FLEXIBILITY PORTFOLIO FOR AUTOMOTIVE MANUFACTURERS

(OTOMOTİV ÜRETİCİLERİ İÇİN ESNEKLİK PORTFÖYÜ)

by

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ABSTRACT

Nowadays, manufacturing companies are in serious competition and in an uncertain environment. As business conditions fluctuate and technological developments occur, customers are less predictable in purchasing behavior. In order to survive in the competition and to increase the market share, flexibility is proposed in this study. The automotive sector is one of the sectors that flexibility is highly needed. The purpose of this study is to find out the best flexibility lever portfolio satisfying customer needs considering also supplier and retailer expectations and providing a quick solution to deal with the uncertainties and the risks this company faces for automotive manufacturer.

As a methodology, a decision making model is developed by combining analytic network process (ANP) and quality function deployment (QFD). Firstly, supplier, retailer and customer expectations are ranked within themselves, and then according to automotive manufacturer their importances are ranked via ANP, secondly the flexibility levers matching the expectations are weighted using two-phased QFD that is house of flexibility concept. In here, a house of flexibility is constructed to relate supplier, retailer and customer expectations with flexibility levers as a first phase. In this part of study, the best portfolio that all expectations can be satisfied maximum with constraint of minimum flexibility is proposed. Later on, a second house is built to detail down the flexibility levers into system factors. As a result, quick solutions are provided to deal with uncertainties and the risks faced by company.

ÖZET

Günümüzde, otomotiv üreticileri ciddi bir rekabet ve belirsizlik ortamındalar. Müşterilerin satın alma davranışları, koşullardaki dalgalanma ve teknolojik gelişmeler meydana geldikçe daha az öngörülebilir olmaktadır. Bu çalışmada, rekabetle başa çıkmak ve pazar payını arttırabilmek için esneklik konsepti önerilmiştir. Otomotiv sektörü, esnekliğin ciddi gerekli olduğu sektörlerden biridir. Bu çalışmanın amacı, otomotiv üreticileri için tedarikçi ve bayilerin beklentilerini de dikkate alarak müşteri ihtiyaçlarını karşılayan en iyi esneklik portföyünü bulmak, belirsizlikler ve şirketin karşılaştığı risklerle başa çıkmak için hızlı bir çözüm sunmaktır.

Metodoloji olarak, analitik ağ süreci (ANP) ve kalite fonksiyon yayılımı (QFD) birleştirilerek karar verme modeli geliştirilmiştir. Öncelikli olarak, ANP aracılığı tedarikçi, bayi ve müşteri beklentileri kendi içlerinde sıralanır ve sonra otomotiv üreticisi göre sıralanır, ikincil olarak beklentileri karşılayan esneklik tipleri ile iki aşamalı QFD konseptinden biri olan esneklik evi yapılır. Burada ilk aşamada, esneklik evi, tedarikçi, perakendeci ve müşteri beklentilerini esneklik tipleri ile ilişkilendirmek için kullanılmıştır. Çalışmanın bu kısmında minimum esneklik tipi kullanılarak tüm beklentilerin maksimum düzeyde karşılanabileceği bir portföy önerilmektedir. Sonuç olarak belirsizliklerin ve şirketin karşı karşıya olduğu risklerin üstesinden gelmek için hızlı çözümler sunulur.

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1. INTRODUCTION

To be flexible means to have the ability to make as many changes as you want according to your needs. Flexibility is the ability to adapt, in a reversible manner, to an existing situation, unlike the irreversible evolution. Companies should move real competition from supply chain to supply chain, not from company to firm (Grigore, 2007).

Dynamic systems have many variables that might be uncalculated. Flexibility becomes a condition in these areas in order to gain and keep a competitive advantage. Flexibility is required to improve the ability to navigate complex business environments for actors in any market (Danilo Brozovic, 2018).

There has even been a proliferation of papers that review the flexibility literature (Gupta and Goyal, 1989; Sethi and Sethi, 1990; Kaighobadi and Venkatesh, 1994; Barad and Nof, 1997; De Toni and Tonchia, 1998; Parker and Wirth, 1999; D'Souza and Williams, 2000, Danilo Brozovic, 2018). Published reviews examine different aspects of flexibility, such as definitions, classification and flexibility measurement, choices, interpretations, and demands for flexibility. (Grigore, 2007).

As diversity and uncertainty increase, businesses respond to business strategies by adding flexibility (Sanchez and Perez, 2005). Flexibility has been recognized as a strategy of managing different types of uncertainty in various disciplines (Masoud Esmaeilikia et al. 2016). Upton defined flexibility as the ability to change or react with little penalty in time, effort, cost or performance in 1994. Flexibility can improve the company's competitiveness especially in the decision making process of application

technology (Jaikumar, 1986; Alvarez Gil, 1994). According to Slack and Upton, managers didn't have a comprehensive view of flexibility because they focus more on machine flexibility than on total system flexibility about 15 years ago (Slack, 1987; Upton, 1994). Nowadays, flexibility is one of their priorities. Company strategies are based on total system flexibility.

Increasing a flexibility dimension does not necessarily lead to a flexible operations system (Gupta and Somers, 1996). Because flexibility is also seen as a response to environmental uncertainty (Riley and Lockwood, 1997), in a global respect, not only manufacturing, but also supply chain logistics and management can be an important source of competitive advantage, because material flows strongly affect business performance (Sánchez, Pérez, (2005). For example, different logistic channels of the supply chain can be activated in order to handle emergency situations such as demand peaks. Subsequently production order assignments to factories, shipping organization and other decisions are critical factors that can reduce the performance of a wide range of products (Sanchez and Perez, 2005).

Flexibility in supply chains can represent a potential source for improving the company's efficiency and can be a significant measure of supply chain performance (Vickery et al., 1999). Supply chain flexibility is defined to cover the flexibility dimensions of the firm that directly affect its customers and under the joint responsibility of two or more functions throughout the supply chain, whether internal (marketing, manufacturing) or external (suppliers, channel members) to the firm (Sanchez and Perez, 2005).

Owing to the increasing uncertainty and diversity in supply chain, companies are aiming to develop their supply chain flexibility, which Huo, Gua and Wangb identify as the capability of a company, both internally and externally in conjunction with its key suppliers and customers in order to reply to uncertainties and customer expectations without excessive costs, time and performance losses (Huo et al, 2018). Automotive is one of the sectors that flexibility is highly needed. The automotive sector consist of wide

range of companies and organizations. They are suppliers, retailers that can also do repairs and maintenance as well as sales, manufacturers, stakeholders, customers who decide to buy, indirect customers (passengers, drivers etc.). In a fast-changing environment, manufacturers have to consider all these actors. Being flexible is critically important in order to handle uncertainties and to meet expectations in this enormous wide environment.

In this study, customer needs, retailer expectations and supplier expectations from company as automotive manufacturer will be defined and will link with flexibility components that depend on internal and external. We will use a method that is QFD. After determining weight of flexibilities according to customers, retailers and suppliers expectations, company resources will link with weighted flexibility types using second QFD. As a result, we will obtain resource distributions under customers, retailers and suppliers expectations being internal and external flexible for the best products and service as an automotive manufacture.

The organization of the thesis is as follows; In chapter 2, literature review is included concept, level of flexibility, and supply chain flexibility components and dimensions. In the next chapter, brief information regarding the automotive sector is provided and by literature review needs of customers, expectations of retailers and suppliers are investigated. In chapter 4, information on ANP and QFD is given. In the following chapter, numerical illustrated of automotive company are provided. Finally as a final chapter, the results are interpreted and possible future works are highlighted.

2. THE CONCEPT OF FLEXIBILITY

Flexibility is a complex, multi-dimensional concept that is difficult to summarize Flexibility types in the manufacturing literature can be analyze through different frameworks (Sánchez and Pérez, 2005). In this section of the thesis, dimensions, components of flexibility are defined and the concept used will be determined.

2.1. Dimensions of Supply Chain Flexibility

There are different understandings when addressing supply chain flexibility. Some studies reviewed supply chain flexibility based on business functions, such as flexibility in procurement, manufacturing, logistics, distribution and marketing (Vickery, et al. 1999; Manders, Caniëls, and Ghijsen 2016).

Sánchez and Pérez's studies are shown Figure 2.1. It adopted a hierarchical perspective that classified supply chain flexibility into shop (basic) which comprise flexibility of the system components: machines, the material handling units and the transporting network, plant (system) which is the basic flexibility types at the manufacturing system level; an important type of system flexibility with implications for the supply chain system is routing flexibility and supply chain-level (aggregate) which is the aggregated attributes of the manufacturing system technology enabling it to cope with the variety of changes and needs at the strategic level (Sánchez and Pérez, 2005).

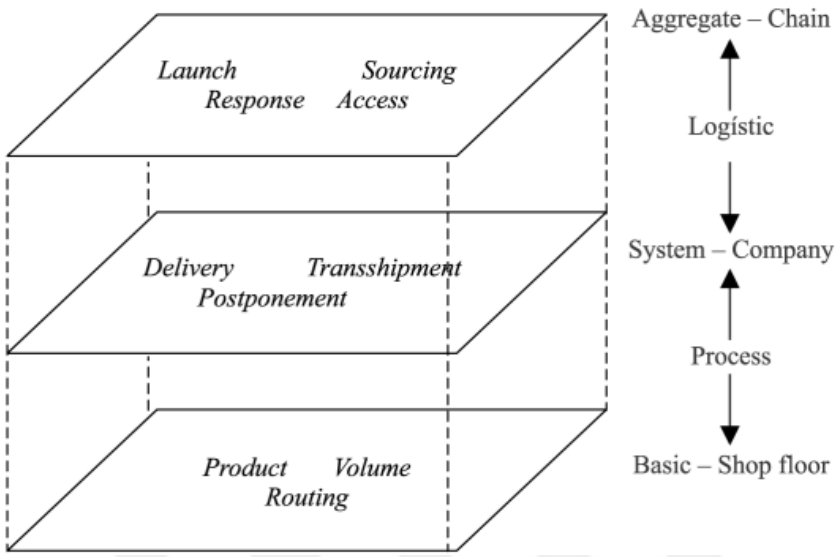


Figure 2.1: Supply Chain Flexibility Dimensions (Sanchez and Perez , 2005)

Treville et al (2007) define three layers of flexibility. these are; Strategic Flexibility how organizations perceive and interpret their environment; Tactical Flexibility that concern defining and measuring flexibility, as well as the translation of flexibility at the strategic level into the technologies, systems, and structures required to realize such flexibility; Operational Flexibility, being technically or theoretically capable of varying the process is only the first step toward achieving flexibility (Treville et al (2007).

Other studies classified supply chain flexibility according to final product or service changes, including volume and mix flexibility (Zhang, Vonderembse, and Lim 2002, 2003; Braunscheidel and Suresh 2009). Baofeng Huo, Minhao Gu and Zhiqiang Wang classified supply chain flexibility into internal, customer and supplier flexibility in 2018. Internal flexibility is company-level capabilities built into internal functions (Yu, Cadeaux, and Luo 2015). Customer and supplier flexibility are external inter-firm capabilities and reside in the links between the focal company and its key supply chain partners (Sánchez and Pérez 2005; Jin et al. 2014). However, there is substantial overlap between these dimensions, which makes the supply chain flexibility concept rather

complicated and the relationships difficult to explore (Huo et al, 2018). Appendix A summarizes how the previous literature categorized the dimensions of supply chain flexibility (Huo et al, 2018).

We classify supply chain flexibility into internal, external flexibility. Internal flexibility is company-level capabilities into internal functions (Yu, Cadeaux, and Luo 2015). External flexibility is external inter-firm capability and reside in the connections between the focal company and its key supply chain partners (Sánchez and Pérez 2005; Jin et al. 2014).

Internal and external flexibility have different tasks in supply chain flexibility for companies (Huo et al, 2018). Internal flexibility recognizes that departments and functions must act synergistically to respond to changes that occur inside the focal company. External flexibility recognizes the importance of the synergistic actions that the focal point company performs with its external customers and suppliers, so that they can better respond to changes in up and down (Huo et al, 2018). Supply chain members to respond in a manner consistent with the uncertainty and to allow it to provide maximum value to customers, both internal and external flexibility are important (Huo et al, 2018).

2.2. Supply Chain Flexibility Components

A complete definition of supply chain flexibility components should include the flexibility dimensions required by all the participants in the supply chain to successfully meet customer demand (Grigore, 2007).

Flexibility in the supply chain adds the requirement of flexibility within and between all partners in the chain, including departments within an organization, and the external partners, including suppliers, carriers, third-party companies, and information systems providers. It includes the flexibility to gather information on market demands and exchange information between organizations (Grigore, 2007).

Components of supply chain flexibility have been identified from the literature on product development, procurement, manufacturing, logistics, marketing, organization and information (financial) business area.

2.2.1. Product Development

Product development flexibility – The ability to respond to changing customer needs with new products and changes made to existing products (Zhang et al, 2002)

New product desing flexibility – The ability to design and present new products to the system (Stevenson and Spring, 2007).

Product modification flexibility – The ability to personalize (standard) products according to customer standards (Vickery et al, 1999; Lummus et al. 2003).

2.2.2. Procurement

Procurement flexibility - The ability to respond to changing requirements regarding the sourcing, purchasing and supply of goods (Manders et al, 2014).

Sourcing flexibility - The ability to find more suppliers for each specific material, component or service (Sánchez and Pérez Pérez, 2005).

Supply flexibility - The ability to respond to changing requirements in terms of location and/or delivery date (based on Tachizawa and Thomsen, 2007).

Purchasing flexibility - The ability to respond to changing needs in the ordering, delivery and receipt of supplied goods ((Manders et al, 2014).

2.2.3. Manufacturing

Manufacturing flexibility – The ability to manage production resources to meet customer demands (Nair, 2005).

Volume flexibility – The ability to adjust (increase or decrease) capacity, batchsizes, output levels and/or amounts in response customer demand (Based on Beamon, 1999; Lummus et al., 2003; Sánchez and Pérez Pérez, 2005).

Mix flexibility – The ability to change the variety or combination of produced or delivered products and/or performed activities (Based on Beamon ,1999; Zhang et al., 2003).

Operations flexibility – To be able to perform an activity in different ways by using alternative process plans, processes and existing assets (Based on Sethi and Sethi,1990; Vokurka and O'Leary Kelly, 2000).

Process flexibility – The ability to produce different (kind) product arrangements or perform different activities in a fixed state (Based on Sánchez and Pérez Pérez, 2005; Stevenson and Spring, 2007; Hopp et al., 2010).

Expansion flexibility – The ability to easy add capacity to the system (Stevenson and Spring, 2007).

2.2.4. Logistics

Logistics flexibility - The ability to align, adapt and adjust the goods flow process, including inbound and outbound activities, and the storage of goods according to the needs of changing customers (Swafford et al., 2000; Nair, 2005; Soon and Udin (2011).

Routing flexibility - The ability to have alternative paths that a part or product can pass through the system for completion (Vokurka and O'Leary-Kelly, 2000; Stevenson and Spring, 2007).

Delivery flexibility – Ability to respond to changes in delivery demands location and / or delivery date (Based on Stevenson and Spring, 2007; Skintzi, 2007).

Storage flexibility – The ability to adjust the storage capacity and/or move the stock between locations to transfer the goods/products in time (Based on Schütz and Tomasgard, 2011; Sánchez and Pérez Pérez, 2005)

2.2.5. Marketing

Marketing flexibility – The ability to adapt to changes in the market environment and / or customer needs by customizing and building close relationships with customers (Based on Vokurka and O'Leary-Kelly, 2000; Lummus et al., 2003; Stevenson and Spring, 2007).

Launch flexibility – The ability to quickly introduce new products and/or product types to the market (Vickery et al., 1999; Sánchez and Pérez Pérez, 2005).

Responsive flexibility – The ability to meet the needs of the target market (Lummus et al.(2003)

2.2.6. Organization

Network flexibility – The ability to respond to changing situations by managing the organizations relationships, structures and controlling its capacity (Based on Yi et al., 2011).

Organizational flexibility – Align organization management and workforce to meet customer demand / service requirements (Lummus et al., 2005).

Labor flexibility – The ability to change the number of workers (Basedon Gong, 2008).

Worker flexibility – A worker can perform several different tasks different responsibilities (Based on Stevenson and Spring, 2007).

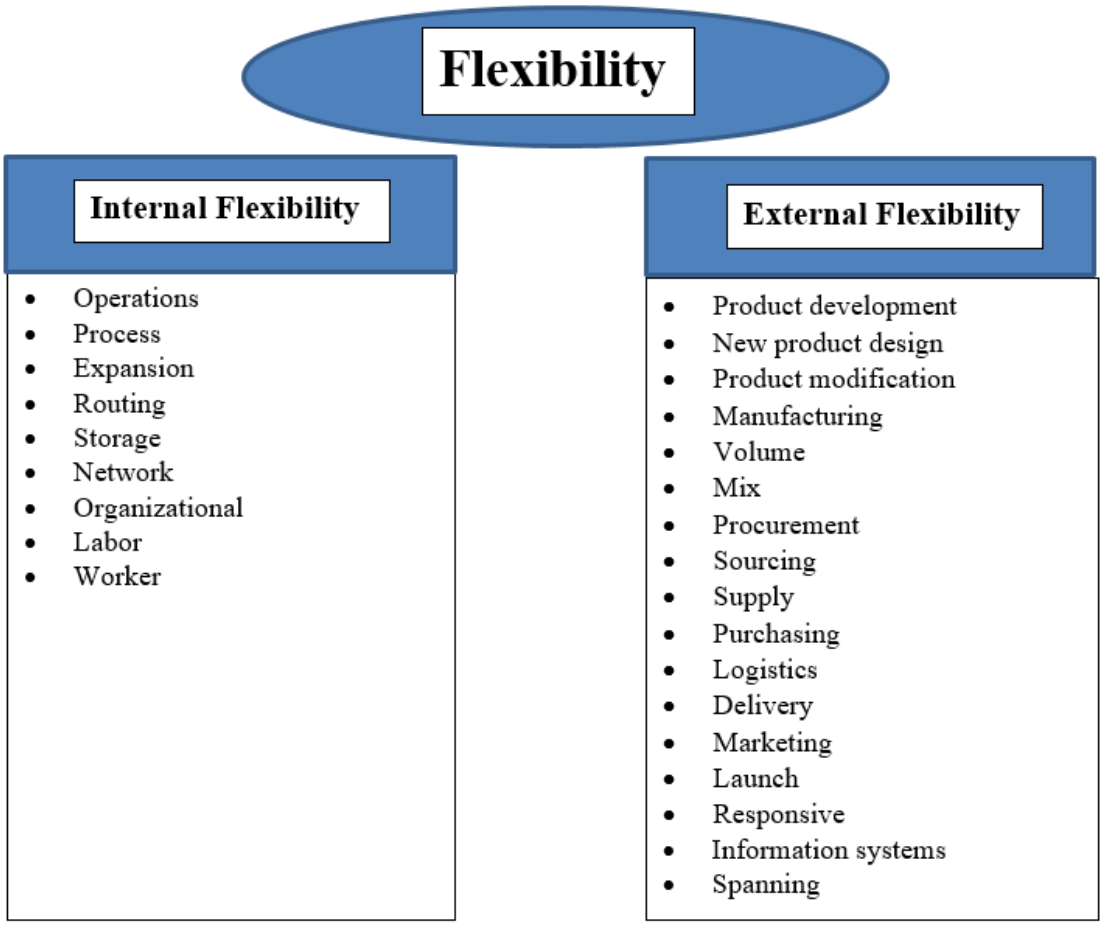
2.2.7. Financial information

Information systems flexibility – The ability to align information system architecture and systems with changing information needs of the organization while responding to changing customer demand (Lummus et al., 2005).

Spanning flexibility – The ability to collect, store and disseminate information in horizontal information links across organizations' supply chain to increase the value of customers (Zhang et al., 2006; Nair, 2005).

We try to group the flexibility components, according to internal and external dimension (Figure 2.1.).

Table 2.1: Components of flexibility according to in/external flexibility



3. AUTOMOTIVE SECTOR

The purpose of this chapter is to explain the reason behind automotive sector and especially producing and selling automotive companies through pointing out the importance and the position of the sector and then to explain customer’s needs, expectations of retailers and suppliers. In the final this chapter, necessity for flexibility is explained in the automotive sector.

3.1. Review on the Automotive Sector

The automotive industries history started with the revolutionary invention of a feasible internal combustion engine. With these machines started to assist fuel-burning within confined spaces in the 1800's (Sheth, 2017). In 1823, London-based engineer named Samuel Brown patented the first internal combustion machine (Sheth, 2017). After that, the sustained efforts made by American manufacturers, especially Henry Ford and his assembly line, opened the way for the mass production of cars (Sheth, 2017).

With 20.century, automobiles could be found in virtually every corner of the globe. In spite of high fuel prices and strict regulations, more cars manufacturing companies try to cover the demands and needs (Sheth, 2017).

According to the latest trends, investments in manufacturing of "smart" and "green" cars is on a steep rise worldwide, vehicles are more convenience, safer, and more sustainability than ever before

At present, the automotive industry is not limited to any geographical region and actually covers the entire planet. There is a huge car culture to be found all across the globe. The $ 257 billion automotive industry perfectly meets the needs of this culture (Sheth, 2017). The industry includes the designing, manufacturing, and repair of them as well. The automotive industry also includes such services as the selling of various accessories and auto/spare parts that are important in providing an efficiently run in automobile systems.

Some of the biggest players of this industry include the German-based manufacturer Volkswagen, BMW and Mercedes-Benz as premium segment, two major automobile companies of Japan (i.e. Toyota Motor Corporation and Nissan Motor Corporation), the US-based rivals of General Motors and the Ford Motor Company, and the Italian company Fiat (Sheth, 2017).

3.1.1. Worldwide

This statistic represents worldwide automobile production from 2013 to 2018. 70.5 million cars were produced worldwide as totally in 2018. The Production declined of around 1.2 percent, compared with the previous year. China, Japan, and Germany were the largest producers of passenger vehicles[1] .China is the largest passenger car manufacturer in the world. They produced more than 23.7 million cars in 2018, and accounted for almost one third of the world's passenger vehicle production[1]. Trend of production were increased excluding 2018.

[1] www.statista.com

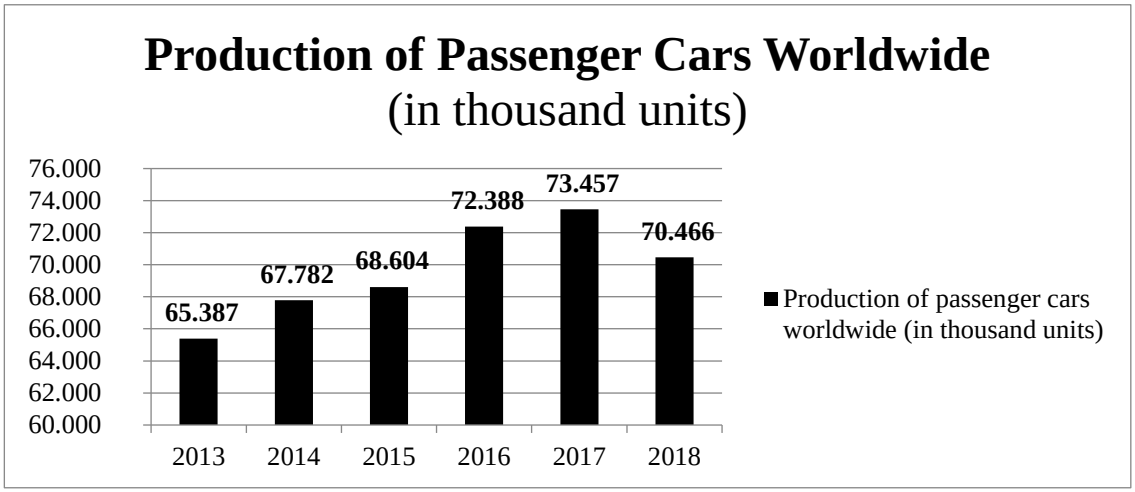


Figure 3.1: Production of Passenger Cars Worldwide (source Statista)

When we look global sales of passenger cars last year (2018) around 86 million passenger cars were sold in the top 54 world markets. Electric car sales recorded an increase of 75%. (Bekker, 2019). According to Jato, sales in 2018 for the first time since 2009 fell a little difficult for the global car market. Nevertheless, worldwide car sales remained close to record levels (Bekker, 2019). Because of trade tensions between the world's biggest economies, political changes in key markets, and new threats to the status quo of the industry, many automakers were influenced negatively (Bekker, 2019).

Car sales in the major car markets of the world were as follows in recent years (Table 3.2.):

Table 3.1: Car sales in the major car markets[2]

Region	2018	2017	2016	2015	2014	2013
Europe (EU+EFTA)	15,624,500	15,631,700	15,131,700	14,201,900	13,006,500	12,308,200
Russia*	1,800,600	1,595,700	1,425,800	1,601,200	2,491,400	2,777,400
USA*	17,215,200	17,134,700	17,465,000	17,386,300	16,435,300	15,531,600
Japan	4,391,200	4,386,400	4,146,500	4,215,900	4,699,600	4,562,300
Brazil*	2,475,400	2,176,000	1,988,600	2,480,500	3,333,400	3,579,900
India	3,394,700	3,229,100	2,966,600	2,772,700	2,570,500	2,554,000
China	23,256,300	24,171,400	23,693,400	20,047,200	18,368,900	16,303,700
*Light vehicles	–	–	–	–	–	–
Combined:	68,157,900	68,325,000	66,817,600	62,705,700	60,905,600	57,617,100

[2] Source: VDA

In 2018, car sales decreased in China, were stable in Europe, Japan and the USA however, increased in Brazil, Russia and India.

3.1.2. Turkey

Production capacity exceeded 1.2 million as of 2018 in Turkey. Companies with production passenger cars are Oyak- Renualt (32,8%), Toyota (25%), Hyundai Assan (19,8%), Tofaş (16,4%), Honda Türkiye (3,7%) and Ford Otosan (2,2%) in Turkey (OSD, 2018).

Passenger car's production units in Turkey were as follows in recent years (Figure 3.3).

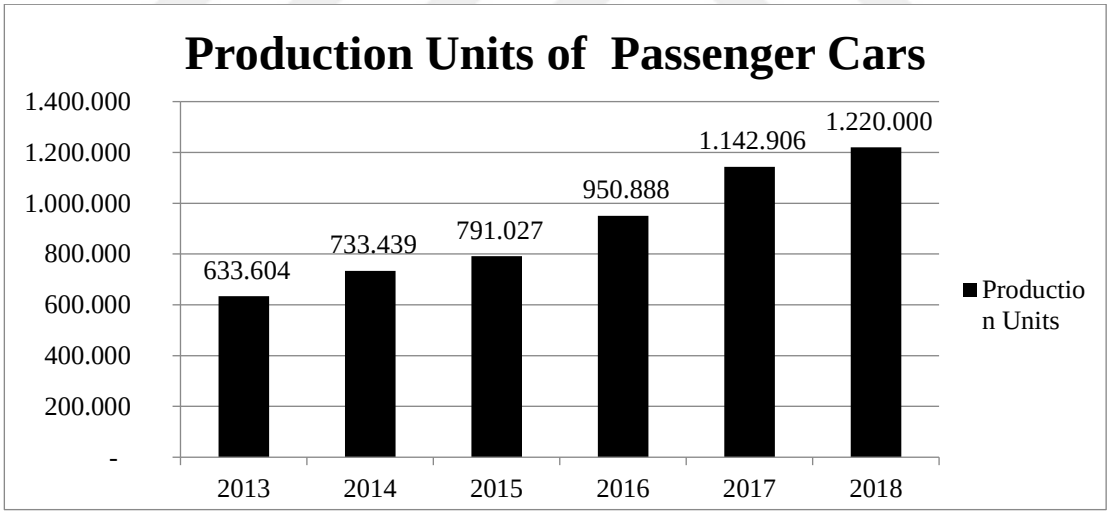


Figure 3.2: Production of Passenger Cars (Source OSD)

It seems to be increasing production however Turkey's has contracted considerably as sales because of increasing currency, overall economic contraction, political tensions. Companies can exports their production with service contact. But generally sales with service agreements do not provide much net profit. When we look passenger car sales

for last two years, serious market contraction is observed (Figure 3.4.). Nevertheless, automotive industry is one of the most important manufacturing industry with contributions about Turkish Economy and as an innovator for other sectors.

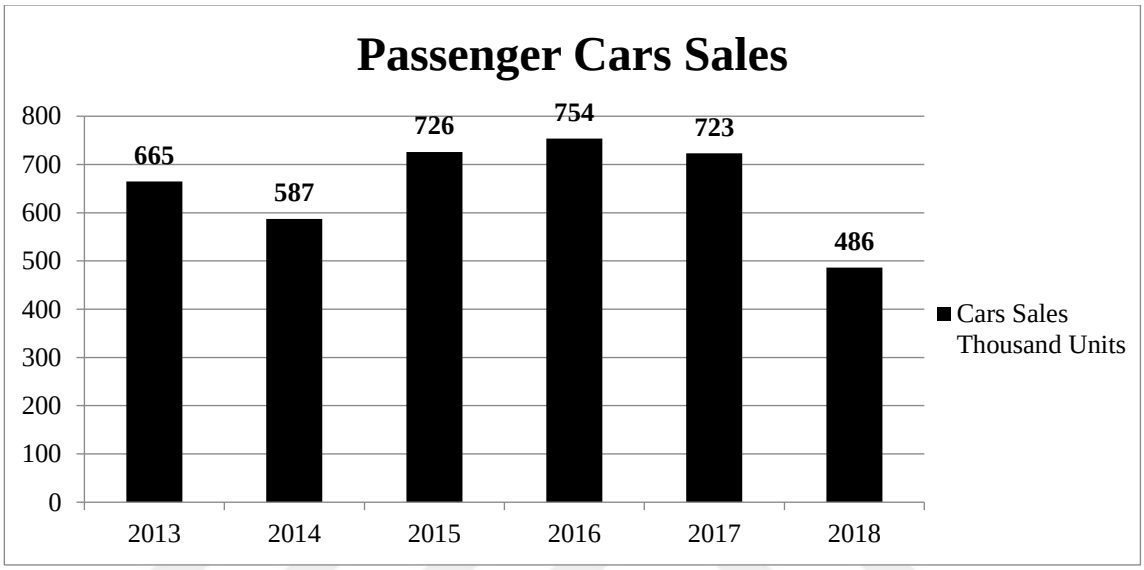


Figure 3.3: Passenger Cars Sales (Source OSD)

3.2. Automotive Sector's Flexibility Demands

The automotive industry is a wide range of companies and organization involved in the design, development, manufacturing, marketing, selling. The automotive sector has many actors that think their profitability. The huge industry covers suppliers, retailers that can also do repairs and maintenance as well as sales, manufacturer, stakeholders, customers who decide to buy, indirect customers (passengers, drivers etc.). Fischer and Schot designed actors as below.

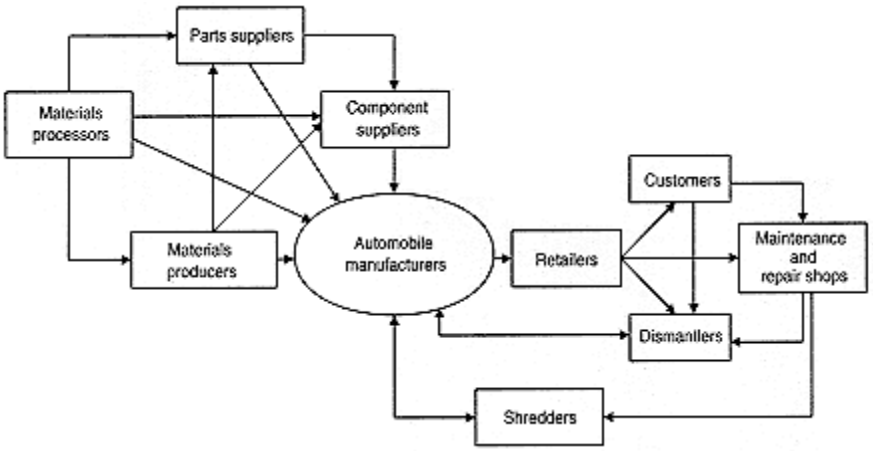


Figure 3.4: Players in the automotive sector (Adapted from Fischer and Schot, 1993)

According to German Association of the Automotive Industry (VDA) reports, most automotive markets throughout the world are keeping from and overcoming their long-standing weakness. This market expanded for the fifth time in succession by just under 5 per cent to 897,100 sold units. China and Japan also increased. Only the light vehicle market in the USA decreased while demand for new cars in Russia and India dropped3.

Automotive companies have to be flexible in order to handle such an uncertain environment since the demands from customers and authorities are changing more rapidly (Francas, 2009). In fact that flexibility is not a new issue for automotive companies. Firstly General Motors started to implemented products flexibility about hundred years ago (Diffner, 2011). After GM's implementation, Ford, Mazda, Volkswagen, DaimlerChrysler followed them (Diffner, 2011).

Since Koste and Malhotra (2000) have created five key flexibilities for automotive manufacturing, their definition was chose as a foundation. Gupta and Goyal (1989)'s definition of flexibility is also less focused on the manufacturing process compared to Koste and Malhotra. The five flexibilities identified by Koste and Malhotra (2000) are: machine flexibility, labour flexibility, mix flexibility, new product flexibility, and modification flexibility. It is assumed for the purposes of this research that internal and external flexibility.

[3] www.vda.de

- Internal Flexibility
- External Flexibility

3.3 Supplier Expectations

In recent times, the relationship between suppliers and automotive manufacturers has changed with developing technology. Suppliers being willing to work with strong automotive companies change their operation and management structures.

Having efficient supply chain and being able to react the dynamic market conditions, firms intend to accomplish greater supply chain collaboration to strengthen the resources and knowledge of related parties (Ince and Ozkan, 2015). Supply chain cooperation plans and maintains activities with supply chain members to carry out operations. (Ince and Ozkan, 2015). This brings along benefits and advantages such as sharing risks, reducing transaction costs, enhancing the productivity and competitive advantage over time to the partners (Cao and Zhang, 2011).

The automotive industry has broad division of labour within the value creation process and a highly complex network of global component suppliers (Mesterharm and Tropschuh, 2012).This complex and large structure has to be sustainable to survive. Varity sustainability definitions are made in literature. Schumacher as early as 1972 firstly mentioned the idea of sustainability, as “permanence”, where “nothing makes economic sense unless its continuance for a long time can be projected without running into absurdities” (Grinde and Khare, 2008).

With Elkington’s (1998) conception of tries to explain economic, environmental and social issues (Gimenez et al., 2012). Economic sustainability refers to production or manufacturing costs. Environmental sustainability refers to reducing the waste, pollution, energy usage, emissions, consumption of hazardous/harmful/toxic materials,

the frequency of environmental incidents, etc. Social sustainability refers both internal (i.e., employees) and external parties that indicate fair potentials, encourage differences, promote independency within whole supply chains, provide life quality and democratic environment and trustable organization structures (Gimenez et al., 2012).In this study, suppliers and automotive producers' expectations from each other are based these three pillars. To be sustainable, they expect each other to be respectful for these three issues.

3.4. Retailer Expectations

Automotive retailers aim to assure their customer's expectations. In order to this aim, they need to be supported by their manufacturer or distributer providing products.

Competition increases and digitalization is more important, automotive dealers have to keep in this step with these changes. Automotive retailers develop the conception of classic sales channel. Nowadays, customers spend much more time for online research. Omni-channel customer experience included active online social presence, online reviews, live chat support, and sales events are more important than face-to-face sales concepts.

Retailers are willing to have capabilities of after sales to keep up with their competitors. After sales capabilities including fast supply of spare parts, optimal stock level, expert technical team. In order these expectations; companies have to support to their retailers, with strong and effective supply system of spare parts, working of min stock and well trained technical team.

In addition, retailers need to have supporting material for sales and aftersales such as videos, movies, applications, brochures, sheets.

3.5. Customer Needs and Expectations

In order to describe customer demands, many articles were written by researchers. There is a well-established tradition of research in the management of technology that suggests that cooperation and communication among marketing, manufacturing, engineering, and R&D leads to greater new-product success and more profitable products (Griffin and Hauser, 1991).

The purpose of this chapter is to determine the customer expectations and needs. The expectations are divided as two parts; products and services provided.

3.5.1. Products

3.5.1.1.Delivery

Explanation of the car when handling over the car: When handling over the car, lack of information giving by dealer can cause dissatisfaction. The explanation has to be contained general cars feature and usage, security warnings, additional features if available for every model.

Delivery Time: The pressure is growing on the automotive industry to provide a more dynamic service with a wider variety of options and quicker turnaround of orders. Customers don't want to wait six weeks for their new car, and so, the industry has to react to customer demand (Fawkes, 2015).

Delivery on schedule: Compliance with the date specified in the delivery is one of the customer expectations. In addition, the instant real time information is offered to customers with tracking apps. These applications also have the advantage of being available for any customer with access to the smartphone.

3.5.1.2. Functionality

Material / finishing quality: Materials including parts from suppliers provide certain level of quality. These levels can be measurable with quality standards. Each part of products should provide quality standards. When the production of the car is completed, finishing quality has to be provided by producers. Nevertheless, material quality is negative relationship between product costs.

Telematic/Connectivity Systems: Technology and innovation become more important day by day. Non-innovative products remain behind the age for whole sector. Suppliers have to be innovative and follow the technology trends. The leader in transformative technology innovation market intelligence, forecasts the global penetration of embedded and hybrid factory installed telematics in new passenger cars to exceed 72% by 2021, according to ABI Research (ABI Researh, 2016). A short list of features that telematics/connectivity now offer, or will soon offer connected drivers, passengers, and even family at home; remote vehicle location by GPS, remote access to vehicle operation information, the ability to remotely limit vehicle speed, turn-by-turn navigation with augmented 3rd-party information, family notification of vehicle collision, automated emergency calling, vehicle diagnostics and maintenance notifications (Novosilska, 2018).

Safety: In order to minimize the occurrence and consequences of traffic collisions automotive makers study and practice of design, construction, equipment and regulation (Anderson, 2016). Cars that can drive themselves may seem like the faraway future of automotive safety. However many of the features tare now industry standards for models (Tellem, 2009). Here is a list of some of those; tire-pressure monitoring, adaptive cruise control/collision mitigation, blind-spot detection/side assist/collision warning (Audi Q7), lane-departure warning/wake-you-up safety, rollover prevention/mitigation (Volvo XC90), occupant-sensitive/dual-stage airbags (2006 Porsche Cayenne), emergency brake assist/collision mitigation, adaptive headlights and/or night-vision assist (Mercedes-

Benz), rearview camera, emergency response etc. (Tellem, 2009). These features are critical for customers.

Overall impression of the exterior design: The importance of its exterior design has considerably increased because of the change of the automobile from a luxury to a commonly used lifestyle product. The exterior design expresses individual customers' preferences and social standing (Pfitzer and Rudolph, 2007). Automotive makers continually update their designs to meet current needs according to tastes of consumers.

Environmental friendliness: Considering the automotive industry, car manufacturers are forcing to have the ecological and sustainable path such as hybrid technologies and electrification (Russo et al., 2015). Consumers generally see eco-friendly innovation as an important driver of differentiation (Kassarjian, 1971). Car manufacturers are aware of this tendency, aiming to take advantage of this trend efficiently (Russo et al., 2015).

3.5.1.3. Economy

Fuel consumption: Fuel consumption is one of the decisive factors to buy a car for customers as decision makers. Relatively customers tend to buy cars that have low gasoline prices instead on car prices, performance, comfort, and style.

Warranty terms: Car manufacturers and their dealers use guarantees to keep customers and achieve win. These customers expect longer warranty coverage or a bargain, respectively (Jagtap and Teli, 2014). Long warranty terms are one of the most important selling tools for car manufacturers and their dealers and in the same time these terms influence purchase decision for customers.

Purchasing Price: A rising number of derivatives, new vehicle functions, requirements for safety and fuel efficiency, and tighter legal requirements cause increase product costs. This situation influences purchase decision of customers. Customers buy car according to their budget. As the price of the car increases, the possibility of the purchase of the car decreases.

Resale or residual value: A car's resale value is the amount it is expected to sell in the future. This depends on a number of factors, including the vehicle's age, mileage, condition, trim level, optional equipment, color and even the region where it's being sold. Customers consider car's resale value in case of sales. This value is wanted to be high.

3.5.1.4. Availability

Reliability: Reliability is probability of not failure per unit device. Today's cars are contained more and more electronics into vehicles, from engine control units to anti-collision controls to driver information to entertainment systems that enhance the overall driving experience with Bluetooth, GPS, and Wi-Fi (Nakauchi, 2014) . This complexity causes increase probability of failure overall. However customers tend to buy reliable cars naturally.

Frequency of maintenance: Many manufacturers use a 30-60-90 schedule, meaning certain items need to be checked, changed, or replaced at 30,000, 60,000, and 90,000 miles. These maintenances are prevented major problems before they occur. Also, periodical maintenances increase the resale value. However, every maintenance means cost, waste of time and effort to customers, long maintenance period is preferred.

Frequency of breakdowns while on road: New cars were loaded with advanced technology designed to keep driver and passengers safe and on the road—not in the

breakdown lane. Technology including maintenance reminders and other safety alerts—could not reduce the number of drivers stranded on the roadside (Korosec, 2016). Breakdowns are actually customer's problem. Customers tend to purchase cars having low frequency of breakdowns.

3.5.2. Services Provided

Sales Activity: Sales activities are important factors to customers. These are the quality of the sales documents provided, possibility of getting a demonstration vehicle such test drive, advice relating to the vehicle type and transport needs to customers.

Financial Service: Financial services are important for customers when they decide to buy. These are the promptness with which proposal was generated to customer, the promptness of credit decision by working with financial institution, the flexibility of conditions of financing agreement (down payment /payment option, buyback option etc.).

Workshops: Product features and sales activities are not enough for purchase decision. After sales, customers expect to take fast and efficient services by dealers. Car manufacturer have to support their dealers to give a better service. These are the expert technical team, flexible responses to customer requirements, rapid handling of warranty issues.

Parts: Supply of spare parts can be a frustration for customers in automotive sector. Therefore, the customer expectations have to be considered about spare parts. These are an availability of spare parts, time taken to obtain parts not in stock, quality of the parts.

4. METHODOLOGY AND BACKGROUND

In the previous chapter, the automotive industry is a wide range of companies and organizations. Nevertheless, there exist many uncertainties and risks in the sector which make it quite difficult to deal with the uncertainties, survive in the competition and increase the market share. Being flexible is one of an obligation to survive and handle such this environment. As mentioned in the second chapter, there are several flexibility types and not all of them are provided by companies in real life. Because of this reason, as a beginning companies should determine the expectations of the segments by severity. Afterwards, these expectations should be ranked according to their values and the types of flexibility to meet these needs should be determined, and then these flexibility types should be detailed down to system factors. For this purpose, as the methodology, a decision making model is developed by combining analytic network process (ANP) and quality function deployment (QFD).

The aim of this section is to explain the reasons for selecting ANP and QFD, and then the methods are introduced.

4.1. Analytic Network Process (ANP)

In order to handle both the complexity of the group decision-making process, Analytic Network Process (ANP) is applied. This method is a further development of Saaty's Analytical Network Process (Saaty, 1996) which is one of the most commonly used multi-criteria decision-making methods in the literature.

In this section, firstly the ANP methodology is defined. Afterwards selection of this method is explained.

4.1.1. Introduction to Analytic Network Process (ANP)

The Analytic Hierarchy Process is a widely used synthesis methodology that converts a complex real world decision-making problem into several linear hierarchies (Saaty 1980). In particular, it can handle benefit, opportunity, cost, and risk separately, and combine these quantitative data with group decision-making or evaluation to achieve an optimized overall result. (Wijnmalen, 2007; Saaty and Sodenkamp, 2010). The ANP may be considered a generalized version of the AHP and this method, using multiple decisions with dependence and feedback component may struggle more (Saaty, 1996). If interdependence exists, the ANP is more valid than AHP.

4.1.1.1. Brief Methodology Review

The ANP expands the AHP to problems with dependence and feedback. Replacing a hierarchy in the AHP with a network provides complex interrelationships among decision elements (Meade & Sarkis, 1999).

The process of the ANP is included of four major steps (Chung et al., 2005; Meade & Sarkis,1999; Saaty, 1996).

1. Network model construction

The problem is solved in a network where nodes correspond to clusters. The elements in a cluster might affect to some or all the elements of any other cluster. Arcs with directions represent these relationships (Figure 4.1). Additional, a looped arc can represent if there is relationship between elements in the same cluster.

Figure 1. Example of network in ANP and hierarchy in AHP (Peykarjou and Safavi, 2015)

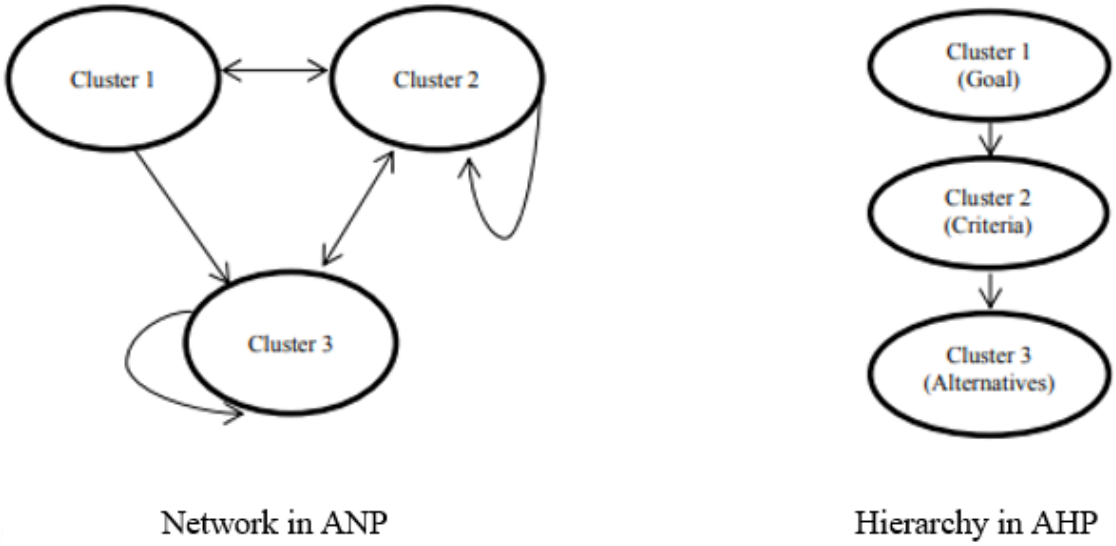


Figure 4.1: Example of network in ANP and hierarchy in AHP (Peykarjou and Safavi, 2015)

2. Pairwise comparisons and priority vectors

Elements of each cluster are compared pair-wisely with respect to their impacts on an element in the cluster. Additionally, pairwise comparisons are done for interdependency among elements outside clusters. When cluster weights are required to weight the super-matrix at the next stage, clusters are also compared pairwisely with respect to their impacts on each cluster (Peykarjou and Safavi, 2015). When pairwise comparisons are made with Saaty's fundamental scale of absolute numbers (Table 4.1.)

Table 4.1: Fundamental Scale for Comparison of Alternatives (Saaty, 1980)

Option	Numerical value(s)
Equal	1
Marginally strong	3
Strong	5
Very strong	7
Extremely strong	9
Intermediate values to reflect fuzzy inputs	2, 4, 6, 8
Reflection dominance of second alternative compared with the first	Reciprocals

The way of managing pairwise comparison and getting priority vectors is the same as in the AHP. A reciprocal value is assigned to the inverse comparison; that is, aji =1/aij, where aij notes the importance of the ith element compared to the jth element. Also, aii = 1 are preserved in the pairwise comparison matrix. Then, the eigenvector method is employed to get local priority vectors for each pairwise comparison matrix (Peykarjou and Safavi, 2015).

3. Supermatrix formation and transformation

Local priority vectors are filled into the appropriate columns of a supermatrix, which is a partitioned matrix where each segment represents a relationship between two clusters. The supermatrix of a system of N clusters is denoted as follows (Peykarjou and Safavi, 2015):

$$W = \begin{array}{r} e_{11} \\ C_1 e_{12} \\ e_{13} \\ e_{k1} \\ C_k e_{k2} \\ e_{k3} \\ e_{n1} \\ C_n e_{n2} \\ e_{nn} \end{array} \begin{pmatrix} w_{11} & \vdots & & \vdots & w_{1n} \\ \vdots & \vdots & \cdots & \vdots & \vdots \\ \vdots & \vdots & & \vdots & \vdots \\ \vdots & \vdots & & \vdots & \vdots \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \vdots & \vdots & & \vdots & \vdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \vdots & \cdots & \cdots & \cdots & \vdots \\ w_{n1} & \cdots & \cdots & \cdots & w_{nn} \end{pmatrix}$$

Ck illustrates the kth cluster (k = 1, 2, . . ., N) that has nk elements denoted as ek1, ek2, . . ., eknk. A matrix segment Wij, illustrates a relationship between the ith cluster and the jth cluster. Each column of Wij is a local priority vector obtained from the corresponding pairwise comparison, representing the importance of the elements in the ith cluster on an element in the jth cluster. If there is no relationship between clusters, the corresponding matrix segment is a zero matrix.

Afterwards, the supermatrix is transformed into the weighted supermatrix each of whose columns sums to one. This ‘column stochastic’ feature of the weighted supermatrix allows convergence to occur in the limit supermatrix.

A proposed approach to achieved the weighted supermatrix is to determine a cluster priority vector for each cluster, which indicates relative importance of influences of other clusters on each cluster. It can be provided by conducting pairwise comparisons among clusters with respect to the column cluster. The resulting priority vector is used to weight the matrix segments that fall in the column below the given cluster. The first entry of the vector is multiplied by all the elements in the first matrix segment of that column and so on. As this weighting procedure is repeated for all the column clusters, the weighted supermatrix is produced (Peykarjou and Safavi, 2015).

Finally, owing to raise itself to powers, the weighted supermatrix is transformed into the limit supermatrix. The weighted supermatrix is multiplied in order to capture the transmission of influence along all possible paths of the supermatrix. The entries of the weighted supermatrix symbolize only the direct influence of any element on any other element, however this weight is not included indirect influence. Squaring the weighted supermatrix captures one-step indirect influences, the cubic power of the matrix obtains two-step indirect influences and so on.

Raising the weighted supermatrix to the power 2k + 1, where k is an optionally large number, allow convergence of the matrix This means the row values converge to the same value for each column of the matrix. The resulting matrix is called the limit supermatrix. This yields limit priorities capture all the indirect influences of each element on every other element (Peykarjou and Safavi, 2015).

4. Final priorities

When the whole network is covered by the supermatrix, the finial priorities of elements are found in the corresponding columns in the limit supermatrix. Due to the structure and logic of ANP, it suitable for the problem with expert judgments in the decision making process (Saaty, T., 2005).

4.1.1.2. Consistency Ratio

Consistency Ratio (CR) is calculated to assess the consistency of the decision maker judgments. In case of founding inconsistent, then they should be reviewed.

The consistency index of a matrix is calculated by $C.I. = (\lambda\max - n)(n-1)$. The consistency ratio $(C.R.)$ is obtained by forming the ratio $(C.I)$ of and the appropriate one of the following set of numbers shown in Table 4.2, each of which is an average random consistency index computed for $n \leq 10$ for very large samples. They create randomly generated reciprocal matrices using the scale 1/9, 1/8,…,1/2, 1, 2,…, 8, 9 and calculate the average of their eigenvalues. The form the Random Consistency Index $R.I.$ uses this average.

Table 4.2: Random Index

Order	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

$C.R.$ should be less than or equal to 0.10. Inconsistency is an adjustment needed to develop the consistency of the comparisons (Peykarjou and Safavi, 2015). However, the adjustment should not be as large as the judgment itself or at the same time so small that it would have result (Peykarjou and Safavi, 2015). The overall inconsistency should be around 10 % on a scale from zero to one. The requirement of 10% can not be made smaller such as 1% or . However inconsistency is important because without it, new information that changes preferences is unacceptable (Saaty, T. L. & Ozdemir, M., 2005).

4.1.1.3. Advantages & Disadvantages of ANP

ANP method of multi-criteria decision-making has confirmed their applicability. ANP encompasses the following advantages:

- As compared to other multi-criteria decision-making approaches, The ANP is not proportionately complex, which helps to improve the management approach and transparency of the modeling technique (Tascalı and Ercan, 2006).
- The ANP has an additional strength that can bind quantitative and qualitative factors to a decision (Tascalı and Ercan, 2006).
- This approach may be compatible with other solution approaches, such as optimization and goal programming (Tascalı and Ercan, 2006).
- In ANP, judicial decisions are finalized by using the separation approach shown in experimental studies to reduce decision-making errors (Tascalı and Ercan, 2006).
- The ANP is a technique that can prove that it is valuable to help a number of parties (stakeholders) reach an acceptable solution by its nature and can be used as a consensus tool if properly implemented (Sarkis and Sundarraj, 2005).
- ANP goes beyond linear relationships between elements and allows relationships between elements (Tran et al. 2004). Instead of hierarchy, the ANP-based system is a network that replaces one-way relationships with dependency and feedback (Saaty, 1996, Saaty 2005, Saaty, 2001). For this reason, ANP is more powerful than AHP in the decision environment with uncertainty and dynamics.
- The reversal of the ANP rank reversal has been corrected, so it is more accurate and useful as a decision support tool (than AHP) for complex situations. ANP and AHP are based on user-supplied preferences and provide useful weights for alternatives. They differ from each other in terms of the number and types of pairwise comparisons as well as the manner in which the useful weights are actually calculated (Cheng and Li, 2004).
- The ANP process facilitates inter-functional and inter-level discussions (Tascalı and Ercan, 2006).

- The ANP also ensures a structural decomposition method to address a wide range of factors, rather than relying entirely on intuition to assess all intangible factors (Tascalı and Ercan, 2006).
- All other ANP calculations can be performed on a management tool such as a spreadsheet, with the exception of the eigenvector calculations where the tools are not freely available (Tascalı and Ercan, 2006).

Disadvantages of ANP methodology

Although ANP provides great advantages, it still has some disadvantages. Yellepeddi et al. (2006) listed as follow:

- The disadvantage of the ANP model is that it requires filling in a lot of questionnaires for accreditation model. Afterwards ANP requires a lot of calculations compared to the AHP process.
- Determination of qualifications requires extensive brainstorming sessions.
- Data collection is a time-intensive process.
- The subjectivity of comparisons is not taken into account

4.2.Quality Function Deployment (QFD)

In this section, QFD methodology is presented. It is an approach that defines customer needs structurally and transforms them into strategic plans. It is proposed to rank the customer needs with ANP and then convert them to flexibility types and more detailed firm needs via QFD. “House of flexibility” conducted by Olhager and West (Olhager and West, 2002) is used as a base study in this study.

4.2.1. Introduction to QFD

QFD introduced first time by Yoji Akao in 1966. This broad total quality management implementation provide to define customer expecatations and transform those into strategic plans. In the 1970s, the spread of quality function (QFD) began in Japan, but not until the 1980s when the Western world began to appreciate it as a technique and began to use it as a tool for decision-making (Mehrjerdi, 2010). QFD has been successfully implemented by many Japanese enterprises to develop their processes and provide competitive advantage. Today, companies are successfully using QFD as a powerful tool to address strategic and operational decisions in businesses (Mehrjerdi, 2010). QFD provides a way to transform customer requirements into appropriate technical requirements whole product development and production steps (Sullivan, 1986).

There are many companies that take into account the QFD technology today to offer customers products that can be produced by marketable and tasteful and production expert teams (Griffin and Hauser, 1992; Chan and Wu, 2002).

In this method, the needs of the customers are converted to substitution quality properties at the product design stage for product benefits. Afterwards these substitution quality characteristics are distributed to the production activities so that necessary control and control points are created before the production begins. These two related targets are the main driving forces of the QFD. So, a product can be designed to meet the needs and expectations of the customers. This methodology focuses on providing value to operations by prioritizing both verbal and non-verbal customer requirements. In parallel, operations and services are optimized to provide competitive advantage in the market. Full awareness of customers' needs provide products with the right specifications and functions. Also this approach tightens customer loyalty, resulting in constant cash flow.

4.2.2. QFD Methodology

Quality Function Deployment includes four phases. First phase is “Product Planning”. Market research provides this phase where customer requirements and expactations, warranty data, competitive opportunities, product measurements, competitive product dimensions and technical organization in order to analyze each customer requirement are detailed down. Afterwards, “Design Deployment” phase includes engineering department conducts part. It is necessary a creative and innovative team in order to find out what is the most important to customers as product when creating product concepts. Then the “Manufacturing Planning” phase is carried out, which is called process planning. In this phase, the flow chart of the production operations and the target values for each process are designed by engineers related to production. Manufacturing and quality assurance departments keep going to conduct the “Production Planning” phase as a final. Risks are evaluated in production processes, performance indicators are created to control system.

The first phase of the QFD method, “Product Planning” includes 11 steps. Each step is applied to fill a particular section of shown house of quality (Figure 4.2.).

1. Customer Requirements – “Voice of the Customer”: The target market segment is determined. Customer requirements for a product or service are collected through market research. Various Diagrams are used to organize and asses this data.

2. Customer Importance Ratings (Priority): Customers will be asked to rate their product or service requirements with scale 1-5. These rates are used later on in the relationship matrix.

3. Customer Rating of the Competition (Competitive Evaluations): Customers are then asked to compare the firm with its competitors according to the terms listed. It is important to draw attention to the knowledge of competitive advantage for each requirement.

4. Technical Descriptors – "Voice of the Engineer" (Product Design Requirements): The team of engineers define product or service attributes in order to measure and comparison of planned output.

5. Direction of Improvement: The direction of movement for each technical descriptor is identified by the team of engineers.

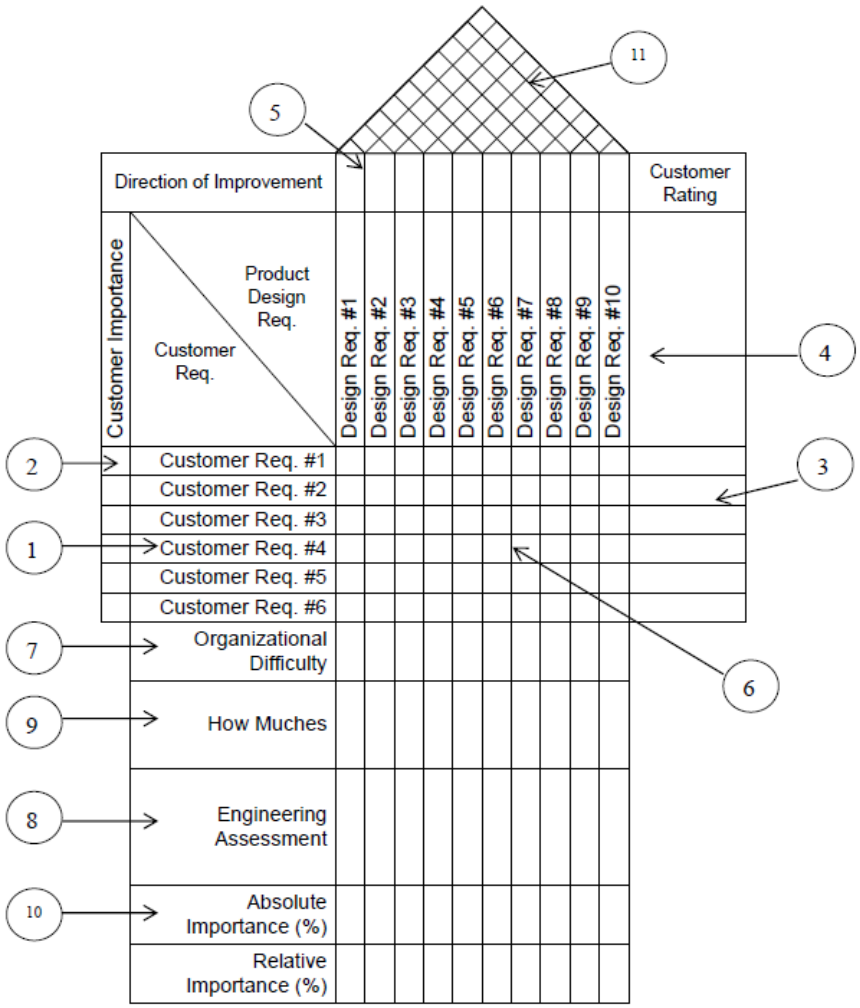


Figure 4.2: House of Quality

6. Relationship Matrix: The degree of relationship between the technical descriptors and customer requirements is evaluated. The relationship can be either verbally weak, moderate or strong, or it can be defined numerically as 1,3 or 9.

7. Organizational (Technical) Difficulty: Design features are graded in terms of organizational challenges.

8. Technical Analysis of Competitor Products (Technical Evaluations): The engineering team compares competitor technical descriptors. Some of this work may be the reverse engineering the customer products.

9. Target Values for Technical Descriptors: Technical team defines the target values for each technical descriptor in order to act as a base-line to compare against.

10. Correlation Matrix: This step is creating of the roof. The output of the correlation matrix examined the engineering team to understand how technical descriptors affect each other.

11. Absolute Importance (Importance Rating): At the final step, the absolute importance is calculated for each technical descriptor. Here, according to each customer's requirement, the value of the cell is multiplied by the value of the customer and then the value of each product is added to the design requirement. The relative importance weights are calculated using absolute importance values.

These steps are repeated for the last three phases of QFD method.

4.2.2.2. House of Flexibility

Concept of house of flexibility were introduce by Olgaher and West in 2002 (Olgaher and West, 2002). They did case study on Ericson that is interested in flexibility in redesigning the manufacturing system. The house of flexibility in its applications is built parallel to the quality house, which is the first stage of QFD. The customer requirements are linked with flexibility types. Other steps are similar. House of flexibility steps compared to the ones in the house of quality in the Table 4.3.. Erol Genevois and Gürbüz studied on automotive sector, Erol Genevois and Yensarfati studied on textile sector using house of flexibility concept.

Table 4.3: The Steps which Build the HoF Relative to HoQ (Olgaher and West, 2002)

Step	HoF	HoQ
1	Abilities – competitive priorities	Customer attributes
2	Relative importance – order winners/qualifiers	Relative importance
3	Customer perceptions	Customer perceptions
4	Flexibility characteristics	Engineering characteristics
5	Relationship matrix – linking abilities and flexibility	Relationship matrix
6	Correlation matrix	Correlation matrix
7	Objective measures, including competitor's visible performance	Objective measures, including competitor's products in technical terms
8	Target measures	Target measures

For house of flexibility, below steps are followed respectively.

First of all, customer requirements are listed. These customer requirement are ranked and determined importance rate by one of ranking method. Then, flexibility types are used in house of flexibility instead of technical descriptors. Each flexibility type can not be suitable for every sector, product and service. So it is a necessary to seek advice of experts the literature has been reviewed. A relationship matrix has been created in which the team evaluates the type of flexibility and the degree to which the customer characteristics affect. The correlation matrix is then filled in and the team members examine how the types of flexibility affect each other. As a final, absolute and relative importance values are calculated.

4.2.3. Advantages & Disadvantages of QFD

QFD encompasses the following advantages:

- In planning and design processes, the voice of the customer is taken effectively.
- Increase customer satisfaction,
- Improve quality,
- Presentation of a lot of information in a chart (e.g. HoQ)
- Companies connect with their customers,
- Developed communication within departments,
- Reducing the number of changes in a product,
- Initial cost is minimized,
- Key production requirements set earlier,
- This methodology is easy to use and to apply to problems.

Disadvantages of QFD methodology;

- Complex and time-consuming,
- Matrix size can be too large,
- It is difficult to distinguish between different and conflicting customer requirements,
- Conflicting Customer Requirements is not easy to resolve,
- Customer requirement is dynamic, only collecting existing customer requirement is not enough,
- Difficulty meeting all customer segments,
- Many technical descriptors could not be considered due to many constraints in time, budget and applicable technology,
- Customer requirements and technical descriptors can be addressed in subjective and ambiguous terms.

(Abu-Assab, 2012; Papic, 2007; Franceschini , et al., 1995; van de Poel, 2007; Kazemzadeh Azad, et al., 2009)

5. A FLEXIBILITY BASED RAPID RESPONSE MODEL IN AUTOMOTIVE SECTOR

As mentioned in the previous chapters, automotive sector including especially passenger cars has a significant role in the Turkish Economy. While sector has so many actors and their variabilities, automobile manufacturer have to assort with higher uncertainty and variability. The purpose of this study is to find out the best flexibility lever portfolio satisfying customer needs considering also supplier and retailer expectations and taking a fast action to handle with the uncertainties and the risks this company faces. In the end, the vision of perspective will be expanded and according to this vision, ability of strategic decision will be acquired to move ahead of competitors. Flexibility is given as a solution for this purpose. Companies that are flexible in their processes are thought to have developed their ability to adapt quickly to internal and external changes.

Initially, the supplier, based on the literature review in the previous sections on retailer and customer needs are consult with the experts. A questionnaire is prepared and the selected customers, suppliers and retailers needs are evaluated. Their needs can contain dependence within themselves. Unfortunately, this makes the evaluation difficult. For handling both the complexity of the group decision-making process, Analytic Network Process (ANP) is applied.

After the ranking of the expectations, the flexibility model based on the work of Olhager and West is applied to match these needs with the flexibility capabilities that the company can achieve. The relative weights calculated in ANP are used in the first house of flexibility as weights of the supplier, retailer and customer expectations. Then experts are asked to evaluate the relationship in between the flexibility types and the expectations. Afterwards to the calculation of the first house, the experts with the help of the literature chose system factors. In the second house, the relationship in between the

flexibility types and the system factors are evaluated. The application chart is given in Figure 5.1.

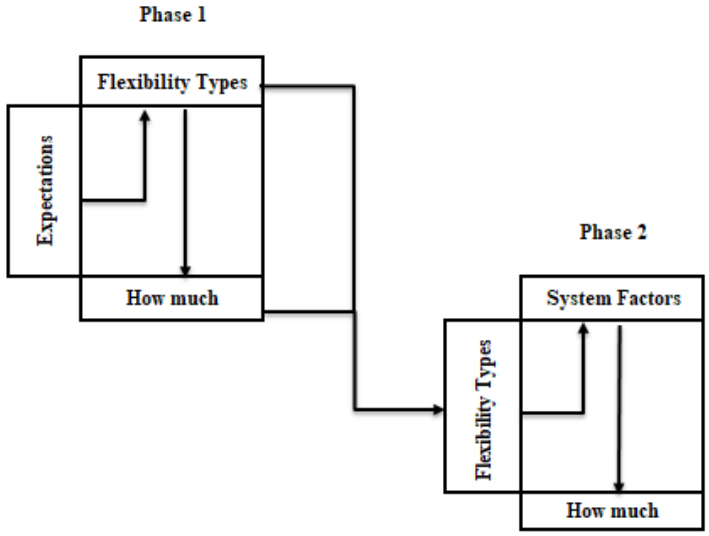


Figure 5.1: Two phases of HoF

As a final step, the results are discussed with the experts.

5.1. ANP Application

In this chapter, suppliers, retailers and customers expectation from automobile manufacturer that define in chapter 3 will be weighted and ranked. The ANP network was established based on recognized relationships between the criteria of expert opinion in Super Decisions software.

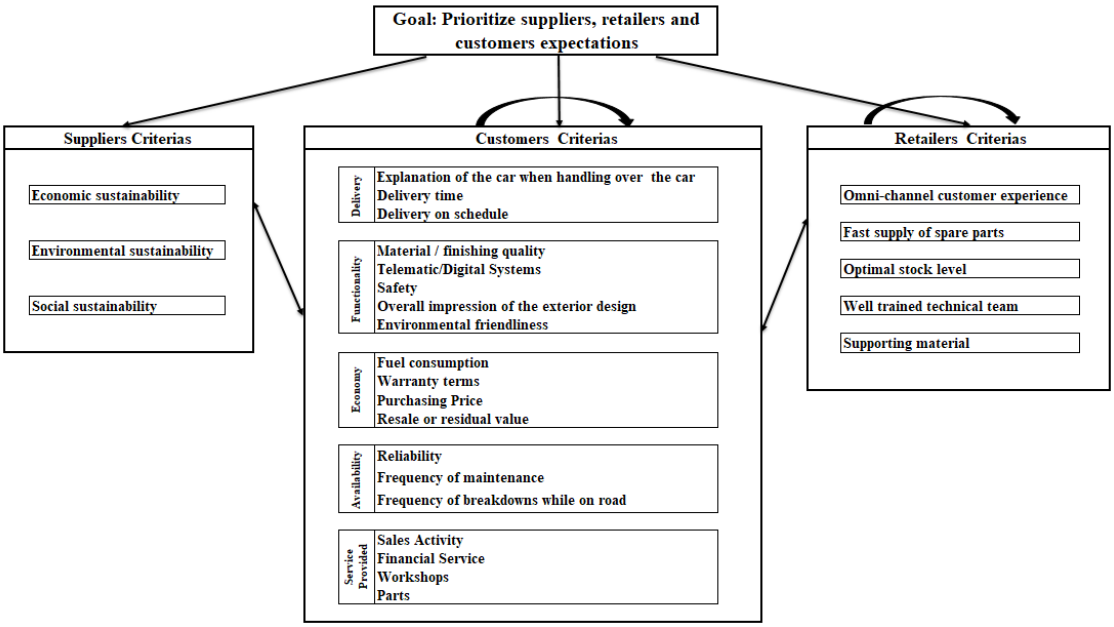


Figure 5.2: Network Model

The relations between criteria have been shown in ANP model in figure 5.1. as internal relations or feedback and also, external relations with other clusters through arrows.

Pairwise comparisons on a cluster level (Table 5.1.);

- Compare three main clusters with respect to the Goal. For example, we say that cluster Customer is more important than Supplier, 8 in Saaty's scale.

Table 5.1: Pairwise comparison on cluster level

	Customers	**Retailers**	**Suppliers**	**Relative Priorities**
Customers	1			0,78377
Retailers	1/8	1		0,08130
Suppliers	1/7	2	1	0,13493
CR	*0,033560*			

Pairwise comparisons on node level;

- Comparisons of the criteria with respect to the goal: For example, comparisons of criteria in Retailer with respect to Goal (Table 5.2.)

Table 5.2: Pairwise comporisons on node level-1

Retailers	Omni-channel customer experience	Fast supply of spare parts	Optimal stock level	Well trained technical team	Supporting material	Relative Priorities
Omni-channel customer experience	1					0,30177
Fast supply of spare parts	1/4	1				0,06186
Optimal stock level	1/3	2	1			0,09057
Well trained technical team	1/2	4	3	1		0,18970
Supporting material	1	4	4	3	1	0,35611
CR	*0,03520*					

- Comparisons of criteria with respect to other criteria – comparisons of the criteria that leave (influence) the criterion with respect to it: Omni-channel customer experience and Supporting Material with respect to Delivery on Schedule (Table 5.3.).

Table 5.3: Pairwise comporisons on node level-2

Delivery on schedule	Omni-channel customer experience	Supporting material	Relative Priorities
Omni-channel customer experience	1		0,75
Supporting material	3	1	0,25
CR	*0*		

Experts have filled the whole tables, their evaluations are presented in Appendix 2. The consistency ratios are calculated for the ANP methodology with the formulas given in Chapter 4. Any values exceeding the upper bound of 0,10 does not exist.

In the last step, according to these pair-wise comparisons, the unweighted, weighted, limit super matrixes are constructed. The weighted super matrix is given in Table B.1.

Then the limiting priorities of the weighted super matrix are calculated. This limiting super matrix is given in Table B.2.

The following table is taken from the ranks obtained for the sub-criteria within the clusters of problem model of research (Table 5.4.).

Table 5.4: Result of ANP

Actors		Criteria Name	Normalized weights by Cluster	Local Ranks (Rate in Cluster)	Total Weight (Limiting)	Total Ranks	Sum of the weights assigned to each cluster
Suppliers		Economic sustainability	0,633708	1	0,09406	3	0,1324
		Environmental sustainability	0,174371	3	0,02353	15	
		Social sustainability	0,191921	2	0,01480	20	
Retailers		Omni-channel customer experience	0,301766	2	0,02343	16	0,0852
		Fast supply of spare parts	0,061856	5	0,00703	26	
		Optimal stock level	0,090570	4	0,00736	25	
		Well trained technical team	0,189702	3	0,01742	19	
		Supporting material	0,356106	1	0,02995	11	
Customers	Delivery	Explanation of the car when handling over the car	0,007917	19	0,00521	27	0,7824
		Delivery time	0,0112	18	0,00768	24	
		Delivery on schedule	0,016412	17	0,01286	22	
	Functionality	Material / finishing quality	0,045138	9	0,03694	10	
		Telematic/Digital Systems	0,133802	1	0,11487	1	
		Safety	0,133066	2	0,10429	2	
		Overall impression of the exterior design	0,028246	14	0,02114	18	
		Environmental friendliness	0,018837	16	0,01376	21	
	Economy	Fuel consumption	0,086524	4	0,06781	5	
		Warranty terms	0,039538	12	0,01099	23	
		Purchasing Price	0,10402	3	0,08153	4	
		Resale or residual value	0,050133	8	0,03929	9	
	Availability	Reliability	0,070578	5	0,06532	6	
		Frequency of maintenance	0,04186	10	0,02809	13	
		Frequency of breakdowns while on road	0,041506	11	0,02253	17	
	Service Provided	Sales Activity	0,022159	15	0,02737	14	
		Financial Service	0,031809	13	0,02993	12	
		Workshops	0,057845	7	0,04524	8	
		Parts	0,059411	6	0,04756	7	

In view of above table, according to obtained weights in this part the most important criteria can be investigated among all criteria and also, they can be seen through elements inside any cluster and priority of criteria can be also determined based on existing weight in column “Total Weight (Limiting)” and in column of “Normalized weights by cluster”, obtained priorities are observable for any criterion in the “Total Rank” column.

As seen from the relative weights in Table 5.4., in the customer segment Telematic/Digital systems and safety, in the retailer segment supporting materials and omni-channel customer experience, in the supplier segment economic sustainability are the most significant criteria. As a automotive manufacturer the main important expectations from us are Telematic/Digital systems, safety and economic suitability overall.

Nowadays, it is evident that the product’s Telematics/Digital system is more important for customers accordingly for automotive manufacturer. Safety is still remains important. As economic sustainability influences to parts/components cost, it is one of priority of automotive manufacturer.

5.2. QFD Application

Manufacturing firms should manage successfully all of the issues and problems stated previously to be a leading figure in the automotive sector. In chapter 2, flexibility types as internal and external are defined. If we have unlimited source which is not possible in the real world, the defined flexibility types are implemented to company. Thereof it is necessary to determine importance of flexibility types according to supplier, retailer and customer in the first house. Using the QFD, which flexibility type can accomplish supplier, retailer and customer expectations and at what extent is evaluated. Then, in the second house, according to the result of fist house, system factors are defined and evaluated by expert.

5.2.1 First House

The flexibility types for this application are divided into two as internal and external flexibility. The flexibility types that define in chapter 2 are used in this application. The experts made their assessment based on the type of flexibilities.

The evaluation of the experts is given in Table 5.5. Boxes that are not evaluated show that there is no relationship between expectations and flexibility types. The value of “1” expresses little correlation, “3” expresses more correlation and “9” expresses great correlation.

Table 5.5: House of Flexibility

			Internal									External																	
Importance (%)	Actors	FLEXIBILITY TYPES / EXPECTATIONS	Operations Flexibility	Process Flexibility	Expansion Flexibility	Routing Flexibility	Storage Flexibility	Network Flexibility	Organizational Flexibility	Labor Flexibility	Worker Flexibility	Product development Flexibility	New product design Flexibility	Product modification Flexibility	Manufacturing Flexibility	Volume Flexibility	Mix Flexibility	Procurement Flexibility	Sourcing Flexibility	Supply Flexibility	Purchasing Flexibility	Logistics Flexibility	Delivery Flexibility	Marketing Flexibility	Launch Flexibility	Responsive Flexibility	Information systems Flexibility	Spanning Flexibility
9,41	Suppliers	Economic sustainability						1					1		1	1	1	9	9										
2,35		Environmental sustainability	3	3	3		1						1			1	1	3	1			1							
1,48		Social sustainability				3	3	3										9	9			3							
2,34	Retailers	Omni-channel customer experience	3	3		3		1			3			3										9	1	9	9	9
0,70		Fast supply of spare parts		9	9	9		9	9	9					1	3	1	3	9	9	9	3	9						
0,74		Optimal stock level					3									3						9							
1,74		Well trained technical team						3	9		9																		
3,00		Supporting material										1	1											9			3		
0,52	Customers	Explanation of the car when handling over the car										1																	
0,77		Delivery time	9	9		3		9		3				9		9	3			9	9	3	9						
1,29		Delivery on schedule	9			9		1	3					9	9	3	9			3	9	9	9						
3,69		Material / finishing quality		3							3	3	1		9		3	9	9										
11,49		Telematic/Digital Systems		3								9	9		9										9		9	9
10,43		Safety		3								9	9		9										3		3	
2,11		Overall impression of the exterior design										3	3	9	3										3			
1,38		Environmental friendliness	3	3				3	1			1	3		1													
6,78		Fuel consumption										3	3		3										3			
1,10		Warranty terms	3																									
8,15		Purchasing Price																						9				
3,93		Resale or residual value																						3				
6,53		Reliability											1		3													
2,81		Frequency of maintenance										1																
2,25		Frequency of breakdowns while on road		9								1																
2,74		Sales Activity							3	1	3													9	9	9		9
2,99		Financial Service							1		1													9		9		
4,52		Workshops		3	9			9	9	9	9																	
4,76		Parts		3			3	3								3	3	3	9	9		9	9					
		WEIGHT	40,0	156,4	54,1	31,7	23,3	95,0	79,2	52,1	85,7	245,0	253,0	44,5	299,8	41,1	51,7	154,7	182,7	59,9	24,8	72,2	67,6	184,8	188,3	72,7	164,7	149,1
		RELATİVE WEIGHT (%)	**1,39**	**5,44**	**1,88**	**1,10**	**0,81**	**3,31**	**2,75**	**1,81**	**2,98**	**8,52**	**8,80**	**1,55**	**10,43**	**1,43**	**1,80**	**5,38**	**6,36**	**2,08**	**0,86**	**2,51**	**2,35**	**6,43**	**6,55**	**2,53**	**5,73**	**5,19**

According to the results of the first house, the importance weights of the flexibility types satisfying the supplier, retailer and customer needs are presented below (Table 5.6). The first five flexibility types are manufacturing, new product design, product development, launch and marketing flexibility.

Table 5.6:Importance Ranking of Flexibility Types by HoF

Flexibility Types	**Relative Importance (%)**
Manufacturing Flexibility	10,432
New product design Flexibility	8,804
Product development Flexibility	8,523
Launch Flexibility	6,552
Marketing Flexibility	6,429
Sourcing Flexibility	6,357
Information systems Flexibility	5,732
Process Flexibility	5,442
Procurement Flexibility	5,381
Spanning Flexibility	5,188
Network Flexibility	3,307
Worker Flexibility	2,982
Organizational Flexibility	2,754
Responsive Flexibility	2,528
Logistics Flexibility	2,513
Delivery Flexibility	2,353
Supply Flexibility	2,084
Expansion Flexibility	1,882
Labor Flexibility	1,812
Mix Flexibility	1,799
Product modification Flexibility	1,550
Volume Flexibility	1,431
Operations Flexibility	1,392
Routing Flexibility	1,102
Purchasing Flexibility	0,863
Storage Flexibility	0,810

The ability to manage production resources to meet demands is still important in automotive sector. If company has a strong ability of manufacturing flexibility, it can

ahead of competitors smoothly. Nowadays, having design flexibility for new product is feature of company leading markets. The ability to respond to changing customer needs with new products and changes made to existing products is one of significant issues for automotive sector. Every year, automotive company makes changes to their own models and launces them to the target market. Marketing flexibility is important as launch flexibility. As a result, in order for the brand to be successful in processes such as Research & Development, design, production and marketing, departments must cooperate and support each other's operations with feedback. These flexibilities cannot considered being independence of each other. However, investment amount of companies should change according to above importance flexibility table. Thereof, the purpose of the second house is to identify the system factors providing the flexibility types and to find out the importance weights of these system factors. The system factors are selected from the literature with the help of the experts, their meanings for this application are given below.

5.2.2. The Best Portfolio

As using the result of first house, the best flexible portfolios can be provides. The aim of this study is that all expectations can be satisfied maximum with constraint of minimum flexibility. Due to many variables, Heuristic Programming is used. We use one of heuristic method which name is Randomly Generated Solutions to have a quickly, reasonable solution.

One relatively straightforward concept is to randomly generate feasible solutions to the problem, evaluate each and choose the best. Baum and Carlson affirmed that one could decide on the number of trials so as to achieve a desired probability that the best solution obtained is better than a prescribed percentage of all solutions.

We choose manufacturing, new product design, product development, launch, marketing flexibilities that are highest weights as external flexibility. For rest of expectations that are not met process and network flexibility choose from internal flexibilities. Sourcing, information systems, procurement flexibility are not took to the suggested portfolio, even

their highly weighted. The reason of this approach, the minimum number of flexibility types is desired to be used because of the constraints. This flexibility portfolio is a reasonable solution in heuristic methodology.

Table 5.7: Minimum Flexibility Portfolio

			Internal									External																	
Importance (%)	Actors	FLEXIBILITY TYPES / EXPECTATIONS	Operations Flexibility	Process Flexibility	Expansion Flexibility	Routing Flexibility	Storage Flexibility	Network Flexibility	Organizational Flexibility	Labor Flexibility	Worker Flexibility	Product development Flexibility	New product design Flexibility	Product modification Flexibility	Manufacturing Flexibility	Volume Flexibility	Mix Flexibility	Procurement Flexibility	Sourcing Flexibility	Supply Flexibility	Purchasing Flexibility	Logistics Flexibility	Delivery Flexibility	Marketing Flexibility	Launch Flexibility	Responsive Flexibility	Information systems Flexibility	Spanning Flexibility
9,41	Suppliers	Economic sustainability						1					1		1	1	1	9	9										
2,35		Environmental sustainability	3	3	3		1						1			1	1	3	1			1							
1,48		Social sustainability				3	3	3										9	9			3							
2,34	Retailers	Omni-channel customer experience	3	3		3		1			3			3										9	1	9	9	9
0,70		Fast supply of spare parts		9	9	9		9	9	9					1	3	1	3	9	9	9	3	9						
0,74		Optimal stock level					3									3						9							
1,74		Well trained technical team						3	9		9																		
3,00		Supporting material										1	1											9			3		
0,52	Customers	Explanation of the car when handling over the car										1																	
0,77		Delivery time	9	9		3		9		3				9		9	3			9	9	3	9						
1,29		Delivery on schedule	9			9		1	3					9	9	3	9			3	9	9	9						
3,69		Material / finishing quality		3							3	3	1		9		3	9	9										
11,49		Telematic/Digital Systems		3								9	9		9										9		9	9
10,43		Safety		3								9	9		9										3		3	
2,11		Overall impression of the exterior design										3	3	9	3										3			
1,38		Environmental friendliness	3	3				3	1			1	3		1													
6,78		Fuel consumption										3	3		3										3			
1,10		Warranty terms	3	1																									
8,15		Purchasing Price																						9					
3,93		Resale or residual value																						3					
6,53		Reliability											1		3														
2,81		Frequency of maintenance										1																	
2,25		Frequency of breakdowns while on road		9								1																	
2,74		Sales Activity							3	1	3													9	9	9		9
2,99		Financial Service							1		1													9		9			
4,52		Workshops		3	9			9	9	9	9																		
4,76		Parts		3			3	3								3	3	3	9	9		9	9						
		WEIGHT	40,0	157,5	54,1	31,7	23,3	95,0	79,2	52,1	85,7	245,0	253,0	44,5	299,8	41,1	51,7	154,7	182,7	59,9	24,8	72,2	67,6	184,8	188,3	72,7	164,7	149,1
		RELATİVE WEIGHT (%)	**1,39**	**5,48**	**1,88**	**1,10**	**0,81**	**3,31**	**2,75**	**1,81**	**2,98**	**8,52**	**8,80**	**1,55**	**10,43**	**1,43**	**1,80**	**5,38**	**6,35**	**2,08**	**0,86**	**2,51**	**2,35**	**6,43**	**6,55**	**2,53**	**5,73**	**5,19**

As a result this flexibility portfolio defined above is met whole supplier', retailer' and customers' expectations (Table 5.7).

5.2.3 Second House

Human resources (workforce): The human resources of the manufacturing company comprise of white-collar and blue-collar employees. Owing to qualified and skilled workforce, operations are performed with minimum waste and highest efficiency.

Creative expert team: Creative expert team determines the trends of passenger car's world by collecting marketing events and feedback from customers, following closely technology development. They also work on Research & Development activities, assist in the selection of raw materials. Provide information with respect to production costs and manufacturing processes is one of their responsibility.

Organizational structure: Organizational structure is an important element. Organization should provide seamless information flow within organizational units and communicate effectively between departments and external stakeholders. It is more likely to make better decisions on time in case of providing of information sharing by organization.

System capacity: System capacity can be defined as the total output rate of the business process. This capacity should be balanced with the work required to meet retailer and customer expectations. System capacity depends on the sum of all organizational units (export, warehouse, etc.) that constitute the whole system.

Raw material: Passenger cars require a wide range of raw materials for their production, including petroleum products used in the construction of automobiles, steel, aluminum, glass, iron, plastic, rubber and special fibers. Raw materials must be processed and tested in order to be liked and purchased the products by the target customer segment.

Product development: Product development process should be handle effectively. It is important to integrated technological and innovative developments. On the other hand, being the first in the market with the right products provides a large amount of competitive advantage. This action makes sure that company becomes leader and causes that competitors tent to follow the leader (Example E-car/Tesla). Concurrent engineering, integrated product-process design, multifunctional teams and incorporation feedback of customers are some of the solutions that enable effective product development.

Research & Development: Research and development activities consist of raw material research for product differentiation, testing the convenience of the safety, matching the product attributes with the raw material properties, etc.

Business development: Participate in fairs, find the necessaire dealer locations, new market development, new marketing and sales channels development are part of business development activities.

Innovation and Technology: Innovation and technology have a positive effect on all the system factors mentioned above. Successful automotive manufacturing companies are using the most advanced innovations and technologies to produce more efficiently.

Supply chain: The supply chain is directly or indirectly related to the fulfillment of the customer expectations. Retailers belong to the supply chain as much as the manufacturer and suppliers do. In the automotive sector, supply chain management is critical issue. Supply chain process must be addressed by actors ideally.

Information systems: Information systems include ERP, SAP, CRM, tracking system, B2B and B2C of retailers. In order to control the operations, processes and to increase the effectiveness of the organization, information systems are integrated to manufacturing company. Information must be accurate and fast to the system. Sorting out customer data from CRM system, preparing special campaign for these customers for a specific time, sending promotion information provide to increase customer loyalty.

Retail and marketing systems: Marketing department faces customer organizational unit in a manufacturing company. Their responsibilities are reunite other departments and

customers. Retail and marketing systems lead campaign, field activities, CRM, sales, advertising and stock management.

Table 5.8: Second House

Relative Importance from First House (%)	System Factors / Flexibility Types	Human resources	Creative expert team	Organizational structure	System capacity	Raw material	Product development	Research & Development	Business development	Innovation and Technology	Supply chain	Information systems	Retail and marketing systems
10,43	Manufacturing Flexibility	1			9	9							
8,80	New product design Flexibility		9			1	3	9	3	9		1	
8,52	Product development Flexibility		9			1	9	9	9	9		1	
6,55	Launch Flexibility			3	1							1	3
6,43	Marketing Flexibility	1		3								3	9
6,36	Sourcing Flexibility	1		3		3					3	3	
5,73	Information systems Flexibility			1					3			9	1
5,44	Process Flexibility	1	1	3			3	3					
5,38	Procurement Flexibility			3							9	1	
5,19	Spanning Flexibility	1		3					9		9	9	9
3,31	Network Flexibility	3		9								1	
2,98	Worker Flexibility	3	3	1									
2,75	Organizational Flexibility	9	1	9									
2,53	Responsive Flexibility		3				3	3	9				9
2,51	Logistics Flexibility				3						9	1	
2,35	Delivery Flexibility				3						9	1	
2,08	Supply Flexibility			1	1						9	1	
1,88	Expansion Flexibility				9								
1,81	Labor Flexibility	9	3	1									
1,80	Mix Flexibility		3		3		9			3			
1,55	Product modification Flexibility	3					9	3		3			
1,43	Volume Flexibility	9		3	9								
1,39	Operations Flexibility			3	3								
1,10	Routing Flexibility		3		1								
0,86	Purchasing Flexibility			3							1		
0,81	Storage Flexibility				3						1		
	WEIGHT	111,33	194,8	184,3	160	130,3	157,2	184,5	189,8	166	178,4	176,2	152,7
	RELATİVE WEIGHT (%)	**5,6**	**9,8**	**9,3**	**8,1**	**6,6**	**7,9**	**9,3**	**9,6**	**8,4**	**9,0**	**8,9**	**7,7**

The house built for the second stage is given above (Table 5.8.) The weights from the house of flexibility and the values obtained from the system factor evaluation are given in the below table (Table 5.9.). Creative expert team has a high importance weight (9,81%). This is the most important system factor in providing flexibility types in the first house. The second and third important system factors are Business Development, and Research and Development respectively. Researching for new market, marketing method,

sales channels and also development product are indispensable system factors. Nowadays, this is expected result for any sector and company. If there is no well structured organization, it is not possible to fulfill the above described flexibilities. Lastly fifth factor is supply chain. Considering supplier and retailer expectations, allows taking place at the top of the list of these factors. Surprisingly, workforce is found to be least important system factors. This can be interpreted as one of the consequences of the current state of technology.

Table 5.9: Importance Ranking of System Factors by HoF

System Factors	Relative Importance (%)
Creative expert team	9,812
Business development	9,558
Research & Development	9,293
Organizational structure	9,281
Supply chain	8,986
Information systems	8,872
Innovation and Technology	8,361
System capacity	8,061
Product development	7,916
Retail and marketing systems	7,691
Raw material	6,562
Human resources	5,608

6. CONCLUSION

As a result, it can be said that today manufacturing companies are in serious competition and in a certainty environment. In order to handle these and increase the market share, being flexible becomes an obligation. Many academic researchers studied on flexibility concept. The automotive sector is one of the areas where flexibility is needed. The main reasons of this can be explain as follow. Firstly, automotive sector consists of many actors such as suppliers, retailers that can also do repairs and maintenance as well as sales, manufacturers, stakeholders, customers who decide to buy, indirect customers (passengers, drivers etc.). Secondly, Due to the impact of technology developments, the environment changes very rapidly. In addition, the sector is a great contribution to both the world and Turkey's economy. For the reasons mentioned above, the application is made for the automotive company and the best flexibility portfolio is being investigated.

As a methodology, a decision-making model was developed by combining analytical network process (ANP) and quality function deployment (QFD). This application is made for passenger cars manufacturer and its aim is to analyze best flexibility lever portfolio based on supplier, retailer and customer expectations. As a result, quick solutions are provided to deal with uncertainties and the risks faced by company. Firstly, supplier, retailer and customer expectations are ranked within themselves, then according to automotive manufacturer their importances are ranked via ANP, secondly the flexibility levers matching the expectations are weighted using two phased QFD which is house of flexibility concept defined by Olhager and West (2002). Finally, system factors are assessed and the result are negotiated with experts.

In general, customer, supplier and retailer are respectively important according to automotive manufacturer. It is a very meaningful result that the first priority of the firms is the customers. Suppliers that are one of the most important elements of the supply chain rank higher than retailers. Due to supplier's performances influences directly to product, this affect causes to influence to customer indirectly. According to total ranks via ANP, the most important expectations is Telematic/Digital systems from customer. Having more technology and digital systems is first priority for passenger car customers as expected result. Safety is secondly important expectations, still today customer do not tend to buy passenger cars that they do not feel safe. Because of this factor, manufacturer should focus more research and development about safety elements. This factor is following by economic sustainability from supplier expectations, purchasing price and fuel consumption from customer expectations. These threes are related to economic expectations. Due to parts prices agreed with suppliers are related indirectly to products price, It is reasonable to take place at the beginning of the list.

In the first phase of QFD, supplier, retailer and customer expectations are reduced to manufacturer requirements, in other words, to types of flexibility. Manufacturing, new product design, product development and launch flexibility constitute an important part of the overall flexibility. Managing production resources to meet demands is still important in automotive sector. Company having a strong ability of manufacturing flexibility can ahead of competitors smoothly. It is expected that new product design, product development are weighted as significant in order to lead market. As a point of view, it is not possible that a company contains whole flexibility types defined above. In the scope of study, the best portfolio that all expectations can be satisfied maximum with constraint of minimum flexibility is proposed. New product design, product development, launch, marketing flexibilities as external flexibility, process and network flexibility as internal flexibility meet whole expectations from manufacturer.

As using the result of first house, the best flexible portfolios can be provides. The aim of this study is that all expectations can be satisfied maximum with constraint of minimum

flexibility. Manufacturing, new product design, product development, launch, marketing flexibilities that are highest weights are selected as external flexibility. For rest of expectations that are not met process and network flexibility chose from internal flexibilities. Sourcing, information systems, procurement flexibility are not took to the suggested portfolio, even their highly weighted. The reason of this approach, the minimum number of flexibility types is desired to be used because of the constraints. Companies suffering from limited resources should invest to these flexibilities at least to provide maximum benefit.

In the second phase of the QFD, the problem types are explained in detail by reducing the flexibility types determined in the first phase to the system factors. Ideally, whole flexibility types are taken into account. Looking at the results of the second house, creative team, business development and Research & Development system factors are prioritized and constitute the majority of the weight. A strong automotive company have to do Research & Development activities and the Research & Development processes should be effectively managed with the strong and creative team. These factors should be supported by business development activities such as find the necessaire dealer locations, new market development, new marketing and sales channels development. Communicating effectively between departments and external stakeholders as organizational structure is one of important factor in order to make better decisions on time.

Organizational structure is an important element. Organization should provide seamless information flow within organizational units and communicate effectively between departments and external stakeholders. It is more likely to make better decisions on time in case of providing of information sharing by organization. Although this factor may seem to implement, it is challenge for automotive companies with fifty thousand employees. Taking account of suppliers and retailer expectations in the scope of study provides, supply chain factor is provided to take place at the top of the list of factors. Experts are surprised on fact that As the another remarkable result of the study, workforce

is found to be least important system factors because of consequences of the current state of technology.

In future work, the scope of expectations can be expanded taking accounts of shareholder expectations to study. Creating portfolio can be made by taking into account the costs of flexibility types to firms. Cost effect influences to decision-making processes. This approach will enable the company to select the best portfolio more realistically and meet expectations. The study might be evaluated to another sector.

REFERENCES

Abi, R. (2016). *ABI Research Forecasts Global Penetration of OEM Telematics in New Passenger Cars to Exceed 72% by 2021.*

Abu-Assab, S. (2012). Quality Function Deployment in New Product Development. In *Integration of Preference Analysis Methods into Quality Function Deployment: A Focus on Elderly People* (Vols. 47-68).

Alvarez-Gil, M.J. (1994). Capital budgeting and flexible manufacturing, *International Journal of Production Economics*, No. 36, pp. 109-28.

Akao, Y. (1987), Quality Deployment*: A Series of Articles, (Lawrence, MA: G.O.A.L., Inc.) Translated by Glen Mazur.*

Anderson, J. E. (2016). *Policy Impact, Evaluation and Change.* Content Technologies.

Russo, A., Morrone, D., & Calace, D. (2015). The Green Side of the Automotive Industry: A Consumer-Based Analysis. *9(2).*

Barad, M. and Nof, S. (1997). CIM flexibility measures: a review and framework for analysis and applicability assessment, *International Journal of Computer Integrated Manufacturing*,Vol. 10 Nos 1/4, pp. 296-308.

Baum S and Carlson R (1979). On solutions that are better than most. *Omega* 7: 249- 255.

Beamon, B. (1999). Measuring supply chain performance. *19(3),275–292*.

Bekker, H. (2019, February 23). *2018 (Full Year) International: Worldwide Car Sales and Global Market Analysis.* Retrieved from Car Sales Statistics: https://www.best-selling-cars.com

Chan L.-K., W. M.-L. (2002). Quality function deployment: a literature review. *143, pp. 463-97*.

Cheng, E., & Li, H. (2004). Contractor Selection Using The Analytic Network Proces. *22*(1021–1032).

Chung, S. H., Lee, A. H., & Pearn, W. L. (2005). Analytic Network Process (ANP) Approach for Product Mix Planning in Semiconductor Febeicator. *96, No. 1, 15-36*.

D'Souza, D.E. and Williams, F.P. (2000). Toward a taxonomy of manufacturingflexibility dimensions, *Journal of Operations Management*, Vol. 18 No. 5, pp. 577- 93.

Francas D. et al.(2009). Strategic process flexibility under lifecycle demand. *International Journal of Production Economics*, 121, 427-440.

De Toni, A. and Tonchia, S. (1998). Manufacturing flexibility: a literature review, International, *Journal of Production Research*, Vol. 36 No. 6, pp. 1587-617.

Diffner, B. (2011). Combining Flexibility And Efficiency In Automotive Assembly - Preparing For New Powertrain Vehicles. *Linköping Studies In Science And Technology*.

Erol Genevois, M., & Gürbüz, T. (2009). Finding the best flexibility strategies by using an integrated method of FAHP and QFD. *IFSA/EUSFLAT Conference*, (pp. 1126-1131).

Erol Genevois & Yensarfati D. (2010). A Flexibility Based Rapid Response Modeling Ready to Wear Sector, in Turkey- İstanbul.

Fawkes, T. (2015 , September 20). *How achievable is one-hour delivery in the automotive industry?* Retrieved from https://automotivelogistics.media.com.

Franceschini , F., & Rossetto , S. (1995). QFD: The Problem of Comparing Technical/Engineering Design Requirements. (270-278).

(n.d.). *General and Statistical Information Bulletin Of Automotive Manufacturers.* 2018: OSD.

Gong, Z. (2008). An economic evaluation model of supply chain flexibility. *184(2),745–758*.

Griffin, A, and Hauser, J. (1991). The Voice of the Customer. *The International Center for Research on the Management of Technology*. Cambridge.

Griffin, A., and Hauser, J. (1992). Patterns of communications among marketing, engineeringand manufacturing – a comparison between two new product teams. *38 No. 3, pp. 360-73*.

Grigore S.D. Supply Chain Flexibility, *Romanian Economic and Business Review*. - 1 : Vol. 2.

Gupta, Y., & Goyal, S. (1989). Flexibility of manufacturing systems: concepts and measurements. *European Journal of Operational Research*, 119-35.

Gupta, Y. and Somers, T. (1996). Business strategy, manufacturing flexibility, and

organizational performance relationships: a path analysis approach, *Production and Operations Management,* Vol. 5 No. 3, pp. 204-31.

Hopp, W. (2010). Vertical flexibility in supply chains. *56(3),495–502*.

Ince, H., & Ozkan, A. S. (2015). THE ROLE OF SUPPLY CHAIN COLLABORATION ON SUSTAINABLE SUPPLY. *Journal of Management, Marketing and Logistics*, 223-231.

Jaikumar, R. (1986). Postindustrial manufacturing, *Harvard Business Review*, Vol. 64 No. 6,pp. 69-76.

Jin, Y., Vonderembse, M., Ragu-Nathan, T. S., & Smi, J. T. (2014). Exploring Relationships among IT-enabled Sharing Capability,Supply Chain Flexibility, and Competitive Perfomance. *153: 24–34.*

Kaighobadi, M. and Venkatesh, K. (1994). Flexible manufacturing systems: an overview, *International Journal of Operations & Production Management*, Vol. 14 No. 4, pp. 26-49.

Kambiz Peykarjou, N. N. (2015). Using Analytic Network Process (ANP) in evaluation and prioritization the barriers of credit rating insurance companies in Iran . *4, No.1*.

Kassarjian, H. H. (1971). Incorporating Ecology into Marketing Strategy: The Case of Air Pollution. *35, 61-65*.

Kazemzadeh Azad, S., Kazemzadeh Azad, S., & Kulkarni , A. (2009). Structural optimization using a mutation based genetic algorithm. (1020).

Korosec, K. (2016, July 20). *Vehicle Breakdowns Hit Record High in U.S. Despite New Car Tech*. Retrieved from http://fortune.com.

Koste, L., & Malhotra, M. (2000). Trade-offs among the elements of flexibility: a comparison from the automotive industry. *Omega*, 693-710.

Lummus, R. (2003). Supply chain flexibility : building a new model Global. *4(4),1–13*.

Lummus, R. D. (2005). Delphi study on supply chain flexibility. *43(13),2687–2708*.

Madan M. Jagtap, S. (2014). Warranty Process Flow Analysis In Automotive Industry. *3, Issue3*.

Manders, J. (2014). Supply chain flexibility : a systematic literature review and research directions for future research. *Annual conference IPSERA (South-Africa).*

Mander, J. H., M. Caniëls, M. C., & Ghijsen, P. W. (2016). Exploring supply chain flexibility in a FMCG food supply chain. *Journal of Purchasing and Supply Management*, 181–195.

Mehrjerdi, Y. Z. (2010). Quality function deployment and its extensions. *27 No. 6*(pp. 616-640).

Meade, L., & Sarkis, J. (1999). Analyzing organizational project alternatives for agile manufacturing process: An analytical network approach. (37 (2): 241-261).

Nair, A. (n.d.). Linking manufacturing postponement,centralized distribution and value chain flexibility with performance. *43(3),447–463.*

Nakauchi, E. (2014, September 16). *Component reliability in the automotive industry.* Retrieved from www.ecnmag.com.

Novosilska, L. (2018, November 29). *5 Ways Telematics is Impacting Connected Car*. (Ignite Ltd.) Retrieved from https://igniteoutsourcing.com.

Olhager, J. & West, B. (2002). The house of flexibility: Using the QFD approach to deploy manufacturing flexibility, *International Journal of Operations & Production Management*, Vol. 22 No. 1, pp. 50-79.

Papic, L. (2007). Deploying customer requirements via four stage team approach in business planning. In I. J. Eng. 14(03) : 263-274.

Parker R, Wirth A (1999). Manufacturing flexibility: measures and relationships. *European journal of operational research* 118(3):429–449.

Pfitzer, S., & Rudolph, S. (2007). Re-Engineering Exterior Design:Generation Of Cars By Means Of A Formal Graph-Based Engineering Design Language. *07/258.* Paris: *International Conference On Engineering Design*.

Riley, M. and Lockwood, A. (1997). Strategies and measurement for work force flexibility: an application of functional flexibility in a service setting, *International Journal of Operations & Production Management*, Vol. 17 No. 4, pp. 413-9.

Saaty, T. L., & Ozdemir, M. (2005). Theory and applications of the analytic network process : decision making with benefits, opportunities, costs, and risks. WS publications.

Saaty, T. (1980). The Analytic Hierarchy Process.

Saaty, T. (1996). Decision making with dependence and feedback: The analytic network process.

Saaty, T. (2001). Decision Making with Dependence and Feedback: The Analytic Network Process.

Sarkis J. and Sundarraj R. S. (2005). Evaluation of Enterprise Information Technologies: A Decision Model for High-Level Consideration of Strategic and Operational Issues. (1-14).

Sánchez A.M.,& Pérez Pérez M. 2005. Supply chain flexibility and firm performance, *International Journal of Operations & Production Management*, Volume 25, Number 7.

Sethi A, & Sethi S (1990). Flexibility in manufacturing: a survey. *International Journal of Flexible Manufacturing Systems* 2(4):289–328.

Schütz, P. (2011). The impact of flexibility on operational supply chain planning. *134(2),300–311*.

Sethi, A. (1990). Flexibility in manufacturing. *2(4),289–328*.

Sheth, K. (2017, April 25). *All About The Automotive Industry*. Retrieved from www.worldatlas.com.

Skintzi, G. (2007). Supply chain design.

Slack, N. (1987). The flexibility of manufacturing systems, *International Journal of Operations& Production Management*, Vol. 7 No. 4, pp. 35-45.

Soon, Q. (2011). Supply chain management from the perspective of value chain flexibility. *22(4), 505–526*.

Pfitzer, S., & Rudolph, S. (2007). Re-Engineering Exterior Design:Generation Of Cars By Means Of A Formal Graph-Based Engineering Design Language. *07/258*.

Stevenson, M. (2007). Flexibility from a supply chain perspective. International Journal of Operations & Production Management .

Sullivan, L. (1986). Quality function deployment . *19 No. 6, pp. 39-50*.

Swafford, P. (2000). A model of global supply chain agility and its impact on competitive performance. *1037–1039*.

T. L. Saaty, &. M. (2010). The analytic hierarchy and analytic network measurement processes: The measurement of intangibles. In *Handbook of multicriteria analysis* (Vols. 91–166). Berlin: Springer: In C. Zopounidis & P. M. Pardalos (Eds.).

Tran, L., Knight, C., & O'neill, R. (2004). "Integrated Environmental Assessment Of The Mid-Atlantic Region With Analytical Network Process. In *Environmental Monitoring And Assessment 94* (Vols. 263-277). Kluwer Academic Publishers.

Tachizawa, E. (2007). Drivers and sources of supply flexibility . *27(10),1115–1136*.

Tellem, T. (2009, May 12). *Top 10 High-Tech Car Safety Technologies*. Retrieved from www.edmunds.com.

van de Poel, I. (2007). Methodological problems in QFD and directions for future. (18:21–36).

Upton, D.M. (1994), The management of manufacturing flexibility, *California ManagementReview*, Vol. 36 No. 2, pp. 72-89.

Vickery, S., Calantone, R. and Dro¨ge, C. (1999). Supply chain flexibility: an empirical study, *The Journal of Supply Chain Management*, Vol. 35 No. 1, pp. 16-24.

Vokurka, R.-K. (2000). A review of empirical research on manufacturing flexibility. *18(4),485–501*.

Wijnmalen, D. J. (2002). Analysis of benefts, opportunities, costs, and risks (BOCR) with the AHP. *46(7), 892–905*.

Yellepeddi, S., Liles, D. D., & Rajagopalan, S. (2006). *An Analytical Network Process (ANP) approach for the development of a reverse supply chain performance index in consumer electronics industry*. Texas: The University of Texas at Arlington.

Yi, C. (2011). Supply chain flexibility in an uncertain environment. *16(4).271–283*.

Yu, K. J. (2015). Operational Flexibility: Review and Meta-analysis. *169: 190–202*.

Zhang, Q. (2002). Product development flexibility.

Zhang, Q. (2003). Manufacturing flexibility. *21(2),173–191*.

Zhang, Q. V. (2006). Spanning flexibility . *1(5),390–399*.

APPENDICES

Appendix A. Summary of the prior empirical literature on supply chain flexibility

Reference	Definition	Dimension	Theoretical lens
Vickery, Calantone, and Droge (1999)	Those flexibilities that directly impact a firm's customers and are the shared responsibility of two or more functions along the supply chain (SC), whether internal or external to the firm	Product flexibility, Volume flexibility, Launch flexibility, Access flexibility, Responsiveness to target markets	
Duclos, Vokurka, and Lummus (2003)	The flexibility within and between all partners in the chain, including departments within an organisation and external partners	Operations system flexibility, Market flexibility, Logistics flexibility, Supply flexibility Organisational flexibility, Information systems flexibility	
Sánchez and Pérez (2005)	Borrowed from Vickery, Calantone, and Droge (1999)	Basic flexibility (product, volume, routing), System flexibility (delivery, transshipment, postponement), Aggregate flexibility (launch, sourcing, response, access)	
Sawhney (2006)	The number of different states (levels, positions or options) that can be achieved with existing resources and the ability to change from one state to another state in a timely and cost-effective manner	Procurement/sourcing flexibility, Manufacturing flexibility, Distribution/ logistics flexibility	Competency–capability relationship perspective

Avittathur and Swamidass (2007) Stevenson and Spring (2007)	Meet particular customer needs in the SC without additional cost It incorporates all internal issues inherent at the plant and firm level together with a wider range of (non-manufacturing) services and external/inter-firm sources of flexibility at the network level, including sourcing, procurement and logistics	Robust network flexibility, Reconfiguration flexibility, Relationship flexibility, Logistics flexibility Organisational flexibility, Interorganisational flexibility	
Wadhwa and Saxena (2007)	The ability to respond to customer demands where every individual node has an option to select subsequent nodes based on the best, least-cost alternative		
Wang and Wei (2007)	The willingness and capability of trading partners to modify their initial arrangements to improve their adaptability to new changes and challenges in SCs		Transaction cost theory, Resourcebased view
Swafford, Ghosh, and Murthy (2008)	Abilities embedded in a firm's internal SC functions, such as those in development, purchasing, manufacturing and distribution, to reduce SC lead time, ensure production capacity and provide product variety while fulfilling customer expectations		

Fantazy, Kumar, and Kumar (2009)	Borrowed from Vickery, Calantone, and Droge (1999)	New product flexibility, Sourcing flexibility, Product flexibility, Delivery flexibility, Information systems flexibility	
Braunscheidel and Suresh (2009)	The ability of an organisation to produce different combinations of products economically and effectively given a certain capacity and to operate at a variety of different output levels without compromising the performance of the system from a cost, quality or service perspective	Volume flexibility, Mix flexibility	
Braunscheidel and Suresh (2009)	The ability of an organisation to produce different combinations of products economically and effectively given a certain capacity and to operate at a variety of different output levels without compromising the performance of the system from a cost, quality or service perspective	Volume flexibility, Mix flexibility	
Winkler (2009)	Borrowed from Vickery, Calantone, and Droge (1999)	Transparency, Simplicity, Responsiveness, Security	
Gosling, Purvis, and Naim (2010)	The ability of a system to change or react with little penalty in time, effort, cost or performance. It is a proactive attribute designed into a system rather than a reactive behaviour that may in fact result in a detriment to time, effort, cost and performance	Internal flexibility (sourcing, vendor), External flexibility (new product, mix, volume, delivery, access)	
Merschmann and Thonemann (2011)	The ability included in core processes (procurement/sourcing and distribution/ logistics) that enables a company to respond more quickly to changes in supply and demand		Contingency theory

Malhotra and Mackelprang (2012)	A system or network of interrelated external flexibilities (inbound and outbound) and internal manufacturing flexibilities, which taken together support the focal firm's performance outcomes from a customer-oriented perspective	Inbound supplier flexibility, Outbound logistics flexibility, Internal manufacturing flexibility	Complementarity theory
Syed and Kamel (2014)	Borrowed from Vickery, Calantone, and Droge (1999)	Dimension borrowed from Fantazy, Kumar, and Kumar (2009)	
Blome, Schoenherr, and Eckstein (2014)	The ability of the SC to react to and compensate for changes in the environment		Knowledge-based view
Jin et al. (2014)	The manufacturer's ability to work with suppliers to provide a wide variety of products, very different production outputs, and various deliveries, which gives the firm the ability to deliver the right product to customers at the right time and to achieve dependable delivery competitive performance	Delivery flexibility, Production flexibility, Logistics flexibility, Suppliers' flexibility, Supply base flexibility	The dynamic and relational extension of the resourcebased view
Singh and Sharma (2014)	The ability to produce a wide variety of products, to introduce new products and modify existing ones quickly and to respond to customer needs	Supplier flexibility, Manufacture flexibility, Customer flexibility	
Thomé et al. (2014)	The application of SC resources according to market dynamics, which requires firms to develop cross-functional and crosscompany strategies that eliminate bottlenecks and create a level of performance that allows firms to trengthen their	Volume flexibility, Mix flexibility	

	competitive advantages in an uncertain market		
Fayezi and Zomorrodi (2015); Fayezi, Zutshi, and O'Loughlin (2015)	An operational ability that assists organisations to efficiently generate changes internally and/or across their key partners when faced with internal and external uncertainties		
Yu, Cadeaux, and Luo (2015)	Borrowed from Vickery, Calantone, and Droge (1999)	Dimensions borrowed from Sánchez and Pérez (2005).	Contingency theory
Tiwari, Tiwari, and Samuel (2015)	An SC is flexible if it can ensure a smooth, undisrupted supply of products from the supplier to the end user under all risks and uncertainties in the environment, with the least variation in the difference between the demand and supply at every demand–supply node and without substantial penalty or impact on SC resources and costs incurred	Upstream exterior flexibility, Interior flexibility, Downstream exterior flexibility	
Luo and Yu (2016)	An SC capability embedded into the firm's strategy, behaviours, processes and technology to respond to environmental uncertainty	Physical distribution flexibility, Demand management flexibility	Asymmetry theory, Contingency theory
Obayi et al. (2017)	A measure of the 'elasticity' of buyersupplier relationships to uncertainties in demand and supply conditions	Configuration flexibility, Planning and control flexibility	Relational perspective, Dynamic capability perspective

Baofeng Huo, Minhao Gu and Zhiqiang Wang (2018)	Capability of a company, both internally and externally in conjunction with its key suppliers and customers, to respond to uncertainties and customer expectations without excessive costs, time and performance losses	Customer flexibility, Internal flexibility, Supplier flexibility

Appendix B – The Tables of ANP

Table B.1: Weighted supermatrix by using ANP

		Goal	Customer_Criteria	Delivery on schedule	Delivery time	Environmental friendliness	Explanation of the car when handling over the car	Financial Service	Frequency of breakdowns while on road	Frequency of maintenance	Fuel consumption	Material / finishing quality	Overall impression of the exterior design	Parts	Purchasing Price	Reliability	Resale or residual value	Safety	Sales Activity	Telematic/Digital Systems	Warranty terms	Workshops	Retailer_Criteria	Fast supply of spare parts	Omni-channel customer experience	Optimal stock level	Supporting material	Well trained technical team	Supplier_Criteria	Economic sustainability	Environmental sustainability	Social sustainability
Goal	Goal	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Customers_C	Customer_Criteria	0,784	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Customers	Delivery on schedule	0,000	0,016	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Delivery time	0,000	0,011	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Environmental friendliness	0,000	0,019	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Explanation of the car when handling over the car	0,000	0,008	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,111	0,000	0,000	0,000	0,000	0,000
	Financial Service	0,000	0,032	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Frequency of breakdowns while on road	0,000	0,042	0,000	0,000	0,000	0,000	0,000	0,000	0,250	0,000	0,000	0,000	0,000	0,036	0,661	0,000	0,399	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Frequency of maintenance	0,000	0,042	0,000	0,000	0,000	0,000	0,000	0,200	0,000	0,000	0,000	0,000	0,000	0,018	0,131	0,000	0,066	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Fuel consumption	0,000	0,087	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Material / finishing quality	0,000	0,045	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,853	0,196	0,105	0,000	0,099	0,161	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,857	0,000	0,000	0,000
	Overall impression of the exterior design	0,000	0,028	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,111	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Parts	0,000	0,059	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000
	Purchasing Price	0,000	0,104	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,569	0,000	0,000	0,000	0,000	0,000	0,483	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,143	0,000	0,000	0,000
	Reliability	0,000	0,071	0,000	0,000	0,000	0,000	0,000	0,800	0,750	0,000	0,889	0,000	0,588	0,896	0,000	0,000	0,227	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Resale or residual value	0,000	0,050	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,284	0,000	0,000	0,000	0,080	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Safety	0,000	0,133	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,199	0,208	0,062	0,000	0,000	0,853	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Sales Activity	0,000	0,022	0,000	0,000	0,000	0,906	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,027	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,889	0,000	0,889	0,000	0,000	0,000	0,000	0,000
	Telematic/Digital Systems	0,000	0,134	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,299	0,000	0,209	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Warranty terms	0,000	0,040	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Workshops	0,000	0,058	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000	0,000	0,000	0,000
Retailers_C	Retailer_Criteria	0,813	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Retailers	Fast supply of spare parts	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,065	0,000	0,000	0,000	0,833	0,000	0,000	0,000	0,062	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Omni-channel customer experience	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,302	0,000	0,111	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Optimal stock level	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,016	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,091	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Supporting material	0,000	0,000	0,250	0,000	0,000	0,094	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,167	0,000	0,000	0,000	0,356	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Well trained technical team	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,190	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Suppliers_S	Supplier_Criteria	0,135	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Suppliers	Economic sustainability	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,147	0,000	0,147	0,116	0,147	0,000	0,147	0,147	0,000	0,147	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,634	0,000	0,000	0,000
	Environmental sustainability	0,000	0,000	0,000	0,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,019	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,174	0,000	0,000	0,000
	Social sustainability	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,192	0,000	0,000	0,000

Table B.2: Limiting supermatrix by using ANP

		Goal	Customer_Criteria	Delivery on schedule	Delivery time	Environmental friendliness	Explanation of the car when handling over the car	Financial Service	Frequency of breakdowns while on road	Frequency of maintenance	Fuel consumption	Material / finishing quality	Overall impression of the exterior design	Parts	Purchasing Price	Reliability	Resale or residual value	Safety	Sales Activity	Telematic/Digital Systems	Warranty terms	Workshops	Retailer_Criteria	Fast supply of spare parts	Omni-channel customer experience	Optimal stock level	Supporting material	Well trained technical team	Supplier_Criteria	Economic sustainability	Environmental sustainability	Social sustainability
Goal	Goal	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Customers_C	Customer_Criteria	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Customers	Delivery on schedule	0,013	0,017	0,000	0,002	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Delivery time	0,008	0,122	0,015	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Environmental friendliness	0,014	0,199	0,000	0,000	0,500	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,037	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,006	0,037	0,000	0,037	0,000	0,000	0,108	0,000	0,500	0,000
	Explanation of the car when handling over the car	0,005	0,009	0,009	0,000	0,000	0,009	0,000	0,009	0,009	0,009	0,009	0,008	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,000	0,000	0,006	0,007	0,008	0,008	0,008	0,000	0,108	0,000	0,500	0,000
	Financial Service	0,030	0,036	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,600	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Frequency of breakdowns while on road	0,023	0,042	0,000	0,000	0,000	0,000	0,000	0,000	0,127	0,127	0,120	0,120	0,119	0,121	0,123	1,122	0,123	0,000	0,123	0,000	0,000	0,005	0,030	0,000	0,030	0,000	0,000	0,003	0,004	0,000	0,000
	Frequency of maintenance	0,028	0,046	0,000	0,000	0,000	0,000	0,000	0,200	0,129	0,129	0,128	0,129	0,120	0,129	0,128	0,128	0,128	0,000	0,128	0,000	0,000	0,003	0,016	0,000	0,016	0,000	0,000	0,001	0,002	0,000	0,000
	Fuel consumption	0,068	0,086	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,123	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Material / finishing quality	0,037	0,047	0,000	0,000	0,000	0,000	0,000	0,052	0,052	0,049	0,049	0,049	0,047	0,048	0,049	0,049	0,049	0,000	0,000	0,000	0,000	0,001	0,035	0,000	0,035	0,000	0,000	0,002	0,003	0,000	0,000
	Overall impression of the exterior design	0,021	0,027	0,000	0,000	0,000	0,000	0,000	0,000	0,028	0,028	0,028	0,028	0,028	0,028	0,028	0,028	0,028	0,000	0,000	0,000	0,000	0,001	0,034	0,000	0,034	0,000	0,000	0,001	0,002	0,000	0,000
	Parts	0,048	0,058	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,768	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Purchasing Price	0,082	0,124	0,000	0,000	0,000	0,000	0,000	0,127	0,127	0,127	0,127	0,127	0,126	0,127	0,127	0,127	0,127	0,000	0,127	0,000	0,000	0,001	0,034	0,000	0,034	0,000	0,000	0,000	0,143	0,000	0,000
	Reliability	0,065	0,072	0,000	0,000	0,000	0,000	0,000	0,800	0,800	0,799	0,800	0,800	0,782	0,796	0,795	0,796	0,795	0,000	0,795	0,000	0,000	0,007	0,004	0,000	0,004	0,000	0,000	0,001	0,002	0,000	0,000
	Resale or residual value	0,039	0,040	0,000	0,000	0,000	0,000	0,000	0,040	0,040	0,040	0,040	0,040	0,040	0,040	0,040	0,040	0,040	0,000	0,040	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Safety	0,104	0,127	0,000	0,000	0,000	0,000	0,000	0,132	0,132	0,129	0,132	0,132	0,095	0,127	0,128	0,128	0,129	0,000	0,129	0,000	0,000	0,001	0,034	0,000	0,034	0,000	0,000	0,008	0,106	0,000	0,000
	Sales Activity	0,027	0,028	0,031	0,000	0,000	0,031	0,000	0,029	0,029	0,030	0,029	0,030	0,023	0,027	0,027	0,027	0,027	0,029	0,029	0,000	0,000	0,375	0,431	0,471	0,431	0,471	0,000	0,365	0,465	0,000	0,000
	Telematic/Digital Systems	0,115	0,132	0,000	0,000	0,000	0,000	0,000	0,135	0,135	0,135	0,135	0,135	0,133	0,135	0,135	0,135	0,135	0,000	0,000	0,000	0,000	0,001	0,034	0,000	0,034	0,000	0,000	0,007	0,097	0,000	0,000
	Warranty terms	0,011	0,030	0,000	0,000	0,000	0,123	0,000	0,237	0,237	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Workshops	0,045	0,043	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,720	0,000	0,000	0,098	0,000	0,000	0,500	0,000	0,000	0,000	0,000
Retailers_C	Retailer_Criteria	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Retailers	Fast supply of spare parts	0,007	0,009	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,065	0,000	0,000	0,000	0,000	0,833	0,000	0,000	0,000	0,062	0,121	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Omni-channel customer experience	0,023	0,019	0,027	0,000	0,000	0,027	0,000	0,026	0,026	0,026	0,025	0,025	0,022	0,025	0,026	0,026	0,026	0,027	0,026	0,000	0,000	0,352	0,404	0,442	0,404	0,000	0,000	0,342	0,436	0,000	0,000
	Optimal stock level	0,007	0,015	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,121	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,102	0,758	0,000	0,758	0,000	0,000	0,000	0,000	0,000	0,000
	Supporting material	0,030	0,032	0,035	0,000	0,000	0,035	0,000	0,034	0,034	0,034	0,034	0,034	0,031	0,033	0,033	0,033	0,033	0,034	0,033	0,000	0,000	0,063	0,073	0,079	0,073	0,079	0,000	0,061	0,783	0,000	0,000
	Well trained technical team	0,017	0,011	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,510	0,095	0,000	0,000	0,000	0,000	0,500	0,000	0,000	0,000	0,000
Suppliers_S	Supplier_Criteria	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Suppliers	Economic sustainability	0,094	0,006	0,000	0,000	0,000	0,000	0,000	0,007	0,007	0,006	0,007	0,007	0,005	0,006	0,000	0,007	0,007	0,000	0,007	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,013	0,016	0,000	0,000
	Environmental sustainability	0,024	0,080	0,000	0,000	0,500	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,213	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,005	0,037	0,000	0,037	0,000	0,000	0,107	0,000	0,600	0,000
	Social sustainability	0,015	0,008	0,000	0,000	0,400	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,367	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,005	0,037	0,000	0,037	0,000	0,000	0,108	0,000	0,620	0,000

BIOGRAPHICAL SKETCH

Elif Merve Su was born in Mersin, Turkey. After completing his schoolwork at Muğla Anatolian High School in Muğla in 2010, Elif entered Galatasaray University in İstanbul.

She graduated from Department of Industrial Engineering in June 2015. In September 2015, she entered the Financial and Logistic Management postprogram at The Galatasaray University.

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