Finding the Best Flexibility Strategies by Using an Integrated Method of FAHP and QFD

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Abstract*—In this study, Turkish automotive sector needs for flexibility will be determined, and the relationships between flexibility levers and flexibility performance criteria will be evaluated with respect to the sectoral needs. The choice of the appropriate lever combinations will be made for the sector by using the results of this evaluation. The flexibility strategies will be ranked by using a fuzzy extended AHP approach. At the second phase of this study, the QFD tool will be used to find the best flexibility lever portfolio related to automotive sector strategies.*

Keywords— Flexibility Management, Fuzzy AHP, QFD, Turkish Automotive Sector.

1 Introduction

The markets in which manufacturers and service firms compete are increasingly influenced by intense foreign competition, rapid technological change, shorter product life-cycles and customers increasingly unwilling to settle for mass-produced items or services with limited value. The "new breed of customer" [1], who demands greater responsiveness to a dynamic set of requirements, and a new competitive environment, which exposes local companies to competition with the companies around the globe, form a new scenario that has challenged firms in most industries ([2]; [3]; [4]). In this new scenario, flexibility may be one of the most important capabilities needed for firms to achieve competitive advantage ([5]; [6]; [7]).

We defined flexibility as the capacity of adaptation under the double constraint of uncertainty and the urgency. This uncertainty can come from the providers (rupture, problems of transport), from the customers (variation of the request) or from the company itself (breakdowns of the equipment, problems of provisioning). The possible behaviors of the company face to these problems are called levers of flexibilities. After the mass production era of Ford and lean management era of Toyota, these days are witnessing the era of flexibility. Modern organization should keep as much as possible flexibility capability to be used in case of an incident.

This paper will briefly summarize the flexibility concept and flexibility levers as well as the existing situation of Turkish automotive industry by the flexibility point of view. It will introduce a model, based on Analytic Hierarchy Process (AHP) and Quality Function Deployment (QFD) methodology, which determine the best flexibility levers' portfolio to deal with consumers needs for flexibility in term of delivering a 5R product (right place-RP, right time-RT, right quantity-RQ, right product-RPr, right price-RPc). The Turkish automotive industry including the parts and components producers is considered in this study as a case industry. Automotive industry is considered as a complete industry covering all entities of the value chain.

In the second section of the paper, the flexibility management literature will be reviewed and Turkish automotive sector needs for flexibility will be determined. In the third section, the fuzzy extended AHP model will be introduced and the flexibility strategies will be ranked by using this approach. At the fourth phase of this study, the QFD tool will be used to find the best flexibility lever portfolio related to automotive sector strategies. The relationships between flexibility levers and flexibility performance criteria will be evaluated with respect to the sectoral needs. The choice of the appropriate lever combinations will be made for the sector by using the results of this evaluation. The study will be concluded with the presentation of the selected portfolio.

2 Flexibility Management

2.1 Literature Review

Flexibility becomes a strategic resource from the late 70s due to the uncertainty in the environment faced by most of the enterprises. This uncertainty is due to several factors, such as diversification in product range, reduced product life cycle, fragmentation and globalization of markets, sophistication of customers etc. In a broad view flexibility is defined as the capability of adaptation to change. The flexibility is a total capacity, which will be activated as a function of events, which are not controlled by the company. It has a passive vision and defensive usage of the capability. But flexibility may create some offensive strategies as well. By offering more diverse products than the competitors, by renewing the products more frequently or by customizing associated services, flexible pioneers can set the rules of game of the industry by creating uncertainty for their competitors. Therefore flexibility is defined as a strategic asset for the companies not only for adapting to the changes in the environment but also to change the environment in favor of itself.

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Some authors distinguish between internal and external flexibilities. For instance, Swamidass [8] distinguishes machine-level flexibility from plant-level flexibility. The former being “predominantly technology based” and the latter being derived from a combination of technology, infrastructure, design and engineering capabilities, and the competitive goals and objectives of a firm. Upton [9] defines internal flexibility as the operations strategy and the set of capabilities a firm nurtures to respond to its environment, and external flexibility as capabilities possessed by the firm and used to accommodate sources of variability to which the firm must respond and which are seen as flexible by the market. This external dimension fits the two major strategies proposed by Hyun and Ahn [10] for using flexibility: reactive and proactive. In the same vein, Gerwin [11] also suggests two major strategies for using flexibility: adaptive and redefinition. The adaptive strategy refers to the defensive or reactive use of flexible competencies to accommodate unknown uncertainty, while the redefinition strategy refers to the proactive use of flexible competencies to raise customer expectations, increase uncertainty for rivals and gain competitive edge.

The reasons companies are motivated to be flexible include the need to make design changes quickly, when competitors introduce new models and customers start switching supply sources; to focus on volume flexibility, when large customers reduce inventories and their demand rates become volatile; more flexible product mixes, when importers or domestic competitors start offering multiple quality and price levels; to respond quickly and supply the new products/services, when the customer tastes change quickly.

Especially, four types of flexibilities are important in point of view of the consumer: the volume (VF), the product mix (PMF), the new product (NPF) and the design flexibilities (DF). Volume flexibility can be defined as the ability to operate profitably at different production volumes [9]. Product mix flexibility is adopted to deal with uncertainty about the products that will be demanded by customers at a particular period ([12]; [13]). It is characterized by the ability to produce several products at one manufacturing facility without incurring a major cost penalty. New product flexibility is the ability of a system to add or substitute new products to the product mix. Finally, the design flexibility is the ability to change the design of a product very economically and quickly

The need for flexibility can be expressed as a satisfaction of the demand with delivery on time (I), at the right place (II), in required quantity (III) with the right product (IV) and the right price (V).

It may be noted that each of the above external elements are the causes beyond the control of any company. Further, none of these needs can be satisfied by the mass production strategy. Consequently, the classical methods as the affair with large production runs and economies of scale are a thing of the past, and are being replaced by a new concept - flexibility management.

To satisfy the need for various types of flexibility, Aggorwal [14] define three groups of levers or mechanisms. The first group is referred to as levers for internal flexibility. Each of these levers remains under the control of management at all times. The salient levers in this group are Planning/Scheduling Flexibility (1), Sequencing Flexibility (2), Routing Flexibility (3), Labor Flexibility (4), Machine/Equipment Flexibility (5), Design/Development Flexibility (6), Process/Technology Flexibility (7), Raw Materials Flexibility (8), Transport/Shipping Flexibility (9), Layout Flexibility (10), Expansion Flexibility (11), Financial Resources Flexibility (12).

The second group consists of levers for soft flexibilities. Each of these levers can enhance internal flexibility. In contrast to hard levers, they are never completely under management's control as each requires heightened participation and support of specialists and other employee groups. The levers constituting this group and their respective code numbers are Organizational Structure Flexibility (13), Decision Making Flexibility (14), Job Design Flexibility (15), Employee's Willingness for Change Flexibility (16), Managerial Perception Change Flexibility (17). These flexibility levers cannot be measured on a hard (quantitative) scale, as was the case with the levers of the first group; therefore they are designated soft levers flexibilities.

The third group of levers involves managerial manipulation of intangibles. Each of these levers can enhance one or more of the flexibilities either externally or internally. Again, their effectiveness cannot be measured on a hard scale, so they are called intangible levers (flexibilities). These are Reputation Building Flexibility (18), Flexibility in Enhancing Knowledge and Experience Base (19), Flexibility in Identifying Undiscovered and Unused Talents of Workforce (20), Flexibility in Development of Standing Agreements with Suppliers and Customers (21).

2.2 Changing Landscape in Turkish Automotive Industry

The present-day automotive industry of Turkey was first developed within the broader context of import substitution in the 1960s. High tariffs, quantitative restrictions and local content regulations were used to create a local vehicle industry. Access to the local market could only be achieved through local production. In Turkey, the government succeeded in attracting a number of assemblers (most notably Ford, Fiat and Renault), and by the early 1970s cars with a high degree of local content were being produced. While the assemblers were joint ventures between foreign companies and local groups by the late 1970s, a thriving components industry was created, much of which was locally owned. The industry continues to grow in the 1970s and 1980s mainly by protectionist policies. The rapid expansion of the automotive industry arose from a coming together of two distinct interests. However, the developing impact of the automotive industry in the 1990s is likely to be very different from that seen in the 1960s and 1970s. This is because the industry has globalized and changed its governance structures

Protectionist policies continued throughout the early 1990s. In 1995, by signing the Customs Union agreement with European Union, Turkey abolished high taxes over European origin vehicles. With customs union Turkish automotive industry changed its nature and it results Turkish

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car manufacturers to produce competitive products both in price and in quality. Another impact of the customs union over the industry is the shift of focus from local market to global markets. As a direct result of globalization, local producers have begun to manufacture vehicles for global markets. Due to global strategies of multinational vehicle producers, manufacturing facilities in Turkey are dedicated to manufacture specific models. This shift in the assemblers had an immediate impact over the suppliers that are faced to the obligations of the globalized environment. It become important in this uncertain environment to be armed with performer flexibility levers in order to deal with the rapid changes in the sector.

3 Proposed Methodology

3.1 Ranking Flexibility Strategies with Fuzzy Extended AHP Approach

In this paper the fuzzy extension of one of the most widely used MCDM methods namely FAHP is used to find the relative importance of the problems alternatives and criteria. The choice of the method used in this stage is arbitrary but the wide range and the ease of use for FAHP was determinant for us to choose it. And with fuzzy logic, we wanted to handle as precisely as possible the unprecised qualitative data collected from the experts.

The FAHP approach is introduced, with the use of Triangular Fuzzy Numbers-TFNs for pairwise comparison scale of FAHP according to the method of Chang's [15] fuzzy extent analysis and the correct normalization formula given later by Wang et al. [16].

In the conventional AHP, the pairwise comparisons for each level with respect to the goal are conducted using a nine-point scale proposed by Saaty [17]. According to Zadeh [18], it is very difficult for conventional quantification to define the complex situations, so the notion of a linguistic variable, whose values are words or sentences, is necessary. To assess the relative importance of the criteria and to evaluate the alternatives with respect to the problems criteria an assumed weighting set has been developed. The decision makers can use this linguistic rating set. The triangular fuzzy conversion scale of the linguistic values in the weighting set is shown in Table 1.

Table1. The triangular fuzzy conversion scale

Linguistic Values	*Triangular Fuzzy Numbers*
Very Low (VL) Very Poor (VP)	$\left(\frac{1}{5},\frac{1}{5},\frac{1}{3}\right)$
Low (L) Poor (P)	$\left(\frac{1}{5},\frac{1}{3},1\right)$
Exactly Equal	$(1,1,1)$
Medium (M) Fair (F)	$\left(\frac{1}{2},\frac{3}{2},\frac{5}{2}\right)$
High (H) Good (G)	$(1,3,5)$
Very High (VH) Very Good (VG)	$(3,5,5)$

Assume that $X = \{x_1, x_2, ..., x_n\}$ is an object set, and $U = \{u_1, u_2, ..., u_m\}$ is a goal set. According to the method of Chang's [24] fuzzy extent analysis, each object is taken and extent analysis is performed for each goal respectively. Therefore, m extent analysis values for each object can be obtained, with the following representation:

$$M_{g_i}^1, M_{g_i}^2, ..., M_{g_i}^m \text{ for } i = 1,2,...,n \quad (1)$$

Note that all the $M_{g_i}^j$, $j = 1,2,\ldots,m$, are TFNs representing the performance of the object x_i with regard to each goal u_j. The steps of Chang's [19] extent analysis can be given as in the following:

- First, by fuzzy arithmetic operations, take the sum of each row of the fuzzy comparison matrix.

$$RS_i = \sum_{j=1}^{n} \tilde{a}_{ij} = \left(\sum_{j=1}^{n} l_{ij},\ \sum_{j=1}^{n} m_{ij},\ \sum_{j=1}^{n} u_{ij}\right), \quad i = 1,\ldots,n \quad (2)$$

- Using fuzzy synthetic extent analysis, the value of fuzzy synthetic extent with respect to the i^{th} object x_i, $i = 1,2,\ldots,n$ that represents the overall performance of the object across all goals can be determined by the following normalization formula given by Wang et al. [25]:

$$\tilde{S}_i = \frac{RS_i}{\sum_{j=1}^{n} RS_j} = \left(\frac{\sum_{j=1}^{n} l_{ij}}{\sum_{j=1}^{n} l_{ij} + \sum_{\substack{k=1\\k\neq i}}^{n}\sum_{j=1}^{n} u_{kj}},\ \frac{\sum_{j=1}^{n} m_{ij}}{\sum_{k=1}^{n}\sum_{j=1}^{n} m_{kj}},\ \frac{\sum_{j=1}^{n} u_{ij}}{\sum_{j=1}^{n} u_{ij} + \sum_{\substack{k=1\\k\neq i}}^{n}\sum_{j=1}^{n} l_{kj}} \right), \quad i = 1,\ldots,n \quad (3)$$

- The degree of possibility of $M_1 \geq M_2$ is defined as :

$$V(M_1 \geq M_2) = \sup_{x \geq y}\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right] \quad (4)$$

- Compute the degree of possibility of $\tilde{S}_i \geq \tilde{S}_j$ by the following equation where $\tilde{S}_i = (l_i, m_i, u_i)$ and $\tilde{S}_j = (l_j, m_j, u_j)$:

$$V(\tilde{S}_i \geq \tilde{S}_j) = \begin{cases} 1, & if \quad m_i \geq m_j, \\ \dfrac{u_i - l_j}{(u_i - m_i) + (m_j - l_j)}, & if \quad l_j \leq u_i, \quad i,j = 1,\ldots,n; i \neq j \\ 0, & otherwise, \end{cases} \quad (5)$$

- To compare $\tilde{S}_i = (l_i, m_i, u_i)$ and $\tilde{S}_j = (l_j, m_j, u_j)$, we need both the values of $V(\tilde{S}_i \geq \tilde{S}_j)$ and $V(\tilde{S}_j \geq \tilde{S}_i)$. The degree of possibility for a convex fuzzy number $\tilde{S}$ to be greater than k convex fuzzy numbers $\tilde{S}_i$, i=1,…,k can be defined by:

$$V(M \geq M_1,\ldots,M_k) = V[(M \geq M_1) \wedge \ldots \wedge (M \geq M_k)] = \min V(M \geq M_i)$$
for $i = 1,2,...,k$

- Assume that for the alternative A_i,

$$d'(A_i) = \min V(S_i \geq S_j), \quad \text{for } j = 1,2,...,n;\ j \neq i \quad (6)$$

- Then the weight vector is given by,

$$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T \quad (7)$$

- Via normalization, the normalized weight vectors are,

$$W = (d(A_1), d(A_2), ..., d(A_n))^T \quad (8)$$

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To illustrate our model, a decision-making group is formed that consists of the 5 experts from the Turkish automotive industry. After a detailed discussion on every criterion, four main criteria of flexibility types have been identified for the hierarchical structure. The AHP hierarchy scheme is constructed and shown in Figure 1.

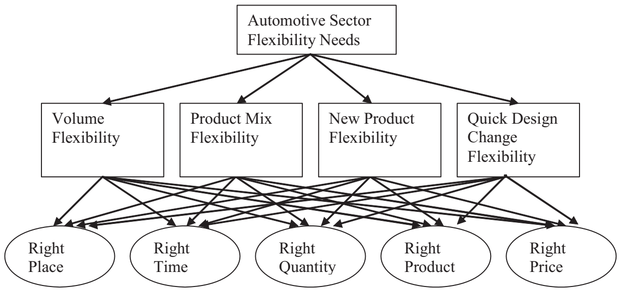

Figure 1. Hierarchical Structure of Flexibility Needs

The aim of the evaluation is to rank the importance of consumers needs for flexibility in the sector. The normalized weight vectors of alternatives with respect to criteria are calculated and shown in Table 2.

Table 2. The normalized weight vectors of the alternatives

	VOLUME	MİX	NEW PRODUCT	QUICK DESIGN CHANGE	
	0,752	0,1	0,045	0,103	
RP	0,108	0,129	0,131	0,083	0,109
RT	0,148	0,144	0,154	0,203	0,154
RQ	0,221	0,094	0,096	0,144	0,195
RPr	0,276	0,228	0,489	0,252	0,278
RPc	0,247	0,404	0,131	0,318	0,265

The need for volume flexibility is highly important in the automotive sector. The consumer demand in this sector is significantly sensible to the global economic indicators. On the other hand, the right price is very important when we are faced to a mix product flexibility problem. In the same way, placing the right product in the market is extremely important when we have to satisfy a new product flexibility need. Finally, the 5R strategies are ranked for their relative importance as follows: $RPr \succ RPc \succ RQ \succ RT \succ RP$.

3.2 Selection of the best flexibility lever portfolio using QFD

Quality function deployment (QFD) is ‘‘an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production (i.e., marketing strategies, planning, product design and engineering, prototype evaluation, production process development, production, sales)’’ [19]. QFD belongs to the sphere of quality management methods, offering us a linear and structured guideline for converting the customer’s needs into specifications for, and characteristics of new products and services. The method involves developing four matrixes, or ‘houses’, that we enter by degrees as a project for a given product or production process is developed on increasingly specific levels [20]. In the present article, our attention focuses on the Planning Matrix, or (HOQ) [21] (Fig. 2).

The HOQ provides the specifications for product design (or engineering characteristics) in terms of their relative importance and of target values that have to be reached in design and production. In a sense, the HOQ is the hub of the whole QFD method: its construction enables us to proceed from the customer’s requirements to the design specifications ([22]; [23]). This paper describes the HOQ and its process following the approaches suggested by Brown [24], and Griffin and Hauser [25]. Step 1: Identify the WHATs. The expected benefits in a product or service in the customer’s own words are customer needs and are usually called customer attributes (CA) or ‘‘WHATs’’, area (A) in Fig. 2. In assigning priorities to WHATs, it is necessary to balance efforts in order to accomplish those needs that add value to the customer. The priorities are usually indicated in the area designated as (B) in Fig. 2. Step 2: Determination of HOWs. Engineering characteristics are specified as the ‘‘HOWs’’ of the HOQ and also called measurable requirements. HOWs are identified by a multidisciplinary team [26] and positioned on the area marked as (C) on the matrix diagram, Fig. 2. Step 3: Preparation of the relationship matrix (D). A team judges which WHATs impact which HOWs and to what degree. Step 4: Elaboration of the correlation matrix. The physical relationships among the technical requirements are specified on an array known as ‘‘the roof matrix’’ and identified as (E) in Fig. 2. Step 5: Action plan. The weights of the HOWs, identified as area (F), are placed at the base of the quality matrix. These weights are one of the main outputs of the HOQ, and are determined by

$$\text{Weight (HOW)}_i = V(\text{HOW})_{i1} * \text{imp}(\text{WHAT}_1) + \dots + V(\text{HOW})_{in} * \text{imp}(\text{WHAT}_n)$$

where $V(\text{HOW})_{in}$ is the correlation value of HOW_i with WHAT_n, and imp (WHAT_n) represents the importance or priority of WHAT_n.

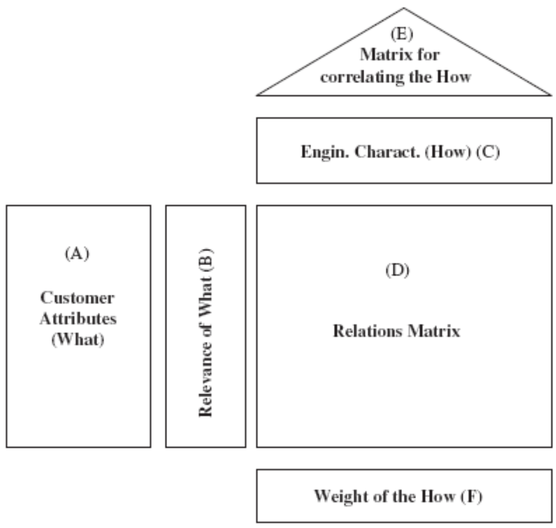

Figure 2. House of quality.

Various quantitative methods have been suggested to use in QFD to improve its reliability and objectiveness, noticeably the methods of management science/operational research (MS/OR), marketing research, and fuzzy logic.

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				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
			Column Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
			Max Relationship Value in Column	3	3	3	9	3	9	9	3	9	3	9	9	3	3	3	3	3	3	3	3	9
			Requirement Weight	214,47	93,371	98,853	471,84	183,76	276,98	388,36	109,98	312,18	157,28	258,78	296,75	194,62	194,62	155,67	102,97	109,71	155,67	247,58	162,94	467
			Relative Weight	4,61	2,01	2,12	10,14	3,95	5,95	8,35	2,36	6,71	3,38	5,56	6,38	4,18	4,18	3,35	2,21	2,36	3,35	5,32	3,50	10,04
			Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	4	5	7	6	5	7	9	6	5	8	8	6	6	6	7	5	5	7	6	4	6
			Minimize (▼), Maximize (▲), or Target (x)	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
			Target or Limit Value																					
Row Number	Max Relationship Value in Row	Relative Weight	Flexibility Levers / Flexibility Requirements	Planning/Scheduling Flexibility	Sequencing Flexibility	Routing Flexibility	Labor Flexibility	Machine/Equipment Flexibility	Design/Development Flexibility	Process/Technology Flexibility	Raw Materials Flexibility	Transport/Shipping Flexibility	Layout Flexibility	Expansion Flexibility	Financial Resources Flexibility	Organizational Structure Flexibility	Decision Making Flexibility	Job Design Flexibility	Employee's Willingness for Change Flexibility	Managerial Perception Change Flexibility	Reputation Building Flexibility	Flexibility in Enhancing Knowledge and Experience Base	Flexibility in Identifying Undiscovered and Unused Talents of Workforce	Standing Agreements with Suppliers and Customers
1	9	10,86	Right Place									9				1	1	1		1	1	1		3
2	3	15,35	Right Time	3	3	1	3	1				3	1			1	1	1		1	1	1		3
3	9	19,48	Right Quantity	3	1		9	3		3		3	3	9	3	3	3	1	1		1	3		3
4	9	27,83	Right Product	3	1	3	9	3	9	9	3	3	3	3		3	3	3	3	3	3	3	3	9
5	9	26,48	Right Price	1				1	1	3	1	1			9	1	1	1			1	3	3	3

Figure 3. The HOQ applied to the flexibility levers portfolio choice

Works applying MS/OR methods to QFD include analytic hierarchy process (AHP) to prioritize customer needs (whats) ([27]; [28]; [29]), AHP and benchmarking integrated to rate ''whats'' [30], AHP and QFD for combining customers' requirements and preferences [31], AHP and two multi-attribute decision-making methods for rating ''whats'' [32], AHP, multiattribute utility theory, and linear programming methods for rating ''whats'' [33], value functions to capture ''whats'' [34], AHP to study the ranking sensitivity of ''whats'' in QFD [35].

In this paper, we are using the F-extended AHP method which is described in the previous section for ranking the WHAT column of the HOQ (fig. 3). These are the flexibility levers in the HOW column. The experts have judged which flexibility levers impact which flexibility needs and to what degree. The physical relationships among the technical requirements are also specified but not given here. Finally, the table 3 indicates the importance weights of the flexibility levers.

4 Conclusions

In this paper, a decision making model, based on Analytic Hierarchy Process (AHP) and Quality Function Deployment (QFD) methodology, which determine the best flexibility levers' portfolio to deal with consumers needs for flexibility in term of delivering a 5R product is developed. Thus, the need for flexibility is calculated with the F-extended AHP method. The experts have judged which flexibility levers impact which flexibility needs and to what degree.

The need for volume flexibility is highly important in the automotive sector. On the other hand, the right price is very important when we are faced to a mix product flexibility problem. In the same way, placing the right product in the market is extremely important when we have to satisfy a new product flexibility need.

Facing continuous change in the automotive industry, using the flexible human resources factors and being able to develop the flexible agreements with suppliers and customers are very important. On the other hand, an automotive firm must have a flexible technology to adapt any change and be highly flexible in his transport and shipping design.

For the future works, the study will develop a Fuzzy-QFD for better represent the vagueness of the experts' opinions on the flexibility levers. In a next time, the three phases of QFD will be included for a global design strategy.

Table 3. The importance weight of the flexibility levers

Row Number	Flexibility Levers	Relative Weight (Relative Importance)
4	Labor Flexibility	10,14%
21	Flexibility in Development of Standing Agreements with Suppliers and Customers	10,04%
7	Process/Technology Flexibility	8,35%
9	Transport/Shipping Flexibility	6,71%
12	Financial Resources Flexibility	6,38%
6	Design/Development Flexibility	5,95%
11	Expansion Flexibility	5,56%
19	Flexibility in Enhancing Knowledge and Experience Base	5,32%
1	Planning/Scheduling Flexibility	4,61%
13	Organizational Structure Flexibility	4,18%
14	Decision Making Flexibility	4,18%
5	Machine/Equipment Flexibility	3,95%
20	Flexibility in Identifying Undiscovered and Unused Talents of Workforce	3,50%
10	Layout Flexibility	3,38%
15	Job Design Flexibility	3,35%
18	Reputation Building Flexibility	3,35%
8	Raw Materials Flexibility	2,36%
17	Managerial Perception Change Flexibility	2,36%
16	Employee's Willingness for Change Flexibility	2,21%
3	Routing Flexibility	2,12%
2	Sequencing Flexibility	2,01%

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References

[1] Handfield, R.B. and Nichols, E.L. *Supply Chain Redesign: Transforming Supply Chains into Integrated Value Systems*, Prentice-Hall, Upper Saddle River, NJ. 2002.

[2] Mehta, S.N., Cisco fractures its own fairy tale, *Fortune*, May, p. 104, 2001.

[3] Monckza, R.M. and Morgan, J., Competitive supply strategies for the 21st century, *Purchasing*, 128(1): 48-59, 2000.

[4] Pagell, M., Understanding the factors that enable and inhibit the integration of operations, purchasing and logistics, *Journal of Operations Management*, 22(5): 459-87, 2004.

[5] Holweg, M., The three dimensions of responsiveness, *International Journal of Operations & Production Management*, 25(7/8): 603-22, 2005.

[6] Storey, J., Emberson, C. and Reade, D., The barriers to customer responsive supply chain management, *International Journal of Operations & Production Management*, 25(3): 242-60, 2005.

[7] Reichhart, A. and Holweg, M., Creating the customer-responsive supply chain: a reconciliation of concepts, *International Journal of Production Planning & Control*, 27(11): 1144-72, 2007.

[8] Swamidass, P., Manufacturing flexibility: operations management association, *Monograph no. 2, National Association of Manufacturers*, Washington, DC., 1988.

[9] Upton, D.M., The management of manufacturing flexibility, *California Management Review*, 36(2): 72-89, 1994.

[10] Hyun, J. and Ahn, B.H., A unifying framework for manufacturing flexibility, *Manufacturing Review*, 5(4): 251-60, 1992.

[11] Gerwin, D., Manufacturing flexibility: a strategic perspective, *Management Science*, 39(4): 395-410, 1993.

[12] Gerwin D., Manufacturing flexibility: a strategic perspective, *Management Science,* 39(4):395–410, 1993.

[13] Bengtsson J, Olhager J., The impact of the product mix on the value of flexibility, *Omega*, 30:265–73, 2002.

[14] Aggorval, S., Flexibility Management: the Ultimate Strategy, *Industrial Management,* Jan.-Fev., 1997.

[15] Chang, D. Y., Applications of the Extent Analysis Method on Fuzzy AHP, *European Journal of Operational Research,* 95: 649–655, 1996.

[16] Wang, Y.-M., Luo, Y., Hua, Z., On the Extent Analysis Method for Fuzzy AHP and its Applications*, European Journal of Operational Research,* 186: 735–747, 2008.

[17] Saaty, T. L., *The Analytic Hierarchy Process*, Mc. Graw-Hill, New York, 1980.

[18] Zadeh, L. A., Fuzzy sets, *Information and Control*, 8: 338-353, 1965.

[19] Sullivan, L.P., Quality function deployment, *Quality Progress*, 19(6): 39–50, 1986.

[20] Akao, Y., *Quality Function Deployment: Integrating Customer Requirements into Product Design*, Productivity Press 1990.

[21] Hauser, J.R., Clausing, D. The house of quality, *Harvard Business Review*, 63–73, 1988.

[22] Schmidt, R. The implementation of simultaneous engineering in the stage of product concept development: A process orientated improvement of quality function deployment, *European Journal of Operational Research* 100(2): 293–314, 1997.

[23] Fariborz, Y.P., Rafael, A.C., Quality function deployment for the good of soccer, *European Journal of Operational Research*, 137: 642–656, 2002.

[24] Brown, P.G., QFD: echoing the voice of the customer, *AT&T Technical Journal*, 18–32, 1991.

[25] Griffin A., Hauser, J., The voice of the customer, Technical report, Working paper 92-106, *Marketing Science Institute*, Cambridge, MA. 1992.

[26] Hauser, J.R., How Puritan7Bennett used the house of quality, *Sloan Management Review*, 34(3): 61–70, 1993.

[27] Armacost, R.T., Componation, P.J., Mullens, M.A. and Swart, W.W., An AHP framework for prioritizing custom requirements in QFD: an industrialized housing application, *IIE Transactions*, 26(4): 72–79, 1994.

[28] Chuang, P.T., Combining the analytic hierarchy process and quality function deployment for a location decision from a requirement perspective, *International Journal of Advanced Manufacturing Technology,* 18(11): 842–849, 2001.

[29] Madu, C.N., Kuei, C.H., Aheto, J., Winokur, D., Integrating total quality management in the adoption of new technologies, *Benchmarking: An International Journal*, 1(3): 52–66, 1994.

[30] Lu, M.H., Madu, C.N., Kuei, C. and Winokur, D., Integrating QFD, AHP and benchmarking in strategic marketing, *Journal of Business & Industrial Marketing*, 9(1): 41–50, 1994.

[31] Lin, B., Fite, D., Managing a sea of quality information at Ark-La-Tex Aquatics, *National Productivity Review* 15(1): 79–85, 1995.

[32] Chan, L.K., Wu, M.L., Prioritizing the technical measures in quality function deployment, *Quality Engineering*, 10(3): 467–479, 1998.

[33] Ho, E.S.S.A., Lai, Y.J. and Chang, S.I. An integrated group decision-making approach to quality function deployment, *IIE Transactions*, 31: 553–567, 1999.

[34] Askin, R.G., Dawson, D.W., Maximizing customer satisfaction by optimal specification of engineering characteristics, *IIE Transactions*, 32(1): 9–20, 2000.

[35] Xie, M., Goh, T.N., Wang, H., A study of the sensitivity of ‘‘customer voice’’ in QFD analysis, *International Journal of Industrial Engineering*, 5(4): 301–307, 1998.