Supply Chain Flexibility Metrics Evaluation

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Abstract The markets in which manufacturers and service firms compete are increasingly influenced by intense foreign competition, rapid technological change, and shorter product life cycles. In this new scenario, flexibility may be one of the most important capabilities needed for firms to achieve competitive advantage. The possible behaviors of the company to the problems it faces are called levers of flexibilities. In a supply chain, the flexibility of one entity is highly dependent on the flexibility of upstream entities. It is a natural area for metrics. A metric is a standard of measurement of performance and gives the basis on which to evaluate the performance of processes in the supply chain. Thus, the purpose of the study is to determine and evaluate the supply chain flexibility levers in order to calculate the benefit of preferring a flexibility lever to another one. The analytic network process (ANP) technique is used for prioritizing evaluated flexibility levers. We are handling the automotive sector for the study.

1 Introduction

Automobile manufacturers today compete in an increasingly global environment. An important part of the equation for competing in today's automotive industry is flexibility. Cadences are tightening to respond to market demands, but manufacturers need to be even more flexible than that. Inflexibility equals lost opportunities. Today's manufacturing line needs to be flexible and agile, which has come about through configurability, distributed control and plug-and-play capabilities. Obviously, the exibility is deployed more often in segments with higher proportion of exible competitors.

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M. G. Cojocaru et al. (eds.), *Interdisciplinary Topics in Applied Mathematics, Modeling and Computational Science,* Springer Proceedings in Mathematics & Statistics 117,
DOI 10.1007/978-3-319-12307-3_33

This study is focused on passenger cars and on segments which are most preferred by customers according to sales numbers. Only four segments will be investigated: A—Basic, B—Small, C—Lower Medium, D—Upper Medium. For a clear understanding, Ford Ka is an example to A class, Volkswagen Polo is an example to B class, Toyota Auris is an example to C class, and BMW 3 series is an example to D class cars.

In this chapter, customer expectations satisfaction via adapting automotive industry flexibility will be studied. Flexibility is defined as the capacity of responding against uncertainties created by various causes in the environment. Possible actions to ensure flexibility are called as levers of flexibility and their performance evaluation tools are called metrics of flexibility. First, automotive industry will be briefly presented via its three actors expectations; supplier, producer, and customer. Second, the concept of flexibility and its importance will be investigated. Third, the methodology including the analytic network process (ANP) technique for prioritizing evaluated flexibility levers by a group of experts will be presented. Finally, the outcome will be discussed according to the results, the metrics to evaluate the system performance will be defined, and possible investments will be proposed.

2 Automotive Sector's Expectations and Related Metrics

Every supply chain has three aspects which are customer, producer, and supplier. In automotive sector, all these three aspects have distinctive and also some common expectations such as cost-minimizing, efficiency, technological advance, sustainability, environmentally friendly production, endurance, reliability, etc.

Customer expectations are considered as customization, high responsiveness, delivery reliability, right quality, and after sales services. Manufacturing firms aim to achieve the highest levels of performance along areas such as quality, flexibility, delivery, and costs [1]. In this study main producer and supplier expectations are considered as process optimization, supply reliability, loyal customer, minimum consumption of resources, and effective risk management.

Metrics are tools for measuring performance. Supply chain operation reference (SCOR) model provides a measure of supply chain performance by dividing it into four parts: plan, source, make, and deliver [2]. According to the literature survey and experts feedback, suitable metrics for ASCI are: forecast accuracy, in-stock availability, perfect order fulfillment, materials quality, weekly/monthly plan keeping, production lead time track, days of inventory track, capacity utilization, output/input ratio, labor performance, and vendor lead time track [3].

3 Flexibility Management in Automotive Sector

Investment channels of the automotive sector are broad and multinational. Also, automotive sector has a high ratio of supply chain cost to revenue. Various drivers should cooperate to ensure efficiency in a supply chain. A key dimension of supply chain performance is flexibility, i.e., the ability to be adapted to internal and external capabilities or a reaction to environmental uncertainty [4].

In literature, it is easy to find various previous studies on flexibility in automotive sector. Barad and Sapir in 2003 [5] studied logistics flexibility. They presented flexibility types and quantitatively investigated one of the dimensions. Sanchez and Perez in 2005 [6] studied supply chain flexibility and firm performance. They clearly defined supply chain flexibility and its subdivisions. Erol Genevois and Gurbuz in 2009 [7] studied flexibility in automotive sector and utilized fuzzy hierarchical process method to determine flexibility levers which can best meet the customer satisfaction.

To prevent confrontations between flexibility levers, we grouped levers under five main parts. These are a supply chain's vital components: mix, volume, delivery, quick-design change, and adaptation levers.

We define mix flexibility as actions against uncertainty as to which products customers will accept leads to the strategic objective of product diversity. Mix flexibility spans modification flexibility (MF) which allows a manufacturing process to implement minor design changes in a given product, decision-making flexibility (DMF) which is an intangible lever ensured by intelligent management of the system. According to us and experts, DMF is the core of the effective management, planning/scheduling flexibility (P/SF), and sequencing flexibility (SF).

Volume flexibility permits increases or decreases in the aggregate production level. It spans labor flexibility (LF), material flexibility which is the ability of the manufacturing function to handle unexpected variations in inputs, DMF, P/SF, SF, and routing flexibility (RF) which is the capability of processing a part through varying routes, or in other words by using alternative machines [8].

Delivery flexibility permits to construct systems that ease to meet true demand in true place and at true time. Delivery flexibility spans transport/shipping flexibility (T/SF), access flexibility (AF) which is demanded for responding customer needs agile as possible, DMF, P/SF, and SF.

Quick design change flexibility is required to ensure company's continuous competitiveness in the market. Banking flexibility is also possible [9]. Quick design change flexibility spans launch flexibility (LchF), design development flexibility (D/DF), changeover flexibility (CF), DMF, and job design flexibility (JDF).

The capability of a manufacturing system that enables it to adapt rapidly and inexpensively to changes in its internal and external operating environment is called adaptation flexibility [10]. Adaptation flexibility spans process/technology flexibility (P/TF), machine/equipment flexibility (M/EF), material flexibility (MatF), employee's willingness to change flexibility (EWF), managerial perception change flexibility (MPCF), LF, layout flexibility (LayF), expansion flexibility (EF), financial resources flexibility (FRF), and organizational structure flexibility (OSF).

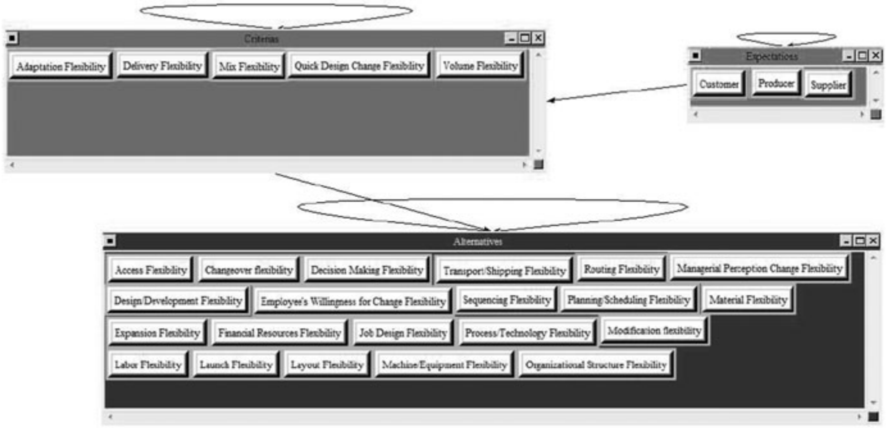

Fig. 1 1 The analytic network process (ANP) network scheme of the decision problem

4 Methodology

ANP is a multi criteria decision making tool considered to be an extension of analytic hierarchy process (AHP) [11]. Whereas AHP models a decision making framework using a unidirectional hierarchical relationship among decision levels, ANP allows for more complex interrelationships among the decision levels and components, like a network [12].

Step 1: The first step is defining our decision problem and then model to be evaluated is constructed. The main objective of the problem is to evaluate the satisfaction degree of automotive sector actors' expectations via attributed flexibility levers. This model has three clusters and their nodes are: expectations (supplier expectations, producer expectations, and customer expectations), flexibility types (mix flexibility, volume flexibility, quick design change flexibility, delivery flexibility, adaptation flexibility) and flexibility levers (MF, DMF, P/SF, SF, LF, MatF, RF, T/SF, AF, LchF, D/DF, CF, JDF, P/TF, M/EF, EWF, MPCF, LayF, EF, FRF, OSF).

Step 2: Given this model, the relevant criteria and alternatives are structured in the form of a simple network by the decision makers. Interdependencies are represented by the arrows among the clusters (outer dependence) and a looped arc within the same cluster (inner dependence). The direction of the arc signifies dependence. Arcs emanate from a controlling attribute to other attributes that may influence it. All the relations among criteria and sub-criteria, and the network of the model can be seen in Fig. 1.

Table 1 Final results

Flexibility levers	Normal
Decision making flexibility	0.1604
Planning/scheduling flexibility	0.1526
Material flexibility	0.1084
Financial resources flexibility	0.0983
Design/development flexibility	0.0926
Transport/shipping flexibility	0.0762
Changeover flexibility	0.0723
Process/technology flexibility	0.0647
Sequencing flexibility	0.0405
Expansion flexibility	0,0895
Others	0,0762

Step 3: In this step of the ANP methodology, comparison sets between clusters and elements are set. To build the comparison matrices, clusters and their elements are compared with respect to a control criterion. To reflect interdependencies in this simple network model, pairwise comparisons among all the clusters/elements/alternatives are performed and these relationships are evaluated. As for the evaluation of the alternatives and criteria, the fundamental comparison scale (1 to 9) is used.

The ANP method is able to handle interdependencies among elements through the calculation of composite weights as developed in a supermatrix. After completing all the pairwise comparisons, the derived priorities of the unweighted supermatrix are obtained for each control criterion. Then, using the cluster weights matrix, the priorities of all factors in each cluster are weighted. The weighted supermatrix, each of whose columns sums to one, is known as a column stochastic matrix. The weighted supermatrix is then raised to limit powers to obtain the final priorities of all elements in the limit matrix. Then the results are synthesized through addition for the entire control criterion. These synthesized results of the priorities are normalized to select the highest priority alternative. The supermatrix and its powers are the fundamental tools needed to lay out the functions of the ANP [13].

Step 4–5–6: The experts' opinions are used to fill in the pairwise comparison matrices for all clusters and then the supermatrix is built according to these pairwise comparison matrices by using the Super Decisions software. Pairwise comparisons tables are completed in consensus by five experts who work in automotive industry.

Step 7: Given the comparison matrices, the Super Decisions software computed the unweighted, weighted, and limit supermatrices. The synthesized results and the priorities are provided.

Step 8: Finally, the first ranking flexibility levers are synthesized and are shown in Table 1. DMF, P/SF, and Mat F have the highest rankings in our final result.

5 Conclusion

In this study, a decision-making model, based on ANP is developed. The needs for DMF, P/SF, and MatF are highly important in the automotive sector. DMF has 16% importance in all levers because its the key factor for quick response to uncertainties and satisfies expectations. It must be ensured with metrics such as forecast accuracy, inventory turnover, and planning cycle time analysis. P/SF has 15% importance. This lever is very important for mix and delivery flexibilities which are essential for satisfying customer and producer expectations. Weekly/daily plan keeping analysis, production lead time track, capacity on time shipment ratio, and on time delivery ratio metrics can be utilized for measuring P/SF. An average car has 12,000 different parts. Thats why MatF has a crucial role in a flexible supply chain. Material quality, input/output ratio are possible metrics to measure this flexibility. For the future works, the study will be developed with a metrics quantification dimension.

Acknowledgement This research has been financially supported by Galatasaray University Research Fund. (Research no: 12.402.008)

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