

A Framework for Supply Chain Efficiency Evaluation of Mass Customized Automobiles

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Abstract—Different tools of the supply chain should be managed very efficiently in mass customization. In the automobile industry, there are different strategies to manage these tools. We need to investigate which strategies among the different ones are successful and which are not. There is lack in literature regarding such analysis. Keeping this in view, the purpose of this paper is to construct a framework and model which can help to analyze the supply chain of mass customized automobiles quantitatively for future studies. Furthermore, we will also consider that which type of data can be used for the suggested model and where it can be taken from. Such framework can help to bring insight for future analysis.

Keywords—Mass customization, supply chain, inventory, distribution, automobile industry.

I. INTRODUCTION

THERE are several aspects which must be considered while analyzing the mass customization as it is a complex phenomenon which demands responsiveness, efficiency and flexibility in the supply chain. It is investigated that one of the major difficulties in implementing mass customization is the management of supply chain [1]. It is important to consider that many companies, undergone mass customization, have failed because they couldnot manage their supply chain accordingly. For a successful mass customization, it is very important that a logistic system is well integrated, suppliers are well communicated and the coordination between the supplier and the producer is rapid [2]. This issue is of vital importance, and any model which addresses the issues for mass customization should bring supply chain into account.

Mass customization has been adopted very efficiently in the computer industry. However, it has not given very good results in automobile industry because of inefficient supply chain [3]. Nevertheless, if we analyse mass customization in the case of the automobile industry, we will find out that some of the companies have adopted it very efficiently while others are poor in the management and adaptation process. There are studies that compare supply chain of different companies in automobile industry; such studies have helped to figure out the positive and negative points more clearly. There is a very detailed study which compares the supply chain of Toyota and Ford, and it brings out major problems and deficiencies;

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however, it did not take the mass customization into account [4].

As an extension of above mentioned study, we need to bring out efficient and inefficient tools of supply chain management under mass customization in automobile industry. There is a lot of qualitative work done in this regard, but literature is lacking in quantitative studies. To provide bases for future quantitative studies, this paper aims to develop a framework and model that investigate how different tools under mass customization should be managed via efficient supply. Thus, the main purpose of current paper is to develop a model for the mass customized products that highlight major issues in supply chain. Such model will develop bases for future studies. It can be tested for different companies. For this purpose, we will explore background in next section, theoretical frame work and model will be discussed in the later sections.

II. BACKGROUND

Mass customization is not a simple phenomenon. It has a lot of challenges, and one of the most important challenges is the management of the supply chain. Since the demand is not predictable under the mass customization, the management of supply chain becomes a significant task. Furthermore, customer should get the product before his taste expires. Therefore, this system needs flexibility, responsiveness and efficiency [5].

Mass customization has failed times in different industries. There are various factors behind the failure or success of this concept, supply chain management is one among them. Supply chain management plays a very important role in the production processes under mass customization. Importance of supply chain management increases more for the firms that have large operation, it is due to the fact that they have large sum of inventories, more number of suppliers and advanced assembling systems. The concept of the supply chain management has got more popularity in the recent times; this popularity is attributed because of the number of reasons. Rapidly changing technology, global conditions and increased competitions have increased uncertainty, and so the system demands more flexibility in supply chain than before [6]. Thus, it is important to consider that the challenges of supply chain become more prominent under mass customization.

Various companies, operating in the same industry may adopt different ways to manage their supply chain of mass customized products. Major linkages important in mass customization are producer's link to the customer (forward Linkage) and the producer's link to the supplier (Backward

Linkage). Automobile industry failed to get the positive outcomes of the mass customization because of the weak supply chain while the computer industry enjoyed it due to the efficient supply chain management [3].

While few automobile companies also have adopted mass customization very efficiently, e.g. Volkswagen claims to save \$1.7 billion annually through the effective operations of mass customization. Such implications show that the mass customization in the same industry may give different results to the different companies; this is due to variance among operational strategies [7]. Mass customization can be made more efficient with the integration with the customers, there is a study, which introduces the term economies of integration to explain the economic benefits of the customer involvement, and it explains integration of customers in three different stages [8]. This study gives a new idea that customer integration can be used to decrease cost instead of increasing.

Since analysis shows that mass customization has given different results depending upon different strategies, we need to develop a model that can investigate different companies quantitatively and evaluate that which strategy can give better results. Since there is enough qualitative work, we will only focus on the development of a model that could be tested quantitatively. This model can give insight for future studies and can be tested for different case studies.

III. THEORETICAL FRAMEWORK OF THE MODEL

To develop a framework, we need to investigate different issues within the supply chain and analyse their impact on the efficiency of supply chain under mass customized environment. For this purpose, firstly we will evaluate that how we can measure the supply chain performance or efficiency, when mass customization has been adopted, and then we will explore some of the major tools that can impact efficiency of supply chain under mass customization.

A. Efficiency of the Supply Chain

To develop a model, we will first develop a measure to evaluate how much efficiency is achieved with the adoption of mass customization. For this purpose, we will investigate a measure to show how mass customization has impacted financial strength of the specific company.

With the increase in the importance of supply chain management, it has become important to evaluate quantitatively. Moreover, if there is a specific measuring of the supply chain performance, it can lead to better understanding of its efficiency [9]. To measure the efficiency of the supply chain with respect to the mass customization, different indicators can be used and these indicators can be of three types, depending on the problem which we want to investigate. These three types can be categorised as output measures, flexibility measures and resource measure. Flexibility measure has limited scope, but resource and output measures are widely used. One of the most widely used measure is profit and it consider both output and resource measure. Moreover, profit considers both cost and sales, which means it can evaluate more aspects. Furthermore, using

profit as an indicator can also tell us about the financial aspects. Moreover, for taking mass customization into account, we will take profit with respect to mass customization adoption.

B. Important Problems in the Supply Chain

It is important to explore the literature to sort out the important factors and relation, which are of significant importance for the supply chain. Success of the supply chain depends upon two main criteria i.e. inventory control process/production planning and logistics/distribution [10], and both of these can be explained here.

1. Inventories Issues

An important tool for efficient supply chain management is optimization of the inventory stock. The main purpose of the inventory stock is to provide a buffer between uncertain supply and demand [11]. However, management of the inventory stock for mass customized products is always a complex task, as under this production method, customers are allowed to tailor their product from the large set of options, this leads to increase in the variety which causes risks in the inventory forecasting [2]. If the forecast is low and actual demand rises more than expected, or vice versa, then the problem of inventories can occur. JIT is one of the modern techniques that are used to overcome the problems of the inventory management. Nowadays, most of the automobile companies (operating mass customization) are focusing to adopt JIT systems to reduce cost. The application of JIT can succeed with the improvements in producer- buyer relation [12]. Moreover, it is important to consider that the information sharing between producer and supplier is much helpful when demand is not easily predictable: it is either the case of high product variety or the short-term [13].

Almost all the companies implementing mass customization are considering JIT, however the extent up to which JIT is implemented depends largely upon the company's relation with the suppliers. This plays a critical role in the companies' inventory management policy.

2. Distributional Issues

Another important issue as explored in literature is the problem of distributions [10]. Distribution must ensure minimization of the cost, complexity and time. Selecting a supplier is crucial decision for the firm, as it have to take into account many aspects. However, many of such aspects have trade off with other criteria; a low price can be offset by the poor delivery reliability. So supplier selection is a multi-objective decision. Distance is one of the important criteria, while selecting supplier, as distance impacts the logistics cost. However, in literature, there is very less work on these criteria. A nonlinear model was developed in one of the study to minimize the logistic costs [14]. It identified that the supplier-producer distance has stronger higher implications on the production costs. The distances in the supply chain have important implications as it increases the logistics costs, complexity and weaken supplier-producer relation. But there is not any empirical testing of this model, thus it is important

to incorporate distance in the model. However, it is also important to incorporate producer-customer distance along with the supplier-producer distance. To investigate the above-mentioned problems, it is important to develop the distance index which can measure the overall spread of the supply chain. The impact of this index on supply chain efficiency could be a critical indicator to measure supply chain efficiency.

IV. DATA INVESTIGATION AND MODEL INTERPRETATION

In this section, we will specify the variables that are investigated in last section and will discuss how and which data can be used to investigate them. Section will first explore each variable by specifying data, and then final mathematical form of the model will be deduced.

A. Relative Profit Measure

Considering profit, as a measure to investigate the efficiency of the supply chain, has given us a broader prospect. We will investigate the change in profit with respect to change in mass customization. Thus, we can see how distribution and inventory planning impact relative profit measure under mass customization adoption in our model.

$$\Delta Y/\Delta MC = \text{change in profit/change in mass customization} \quad (1)$$

For analysing profit, we can use the data from financial reports of the companies, and automobile companies provide data on EBIT, which can be best used to analyse this variable.

B. Mass Customization

Mass customization can be calculated by investigating the number of options available for customization. For example, in the case of an automobile company, the number of options available for trim, paint, packages, upholstery, wheel leads to the extent of customization possible. Higher the number of options available more will be the extent of the customization possible.

$$MC = x_1 * x_2 * x_3 * x_4 * x_5 \quad (2)$$

where, X1=No. of options for paint, X2=No of options for upholstery, X3=No of options for trim, X4=No of options for wheel, X5=No of individual options.

C. Inventories

One of the important variables that need to be analysed is inventory stock which can give us idea about the extent of JIT applied. Moreover, to have a clearer analysis we can take inventories as a proportion of the total production, and three types of inventory stocks can be used for analysis.

$$Irp = \text{Inventory of raw material/total production} \quad (3)$$

$$Ifp = \text{Inventory of finished products/ total production} \quad (4)$$

$$Iwp = \text{Inventory of work in progress/ total production} \quad (5)$$

Irp, Ifp and Iwp show inventories as a proportion of total production and this can give us an idea about what is the proportional inventories used by company. Furthermore, it can also tell us up to what extent JIT is applied.

D. Distributional Distance

This term Distribution distance, Dd is introduced to measure the proportional amount of logistics that would be used, i.e. it measures the spread and concentration of supply chain to different regions. This variable will be constructed to see how much transportation company has to undergo. This variable will be affected by two relations: first, if the distance (D) will increase, then the distribution distance (Dd) will increase,

$$Dd \propto D$$

Secondly, if the amount of the transported product (d) increases, then Dd will increase.

$$Dd \propto d$$

For example, if production is taking place in Germany and product is transported to America, then the spread Dd is less if only 1 % products are transported; however, if the amount of product to be transported increase, then this distributional distance Dd will increase. So, if the amount of product is kept constant then Dd of Europe will be lesser as compared to Dd for America (for the product produced in Germany). So, Dd will be positively affected by the distance and the amount of product to be transported to the country. In other words, we can say that Dd will actually measure the logistics used by the company.

So, Dd for any specific company is positively affected by the distance and amount of product to be transported to that location.

Proportional amount of product to be transported * distance to be transported

In our analysis, we can take Dd in two forms, Dd in sales (DdS) and Dd in production (DdP). DdS will be calculated for the distance that the raw material or parts have to travel to reach the production point while DdP will be calculated for the distance covered by the final products.

$$DdS = \text{Proportional amount of product * distance covered by the final product} \quad (6)$$

$$DdP = \text{Proportional amount of product * distance covered by the raw material/parts to reach production point} \quad (7)$$

E. Final Model

The above analysis gives details about the important determinants in the supply chain and this analysis can help to construct a model which can lead to conduct studies in future. The positive aspect of variables investigated from (1)-(7) is that all of these are quantitatively measurable. The analysis can help us to build a basic model interpreted in (8), which

shows that profit of the company is dependent upon several aspects of the supply chain. An econometric analysis for this equation can be done for the automotive industry through various case studies.

So after analysing all the aspects, we can interpret change in profit due to change in mass customization; as a function of supply chain inventory management, distribution, customer satisfaction. Combining the above mentioned criteria's in the formula gives us (8).

$$\frac{\Delta Y}{\Delta MC} = f(I_r, I_f, I_w, DDP, DDS) \quad (8)$$

where; ΔY is the change in Profit, ΔMC is the change in level/extent of customization, I_r is inventories of raw material, I_f is inventories of finished products, I_w is inventories of work in progress, DdP is distributional distances in production and DdS is distributional distance in sales.

In simple words, we can say that analysis of (8) can give us idea that how the parameters of supply chain are impacting the efficiency of company, under mass customization.

The equation derived above is the basis for the future studies. It can be investigated for different automotive industries and can explain how different parameters should be controlled under mass customization. Thus, this model can be used to investigate broader questions in automobile industry.

V. CONCLUSION AND FUTURE SUGGESTIONS

Mass customization is trending among many industries and it is considered to increase the customer value, however this system creates complexities in the supply chain. Many companies have failed in this phenomenon because of inefficient supply chain management. Moreover, if in any industry, few firms are getting benefits from mass customization while other faces losses then it shows that there is need to improve the strategies in the supply chain. There is lot of qualitative work, in this regard. However, literature lacks behind in quantitative analysis. Keeping this in view we developed a framework for model, this model can be applied for different companies and can be used for comparison purposes.

To develop our model, we first investigated how efficiency of supply chain can be measured when firm is adopting mass customization. We use profit as a measure to determine efficiency of odd supply chain. This provides vast benefits and it is a type of measure for which data are also available. Furthermore, to see how different tools of supply chain are affecting, we have divided tools of supply chain in several aspects. The two main important criteria's in the supply chain are inventory planning and distribution. Inventory management plays a vital role in the management of supply chain. Evaluation of inventory management gives idea about the policies related to the supplies and finished products. Moreover, the second important area of the supply chain (distribution) has been addressed via variable "Distribution distance" which can investigate weighted distribution in the distance. This variable will be positively affected by the

distance and the amount of the product to be transported. Distribution distance will be taken for sales and productions. Another important aspect to consider is how mass customization has impacted the profitability. For this purpose, it has also been incorporated in detail. To address how to measure customization, we used total options available as a measure for measuring customization.

We are then able to build a model which incorporated all these variables. Moreover, it should be considered that the supply chain efficiency was evaluated by profitability in the model, thus it gave us a broader insight for investigating the impact of extent of the mass customization on company's financial performance.

This paper delivers a model that can be explored quantitatively for the companies pursuing mass customization.

The model presented is very complete, as it shows that how different tools of supply chain are impacting efficiency when the company is adopting mass customization. It can explain which strategies should be pursued and which should be ignored. Future work, in the light of above study, can be carried out in these following areas:

- Quantitative analysis of model for different companies
- Investigation of the customization and the customer satisfaction relation
- Investigation of distributional distance in detail
- Analysis of impact of mass customization on the profits

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