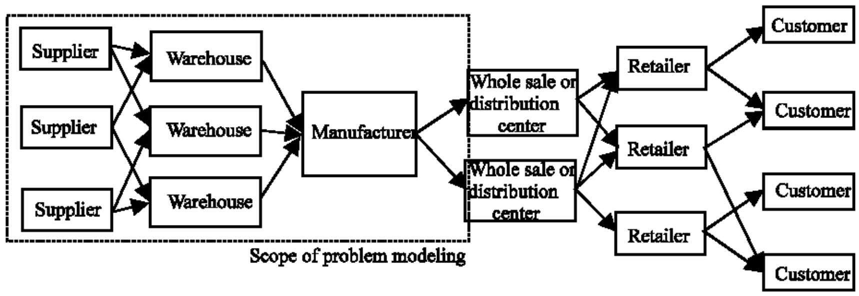

Fig. 1: The structure of the supply network

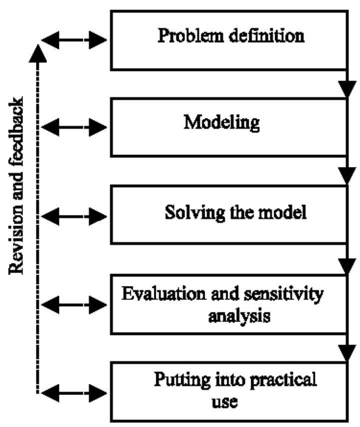

Fig. 2: Modeling process

product architecture process and development of a new product, what combination of existing components and parts can be used? and (2) in between existing part families, what elements can be selected as common components and be replaced in order to reduce the multiplicity of existing parts of the existing products? After answering these questions, the optimum times can be determined, analyzed and be compared to the times before the resource sharing. It is important to note that the modeling approach is based on creating product families and the idea is derived from modeling methods in cellular design and cellular manufacturing systems (Wang, 2003). Accordingly based on Fig. 2, after the problem definition is presented, the mathematical model will be developed and solved. Evaluation and sensitivity analysis of the proposed model and finally putting it into practical use are additional steps that can be followed:

Modeling assumptions

- All the parameters are defined and certain
- Production capacity for each part is defined and fixed
- The modeling is performed in the part level; however, it can be generalized and revised to be used in module or product levels
- It is presumed that resources (parts) can be shared between existing products and also be considered in the design of new products
- The structure of the supply network and its related strategic and tactical decisions are considered the same before and after resource sharing
- There may be several constraints throughout the whole network for a specific part such as part procurement constraints, transportation constraints, production constraints and so on. Therefore in the model the minimum of all the above constraints will be considered
- In the proposed model, the time elements for commonality are considered in the domains of supply and manufacturing. Distribution and sales domains are not considered
- In the proposed model, it is assumed that commonality is operationally and technically possible between intended elements through product architecture process in the chain
- The time functions correspond to definitions presented in the model
- The intended cycle time in this study is considered as the sum of all individual process times

Decision variables and parameters
Sets

I : Subscript denoting parts of existing products
N : Subscript denoting parts of the new product
M : Subscript denoting manufacturers
P : Subscript denoting existing products
S : The set of suppliers
W : The set of warehouses

Parameters

D_{jk} : Amount of demand for part i of product k

D'_n : Amount of demand for part n of a new product

α_{jkip} : Commonality coefficient between part j of existing product k and part i of existing product p

α'_{nip} : Commonality coefficient between part n of a new product and part i of existing product p

LT_{ipsw} : Average lead time for part i of existing product p from supplier s to warehouse w

LT'_{nsw} : Average lead time for part n of a new product from supplier s to warehouse w

ST_{ips} : Average setup time for part i of existing product p in supplier s

SST_{ns} : Average setup time for part n of a new product in supplier s

DT_{ips} : Average design and engineering time for part i of existing product p in supplier s

DDT_{ns} : Average design and engineering time for part n of a new product in supplier s

PT_{ips} : Average production time for part i of existing product p in supplier s

PPT_{ns} : Average production time for part n of a new product in supplier s

CT_{ipwn} : Average transportation time per unit for part I of existing product p from warehouse w to manufacturer m

$C'T_{nwm}$: Average transportation time per unit for part n of a new product from warehouse w to manufacturer m

MT_{ipm} : Average assembly time for part i of existing product p in manufacturer m

MT'_{nm} : Average assembly time for part n of a new product in manufacturer m

ST'_{ipm} : Average setup time for part i of existing product p in manufacturer m

SST'_{nm} : Average setup time for part n of a new product in manufacturer m

DT'_{ipm} : Average design and engineering time for part i of existing product p in manufacturer m

DDT'_{nm} : Average design and engineering time for part n of a new product in manufacturer m

L_{ipm} : Production line down time caused by the lack of part i of existing product p in manufacturer m

L'_{nm} : Production line down time caused by the lack of part n of a new product in manufacturer m

Cap_{ip} : Capacity of part i of existing product p

b : Element for conversion of commonality coefficient to time

Decision variables

X_{jkip} : Binary variable; equals to 1 if part j of existing product k gets assigned to part i of existing product p, else it equals to 0

Y_{nip} : Binary variable; equals to 1 if part n of a new product gets assigned to part i of existing product p, else it equals to 0

Commonality time optimization model: The first expression in the objective function of the optimization model includes the sum of setup times in suppliers calculated for the forefront product. The second expression denotes the sum of manufacturing times in suppliers. The third expression of the objective function, calculates the sum of design and engineering times in suppliers which include design and engineering time of the forefront part plus a coefficient of design and engineering times belonging to common shared parts. The forefront part is the part which is selected to be the shared resource and replaced with its subgroup parts in the resource sharing process. The forth expression sums the setup times in manufacturers for the forefront component. The fifth expression is the sum of assembly times in manufacturers and the sixth calculates the design and engineering times in manufacturers including design and engineering time of the forefront part plus a coefficient of design and engineering times belonging to common shared parts. The seventh expression denotes the sum of supply times from suppliers to warehouses and the eighth denotes the sum of transportation times from warehouses to manufacturers. The ninth expression includes the sum of line down times caused by lack of parts which are calculated for the forefront part. The tenth and eleventh expressions represent the sum of times caused by inconsistencies and dissimilarities in between existing product parts and also between new product parts and existing product parts. These two expressions are added to the model correspondent to commonality and diversification. First and second constraints assure that unless a part is marked as forefront, no other parts can get common with it. The third and forth constraints assure that parts belonging to existing products and new product have to be in a single group (get common with one forefront part). The fifth constraint is capacity constraint related to parts and the sixth constraint assures that decision variables are binary. In order to actualize the model, at first a commonality coefficient (g) is considered. If α_{jkip}<g or α'_{nip} then at the very beginning of the model, X_{jkip} and Y_{nip} get equalized to 0.

Commonality time optimization model

$$\text{MIN}: Z = \sum_{s\in S}\sum_{p\in P}\sum_{i\in I} ST_{ips}X_{ipip} +$$

$$\sum_{s\in S}\sum_{p\in P}\sum_{i\in I} PT_{ips}\left(\sum_{k\in P}\sum_{j\in I} D_{jk}X_{jkip} + \sum_{n\in N} D'_n Y_{nip}\right) +$$

$$\sum_{s\in S}\sum_{p\in P}\sum_{i\in I}\left[(1-k)DT_{ips}X_{ipip} + k\left(\sum_{k\in P}\sum_{j\in I} DT_{jks}X_{jkip} + \sum_{n\in N} DDT_{ns}Y_{nip}\right)\right] +$$

$$\sum_{m\in M}\sum_{p\in P}\sum_{i\in I} ST'_{ipm}X_{ipip} +$$

$$\sum_{m\in M}\sum_{p\in P}\sum_{i\in I} MT_{ipm}\left(\sum_{k\in P}\sum_{j\in I} D_{jk}X_{jkip} + \sum_{n\in N} D'_n Y_{nip}\right) +$$

$$\sum_{m\in M}\sum_{p\in P}\sum_{i\in I}\left[(1-k')DT'_{ipm}X_{ipip} + k'\left(\sum_{k\in P}\sum_{j\in I} DT'_{jkm}X_{jkip} + \sum_{n\in N} DDT'_{nm}Y_{nip}\right)\right] +$$

$$\sum_{s\in S}\sum_{w\in w}\sum_{p\in P}\sum_{i\in I} LT_{ipsw}\left(\sum_{k\in P}\sum_{j\in I} D_{jk}X_{jkip} + \sum_{n\in N} D'_n Y_{nip}\right) +$$

$$\sum_{m\in M}\sum_{w\in w}\sum_{p\in P}\sum_{i\in I} CT_{ipwm}\left(\sum_{k\in P}\sum_{j\in I} D_{jk}X_{jkip} + \sum_{n\in N} D'_n Y_{nip}\right) +$$

$$\sum_{m\in M}\sum_{p\in P}\sum_{i\in I} L_{ipm}X_{ipip} + \sum_{p\in P}\sum_{i\in I}\sum_{k\in P}\sum_{j\in I}\left(1-\alpha_{jkip}\right)bX_{jkip} +$$

$$\sum_{p\in P}\sum_{i\in I}\sum_{n\in N}\left(1-\alpha'_{nip}\right)bY_{nip}$$

S.T :

$$X_{jkip} \le X_{ipip} \quad \forall i,j\in I, \forall k,p\in P$$

$$Y_{nip} \le X_{ipip} \quad \forall n\in N, \forall i\in I, \forall p\in P$$

$$\sum_{p\in P}\sum_{i\in I} X_{jkip} = 1 \quad \forall j\in I, \forall k\in P$$

$$\sum_{p\in P}\sum_{i\in I} Y_{nip} = 1 \quad \forall n\in N$$

$$\sum_{j\in I}\sum_{k\in P} D_{jk}X_{jkip} + \sum D'_n Y_{nip} \le Cap_{ip} \qquad \forall i\in I, \forall p\in P$$

$$X_{jkip}, Y_{nip} \in \{0,1\}$$

Time function prior to commonality

$$f(x) = \sum_{s\in S}\sum_{p\in P}\sum_{i\in I} ST_{ips} +$$

$$\sum_{s\in S}\sum_{p\in P}\sum_{i\in I} PT_{ips}D_{ip} + \sum_{s\in S}\sum_{p\in P}\sum_{i\in I} DT_{ips} + \sum_{m\in M}\sum_{p\in P}\sum_{i\in I} ST'_{ipm} +$$

$$\sum_{m\in M}\sum_{p\in P}\sum_{i\in I} MT_{ipm}D_{ip} + \sum_{m\in M}\sum_{p\in P}\sum_{i\in I} DT'_{ipm} +$$

$$\sum_{m\in M}\sum_{p\in P}\sum_{i\in I} L_{ipm} + \sum_{s\in S}\sum_{w\in W}\sum_{p\in P}\sum_{i\in I} LT_{ipsw}D_{ip} +$$

$$\sum_{m\in M}\sum_{w\in w}\sum_{p\in P}\sum_{i\in I} CT_{ipwm}D_{ip} + \sum_{s\in S}\sum_{n\in N} SST_{ns} +$$

$$\sum_{s\in S}\sum_{n\in N} PPT_{ns}D'_n + \sum_{s\in S}\sum_{n\in N} DDT_{ns} +$$

$$\sum_{m\in M}\sum_{n\in N} SST'_{nm} + \sum_{m\in M}\sum_{n\in N} MT'_{nm}D'_n + \sum_{m\in M}\sum_{n\in N} DDT'_{nm} +$$

$$\sum_{s\in S}\sum_{w\in w}\sum_{n\in N} LT'_{nsw}D'_n + \sum_{m\in M}\sum_{w\in w}\sum_{n\in N} C'T_{ndw}D'_n +$$

$$\sum_{m\in M}\sum_{n\in N} L'_{nm}$$

SOLUTION ALGORITHM

As mentioned before, since the commonality model presented in this study is a developed form of cellular manufacturing problems and in the literature, this kind of problems are grouped as Np-Hard, therefore, the problem developed in this study can also be grouped as Np-Hard. In order to solve this kind of problems, Meta Heuristic approaches are recommended. Accordingly, in this study a Meta Heuristic approach called Simulated Annealing (SA) is used. SA is mathematically proved to be effective in finding the optimum result. The extent of this problem depends on the number of products and parts and in the stage of arithmetical calculations, it is possible to identify its sensitivity to the existing parameters by solving the problem several times. The SA method is a random search approach that discovers near optimum solutions (Kirkpatrick *et al*., 1983).

In order to demonstrate the results, an n×n matrix is used with elements of zero and one. When part i gets assigned to part j (indicated as a common part), the (i,j) entry of the matrix will be set to 1 and otherwise it will be 0. Therefore, in this matrix, just one value in each row can be set to 1 because each part can be assigned to just one part family. In this matrix if the (i,i) entry gets equal to 1, this means that the i-th part is chosen as a common component. Figure 3 show an example of a result for 5 parts. The first part is for a new product and the remaining four are parts of existing products. It can be seen that in this example, 3 part families have been formed with parts 2,4 and 5 as the platforms or forefronts that will be used as shared components. Other parts will be randomly assigned to one the functionally compatible groups. Therefore, part 3 has been assigned to a group (family) with part 2 as the platform. In other words, instead of part 3, part 2 will be used in the related products. Thus it can be seen that in this example, the variety of five parts has been reduced to three.

Part No.	1	2	3	4	5
1	0	0	0	1	0
2	0	1	0	0	0
3	0	1	0	0	0
4	0	0	0	1	0
5	0	0	0	0	1

Fig. 3: Result demonstration

Computational results and sensitivity analysis: The computational results presented here are purposed to evaluate the performance of SA algorithm. The presented SA algorithm is encoded by Visual Basic 6 (VB6) and solved for an extent of 5 to 50 products. The objectives in this stage are: (1) to evaluate the performance of the presented heuristic algorithm and (2)

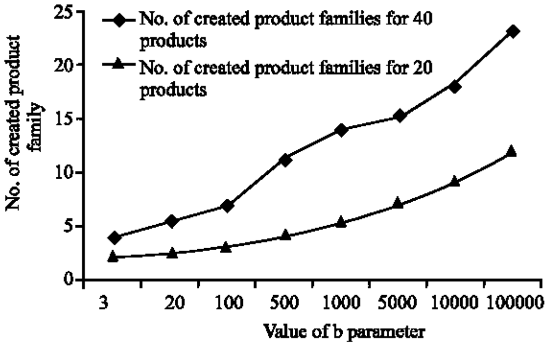

Fig. 4: The effect of the b parameter on the number of created product families

Table 2: The results of SA Algorithm compared to the optimum results

No.	No. of products	Heuristic solution	Optimum solution	Error (%)	Overall time before resource sharing
1	5	2413.0	2413.0	0.00	2573
2	10	2907.8	2907.8	0.00	4370
3	15	3897.2	3897.2	0.00	7024
4	20	5012.7	5012.7	0.00	10876
5	25	5911.2	5911.2	0.00	13154
6	30	7358.1	7264.3	1.29	17926
7	35	8476.3	8322.9	1.84	21894
8	40	9822.1	9637.1	1.92	29230
9	50	11596.3	11349.4	2.18	44612

to study the impact of changes in the b parameter on the number of created product families. In order to evaluate the performance of the presented simulation algorithm, the problem is also solved with LINGO 8 software and the results are compared. As shown in Table 2, the results of SA algorithm are optimum or near optimum. Moreover, it can be realized that in each problem, making common parts has led to remarkable time reductions. By comparing the outputs of the objective function with the outputs gained from the time function before commonality, the time savings gained by resource sharing or commonality can be measured. Accordingly, as the number of components and elements grows, utilizing the CP strategy leads to greater savings.

Figure 4 show the effect of the b parameter on the number of created product families. As it can be realized, by increasing the value of the b parameter (which can be determined by expert opinion), the number of created product families grows. Setting this parameter to a very large number will result in a state in which each part is shared with itself or in other words, no part will be selected as a platform and shared by several products. Thus, it can be concluded that in real world, a tradeoff has to be created between the benefits of commonality and the times and costs of losing some levels of part functionality.

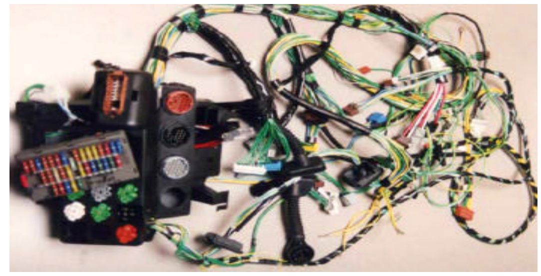

Fig. 5: Main wire harness of an automobile

Application of time model in real world: By applying the developed model here, it is tried to calculate the time savings for a real world problem. The required data is gathered from the Iran Khodro automotive company (IKCO) regarding the commonality of electrical main wiring harness of its Samand car family. Fifteen different models of Samand are produced in IKCO, each of them using a distinct type of main wire harness (Fig. 5). The key questions are: considering the functional similarities between different types of Samand main wire harnesses, what is the best combination for commonality amongst these different types? and applying the commonality approach, how much time savings can be achieved?

Below are some of the main reasons to choose the main wire harness for commonality practice:

- The main wire harness of Samand car is a strategic part in supply and production system of IKCO
- There is a wide variety of main wiring harnesses (a distinct type for each car model) whereas the differences between these variable parts are very little
- The main wire harness is regarded as an expensive part in a car
- In the supply base for IKCO, there are few companies that can supply this part (only two)
- Supply management of these different types of main wire harnesses (procuring the right quantity at the right time) is a complex and risky effort

It is important to note that solving the proposed model with real world data will also provide a verification and validation basis for its functionality. The platform for solving the model is Lingo 8 software.

Lingo results: Considering the structure of input data, the problem consists of choosing the best combination of common components as well as calculating the time savings. Accordingly, for different hypothetic combinations of common components (main wire

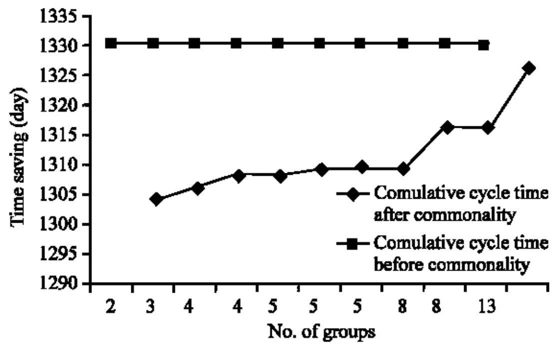

Fig. 6: Cumulative cycle time before and after commonality

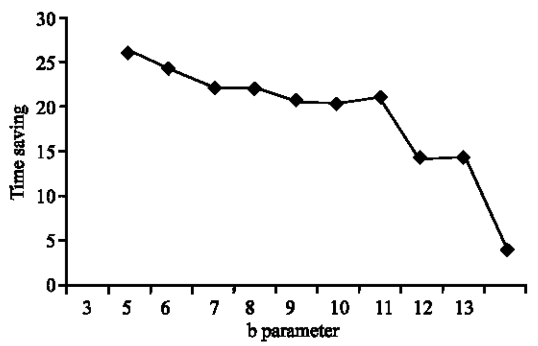

Fig. 7: The comparison of component variety and time saving (days)

harnesses), the summation of cycle times of 15 car models is calculated and compared to the same summation calculated before making any changes and therefore calculating the amount of time savings. The calculated summation before making any commonality changes to the system is 1330 days (Fig. 6).

According to the fact that the proposed model is structurally related to the b parameter, the problem is solved by considering different b values and choosing the best choice. The calculations indicate that by increasing the value of the b parameter, the number of common components increases to the point that each part gets to be shared only with itself and as a result the amount of time savings will decrease (Fig. 7). Accordingly, the best feasible combination of common components can be recognized based upon the expert opinion, taking into consideration the technical, economical and functional aspects.

CONCLUSION AND FUTURE RESEARCH

This study discussed the competitive advantages gained by the platform approach which are revealed in various industries in the form of cost, time and flexibility improvements. The study also showed that development and integration of the platform approach along with the concepts of SCM. In other words, developing and improving supply chains based on common platforms creates a more advanced and synergistic approach which leads to significant improvements in performance indicators including the time factor. It was discussed that organizing a platform based supply chain system calls for meeting several strategic and operational requirements which have to be taken into account. Moreover, in order to answer the main research question about selecting the best combination of common elements through the chain to reduce the multiplicity of components in the product architecture process along with time savings, a mathematical model was proposed for supporting the decision making process. In order to further clarify the concept of the supply chain based on common platform and its conditions for time management, a numeral example was presented and a solution algorithm based on SA method for the presented model was discussed. To further verify the developed mathematical model, it was tested with real world data gathered from a case study about a chosen car manufacturer.

The concluded results and the insights gained from solving the developed mathematical model and testing it in real world include:

Insight 1: Commonality throughout the chain can lead to remarkable time savings which is of more importance dealing with large number of products and parts. The aforementioned can be obviously inferred from Fig. 6, 7 and Table 3. Using the least number of possible parts shared between various products would be the best possible scenario specially when dealing with a variety of products.

Insight 2: The best case scenario would not be practical regarding the technical and economical restrictions in sharing common parts. In fact, there is a tradeoff between commonality and differentiation of parts that form the products. This is because due to commonality, a level of expected functionality for each shared element may be lost for covering the communal functions which may lead to increase in time and cost. The developed model addressed this issue by incorporating the b parameter. Accordingly, taking proper decisions to specify an acceptable level of commonality through the chain is very critical and has to be made by decision makers and expert systems.

In the end, further research in this field may include studying and multi objective modeling of the success factors in supply chains based on common platforms including time, cost and flexibility. Development and generalization of the proposed model in the whole

Table 3: Comparative analysis of achieved time savings gained by combination of common components (days)

Main wire harnesses to be made common	Variety of common parts	Achieved time saving	Summation of cycle times after commonality (regardless of the b parameter)	Time value of b parameter	Summation of cycle times after commonality (considering the b parameter)	The value of b parameter
{13-12-7-4-5} and {14-11-10-9-8-6-3-2-1-15}	2	26.1	1303.9	7.80	1311.7	3
{15-1-3-4} and {11-2-6-8-9-10} and {5-4-7-12-13}	3	24.2	1305.8	10.75	1316.6	5
{15-1-3-14} and {9-2-10} and {5-4-7-13} and {8-6-11-12}	4	22.1	1307.9	10.80	1318.7	6
{15-1-3-14} and {9-2-10} and {5-4-7-12-13} and {8-6-11}	4	22.1	1307.9	12.60	1320.5	7
{8-6-11-12} and {9-10} and {5-4-7-13} and {2} and {15-1-3-14}	5	20.7	1309.3	12.40	1322.3	8
{8-6-11-12} and {9-10} and {5-4-7-13} and {2} and {15-1-3-14}	5	20.1	1309.9	13.90	1323.8	9
{8-6-11} and {5-4-7-12-13} and {15-3-14} and {2} and {1-9-10}	5	20.7	1309.3	15.50	1325.4	10
{5-4-7-13} and {15-3-14} and {2} and {1} and {9} and {12} and {10} and {8-6-11}	8	14.1	1315.9	10.40	1326.3	11
{5-4-7-13} and {15-3-14} and {2} and {1} and {9} and {12} and {10} and {8-6-11}	8	14.1	1315.9	11.40	1327.3	12
{1} and {2} and {3} and {6} and {8} and {9} and {10} and {11} and {12} and {13} and {14} and {15} and {5-4-7}	13	4.1	1325.9	2.80	1328.7	14

network and additional levels of product architecture and also consideration of the supply network as an open system in order to study the effects of outsider elements (market, customers, etc.) are additional subjects that can be studied. In addition, studying and modeling the time of chain based on network theory can be a valuable contribution. From modeling perspective, more advanced models like probability, robust or fuzzy can be developed or the problem scope and constraints can be modified and studied. Additional heuristic and Meta heuristic solution methods can also be applied.

REFERENCES

Appelqvist, P., J.M. Lehtonen and J. Kokkonen, 2004. Supply chain design: Literature survey and case study. J. Manufact. Technol. Manage., 15: 675-686.

Chopra, S. and P. Meindl, 2007. Supply Chain Management, Strategy, Planning and Operation. 3rd Edn., Prentice Hall, USA., ISBN: 0-13-173042-8.

Croom, S., P. Romano and M. Giannakis, 2000. Supply chain management: An analytical framework for critical literature review. Eur. J. Purchas. Supply Manage., 6: 67-83.

Fathollah, M. and M.A. Shafia, 2006. A survey of common platform applications and research issues for industries and industrial engineers. Int. J. Applied Manage. Technol., 4: 18-45.

Fellini, R., M. Kokkolaras, N. Michelena and P. Papalambors, 2004. A sensitivity based commonality strategy for family products of mild variation, with application to automotive body structures. Struct. Multidisc. Optim., 27: 89-96.

Fixson, S.K., 2005. Product architecture assessment: A tool to link product, process and supply Chain design decisions. J. Operat. Manage., 23: 345-369.

Ghosh, S., N. Murthy and J. Park, 2004. Integrating product platform development with supply chain configuration in a global environment. Technical Report, Dupree College of Management, Georgia Institute of technology, USA.

Gonzalez, J.P., K.N. Otto and J.D. Baker, 2001. Assessing value in platform product family design. Res. Eng. Design, 13: 30-41.

Gunasekaran, A., C. Patel and E. Tirtiroglu, 2001. Performance measures and matrices in a supply Chain environment. Int. J. Operat. Prod. Mnage., 21: 71-87.

Jones, R.M. and D.R. Towill, 1999. Total cycle time compression and the agile supply chain. Int. J. Prod. Econ., 62: 61-73.

Kirkpatrick, S., Jr. C.D. Gelatt and M.P. Vecchi, 1983. Optimization by simulated annealing. Science, 220: 671-680.

Krishnan, V. and K.T. Ulrich, 2001. Product development decisions: A review of the literature. Manage. Sci. Des. Dev., 47: 1-21.

Lamothe, J., 2006. An optimization model for selecting a product family and designing its supply chain. Eur. J. Operat. Res., 169: 1030-1047.

Ma, S.H., W. Wang and L.M. Liu, 2002. Commonality and postponement in multistage assembly systems. Eur. J. Operat. Res., 142: 523-538.

Meixell, M.J. and V.B. Gargeya, 2005. Global supply chain design: A literature review and critique. Transport. Res. Part E: Logistic Transport., 41: 531-550.

Muffatto, M. and M. Roveda, 2000. Developing product platforms: Analysis of the development process. Technovation, 20: 617-630.

Nobelius, D. and N. Sundgren, 2002. Managerial issues in parts sharing among product development projects: A case study. J. Eng. Technol. Manage., 19: 59-73.

Otto, A. and H. Kotzab, 2003. Dose SCM really pay? Six perspectives to measure the performance of managing a SC. Eur. J. Operat. Res., 144: 306-320.

Prasad, S., J. Tata and M. Madan, 2005. Build to order supply chain in developed and developing countries. J. Operat. Manage., 23: 551-568.

Salvador, F., F. Forza and M. Rungtusanatham, 2002. Modularity, product variety, production volume and component sourcing: Theorizing beyond generic prescriptions. J. Operat. Manage., 20: 549-575.

Sheu, C. and G. Wacker, 1997. The effects of purchased parts commonality on manufacturing lead time. Int. J. Operat. Prod. Manage., 17: 725-745.

Siddique, Z. and D.W. Rosen, 2001. Identifying common platform architecture for a set of similar products. World Congress on Mass Customization and Personalization, Hong Kong, October 1-2.

Simpson, T.W., 2003. Product platform design and optimization: Status and promise. Proceedings of DETC'03 ASME Design Engineering Technical Conferences and Computers and Information in Engineering Conference Chicago, September 2-6, Illinois USA., pp: 1-56.

Simpson, T.W., Z. Siddique and J. Jiao, 2007. Platform Based Product Family Development. Product Platform and Product Family Design. 1st Edn., Springer Science and Business Media Inc., USA, ISBN: 0-387-25721-7.

Tan, K.C., 2001. A framework of SC management literature. Eur. J. Purchas. Supply Chain Manage., 7: 39-48.

Ulrich, T.W. and J.R. Bradley, 2002. The effect of product variety on supply-chain performance. Eur. J. Operat. Res., 143: 548-569.

Wang, J., 2003. Formation of machine cells and part families in cellular manufacturing systems using a linear assignment algorithm. Automatica, 39: 1607-1615.

Zha, F. and R.D. Sriram, 2006. Platform based product design and development: A knowledge intensive support approach and implementation. Knowledge Based Syst., 19: 524-543.