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A CUSTOMER-ORIENTED DECISION APPROACH FOR QUALITY IMPROVEMENT IN HOUSEHOLD APPLIANCES INDUSTRY

Ece ÖZTÜRK

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prepared by **Ece ÖZTÜRK** in partial fulfillment of the requirements for the degree of **Masters of Logistics and Financial Management** at the **Galatasaray University** is approved by the

Examining Committee:

Assist. Prof. Dr. Zeynep Şener (Supervisor)
Department of Industrial Engineering
Galatasaray University -------------------------

Assist. Prof. Dr. Mehtap Dursun Usta
Department of Industrial Engineering
Galatasaray University -------------------------

Assist. Prof. Dr. Jbid Arsenyan
Department of Industrial Engineering
Bahcesehir University -------------------------

Date: 13.07.2015

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LIST OF SYMBOLS

QFD	**:** Quality Function Deployment
HOQ	**:** House of Quality
LP	**:** Linear Programming
GP	**:** Goal Programming
PQ	**:** Product quality
PLS	**:** Product life span
NW	**:** Number of workers in repair service
NRP	**:** Number of repair services
PSP	**:** Sleight of the procurement of spare parts
CD	**:** Contract duration
SHCC	**:** Support&help of call centers
SQ	**:** Service quality of the workers
STA	**:** Shipping time and accuracy
CSL	**:** Corruption,short life span
PS	**:** Low performance,suction
F	**:** Usability, form, affordability
MA	**:** Misinformation and attitude of the store
RSP	**:** Repair service problems
PRC	**:** Product return or change
CP	**:** Contract problems
DM	**:** Decision Maker
VOC	**:** Voice of the Customer

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ABSTRACT

Quality Function Deployment (QFD) technique is a very popular topic for business and for industry. Each organisation has customers and they often have a struggle to satisfy them in order to be successful and to have a profit. QFD is an important tool to manage these aims and accomplish these goals of the organisations. To put it in another way, QFD is the concept of listening ‘‘the voice of the customer’’ and suggesting a respond to the needs of the customers in various ways.

In academic world, QFD has a growing attention in the past decade with many different application areas. In most of the studies in literature, the main aim is to maximize customer satisfaction. In order to find this, customer expectations are used. However, the data is vague and limited, so it does not give trustful results.

In this study, apart from other conventional studies, a novel fuzzy decision making approach is proposed. “The voice of the customer” concept is looked from a unique perspective in which customer complaints are used instead of customer expectation.The aim in this study is to minimize customer complaints, in other words, minimize the dissatisfaction of the customers. To put it in another way, it is to maximize the satisfaction of the customers. The customer expectation data is hard to collect and to identify. Because of this reason, using customer complaint data is more realistic and helps to get better results. The customer complaints are recorded in all companies and the customers do not hesitate to share their complaints via Customer Complaint Platforms on Internet.

The selected application area of the study is the product improvement process which crucial for organisations.

The proposed methodology of the paper starts with the identification of customer and technical data.In order to be effective, real customer complaints, retrieved from a complaint platform, are used and it is corroborated with the selection of the most common ones. Then, with the selection of the main technical attributes, five experts are evaluated those data with surveys. They evaluated their interrelationships and also their correlations. Fuzzy data is used to be realistic and to show better the vagueness of the written information that the customers gave. Using these fuzzy data, the main components of House of Quality (HOQ), the matrices, are constructed. With the defuzzification technique the final scores are encountered. Moreover, with the usage of those scores, the most crucial technical attributes in the development of a product are found. The paper proposed the method of Goal Programming (GP) to come up with a solution for objective function in the frame of the solution space of the goals determined. It is aimed to simplify the processes in a company concerning the customer complaints so that the companies can be applied to their relevant processes.

The proposed approaches are illustrated using the household appliance industry in Turkey. It is one of the most important, fast-growing industries in Turkey. The vacuum cleaner product is selected as an example to reduce the scope of the complaint database and to study on a single product of this industry.

ÖZET

Kalite Fonksiyonu Yayılımı iş hayatında ve sanayide sıkça karşılaşılan ve kullanımı yaygın olan metotlardan biridir. Her firma müşterilere sahiptir ve firmalar müşterilerin beklentilerini karşılayıp onları mutlu etme konusunda çoğunlukla sıkıntılar yaşarlar. Bu da doğrudan firmanın karlılığını ve başarısını etkiler. Kalite Fonksiyonu Yayılımı, bu anlamda şirket amaçlarını yönetmek ve bunlara ulaşılmasını sağlamak için önemli bir yöntemdir. Diğer bir deyişle, Kalite Fonksiyonu Yayılımı, müşterilerin seslerini dinlememizi sağlar ve birçok farklı şekilde, gerekli aksiyonların alınmasını sağlar.

Kalite Fonksiyonu Yayılımı, akademik çevrelerde son zamanlarda sıkça karşılaşılan ve uygulanan bir yöntem olarak öne çıkar. Literatürdeki birçok araştırmada, temel amaç olarak müşteri memnuniyetini maksimize etmek kullanılır. Bu amaca ulaşmak için ise müşteri beklentileri verileri kullanılır. Bu veriler bulanık vekesin olmayan verilerdir, bu nedenle, kesin ve güvenilir sonuçlar veremez.

Bu çalışmada, diğer geleneksel yöntemlere bağlı kalarak yazılmış çalışmalardan farklı olarak, değişik bir bulanık, karar verme yöntemi önerilmiştir. Bu yöntemde, “müşterinin sesi” konsepti yenilikçi bir şekilde kullanılmış, uygulamada kesin olmayan müşteri memnuniyeti verileri yerine, gerçek müşteri şikayetleri tercih edilmiştir. Buradaki asıl amaç, müşteri şikayetlerini minimize ederek müşteri memnuniyetini maksimize etmektir. Diğer bir deyişle, çalışmadaki hedef, müşteri memnuniyetsizliğini minimize etmektir. Müşteri beklentileri verileri zor toplanabilen ve ayırt edilmesi zor verilerdir fakat müşteri şikayetleri daha realistik ve daha iyi sonuçlar veren verilerdir. Müşteri şikayet verileri her firmada kayıt altında olan verilerdir. Şirketlerden bu verilere ulaşılamasa bile, çeşitli müşteri şikayet platformlarından bu verilere rahatça ulaşımı mümkündür. Müşteriler, şikayetleri olduğunda mutlaka bunu bir şekilde

iletirler ve bu da bu verilerin kesinliğini ortaya koyar. Bu çalışmada, bu şikayet verileri ürün geliştirme süreçlerinde kullanılmıştır.

Etkili bir yönteme sahip olmak için; çalışmada, ünlü bir şikayet sitesinden gerçek şikayet verileri kullanılmış, en sık görülen şikayetler başlıklar altında toplanarak seçilmiş, bu şekilde şikayet başlıkları belirlenmiştir. En önemli ürün teknik özellikleri de belirlendikten sonra, sektörün içinde bir şekilde yer alan beş karar vericiden anket yöntemiyle değerlendirmeler yapılması istenmiştir. Bu uzmanlar bu verilerin kendi aralarındaki ve birbirleri arasındaki ilişkileri değerlendirmiş, bu şekilde Kalite Evi matrisleri oluşturulmuştur. Bu değerlendirmeler, daha gerçekçi sonuçlar almak amacıyla, bulanık sayı yöntemi kullanılarak yapılmıştır. Bulanık veriler daha sonra kesin verilere çevrilmiş ve bu şekilde en önemli ürün teknik özellikleri belirlenmiştir. Son olarak, bu önemli özellikler kullanılarak Hedef Programlama metodu uygulanılması önerilmiştir. Örnek bir modelle bu uygulamanın nasıl yapılabileceği ve konabilecek hedefler göz önünde bulundurularak amaç fonksiyonunun nasıl minimize edebileceğimiz gösterilmiştir.

Çalışmada, ürün geliştirme süreçlerinde kullanılan Kalite Fonksiyonu Yayılımı metodu kullanılmıştır. Sektör olarak Türkiye'deki küçük ev aletleri sektörü seçilmiş ve ürün fazlalığından doğabilecek işlem yanlışlarından kurtulmak amacıyla belli bir ürünün verileri kullanılmıştır. Elektirkli süpürge üzerine yazılan şikayet platformlarındaki tüm şikayetler çalışmada baz alınmıştır.

1. INTRODUCTION

Nowadays, every successful company uses data analysis techniques to come up with the current product problems. These data include manufacturing and performance history of the product and field test data. There is also customer complaint information that should be kept in my mind and that most of the companies has incomplete information. Companies do not spend enough time to customer complaints; do not make comparisons with other data that supports those(Tapke et al., nd).

Complaints are expensive, both as direct and indirect costs. But for this price, companies can extract priceless knowledge, because complaints contain the direct voice of the customer (VOC). Companies should make sure that the VOC is completely understood when a complaint arises (Bosch & Enriquez, 2005). This sentence is the starting point of this thesis which explains the focus area of the thesis.

A novel fuzzy decision making approach is proposed in this paper by giving a unique perspective of “The voice of customer” concept which can be very useful for companies. Using customer complaint data gives more realistic and trustful results instead of the usage of customer requirement data. In literature, there exists also a study of Bosch & Enriquez (2005) in which Customer Complaint Management System is constructed. But, in this study, the House of Quality (HOQ) is not constructed with customer complaint data and there are no traces of a numerical example.

So, we can easily say that the application does not exist in literature, which makes the application an innovative one. The aim in this study is to minimize customer complaints, in other words, minimize the dissatisfaction of the customers. To put it in another way, it is to maximize the satisfaction of the customers.

In this study, the main focus is this customer complaint data type instead of customer requirements and how to analyse this data using QFD format which has a property of listening ‘‘the voice of the customer’’ and suggesting a respond to the needs of the customers in various ways. The concept enables simultaneous engineering and it focuses to provide a high quality product for the customers with the appropriate quantity and time.

The methodology starts byidentifying technical attributes and customer complaints. After that, the correlations and interrelations among them are found and placed in the matrices of HOQ. With the results found by HOQ, the paper aims to construct an illustrative goal programming model to find a solution for objective function in the frame of the solution space of the goals determined. It is aimed to simplify the processes in a company concerning the customer complaints so that the companies can be applied to their relevant processes.

The study is organised as follows: Firstly, the key concept of the paper, QFD, is explained in details. Then, brief literature reviews are made for QFD and different concepts with QFD. After indicating detailed information about the proposed methodology, the application part is stated. Moreover, steps of the numerical part are explained and the results are shown.

2. QFD

Today, companies oftenly struggle with the balance of customer satisfaction and profitability. As Lager(2005) indicates, a development methodology like QFD is crucial in industrial product and process development. It overcomes with the problem of being aware of and able to analyze the voice of the customer.

Quality Function Deployment (QFD) is a mechanism which enables an organization to be proactive to quality problems rather than being reactive to these issues and related customer complaints. The main aim of this concept is to establish a competitive advantage by comparing product quality standards of the competitors (Zairi& Youssef,1995).

QFD translates the 'voice of the customer' in the various stages of product planning, engineering, and manufacturing into a final product (Iranmanesh et al., 2005). The concept is crucial in the improvement of the existing products, processes and services and also, in the new product improvement stages. So, the concept enables simultaneous engineering and it focuses to provide a high quality product for the customers with the appropriate quantity and time.

QFD is an innovative technique born in 1967 which, as Zairi& Youssef (1995) mentions, it did not emerge as a viable methodology until 1972 when it is used in Kobe Shipyard of Mitsubishi Heavy Industries Ltd.

In the west, the extensions of the technique and its appearance in the West were very slow. The American Supplier Institute (ASI) and GOAL/QPC (Growth Opportunity Alliance of Lawrance, Massachusetts/Quality Productivity Center) have publicized this technique in the United States in late 1980s. Ford and Xerox are also introduced this concept in USA. There are some important users of the concept were: Ford, General Motors, Chrysler, AT&T, Procter&Gamble, Hewlett-Packard, Digital Equipment, ITT and Baxter Healthcare. In those days, it was not popular as a design technique but it is used oftenly in diverse organizations of any size (Prasad, 1998).

Toyota and its suppliers had developed QFD in numerous ways and it has been used successfully by Japanese manufacturers of consumer electronics, home appliances, clothing, integrated circuits, synthetic rubber, construction equipment and agricultural engines. Japanese designers use it for services like swimming schools and retail outlets and even for planning apartment layouts (Hauser &Clausing, 1988).

In some studies, it is mentioned that QFD was born by YojiAkao who considered as the founder of this concept. In Akao (1997), he mentions the seeds out of which QFD was conceived. Firstly, he indicates that people started to recognize the importance of design quality, but how it could be done was not found in any books available in those days. Secondly, he talks about companies were already using QC process charts, but the charts were produced at the manufacturing site after the new products were being churned out of the line.

As Prasad (1998) also mentioned in his study, Akao defines QFD concept as follows: QFD is the converting of customer demands (WHATs) into quality characteristics (HOWs) and developing a quality plan for the finished product by systematically deploying the relationships between customer demands and the quality characteristics, starting with the quality elements in the product plan. Then, QFD deploys this WHATs and HOWs relationship with each identified quality element of the process and production plan.

In Prasad (1998), the application areas of this concept are also mentioned. Many companies apply this concept in diverse cross-functional team environments for existing product improvements and new product developments. QFD focuses and helps the coordination of workgroup skills within an organization. It is intended to meet customer demands in a better way, increase organizational capabilities and at the same time maximize company goals.

The significance of QFD in industry is also mentioned in Akao (1997): "QFD has changed what we have known about quality control in manufacturing processes and established quality control for development and design. QFD also has provided a communication tool to designers. Engineers, positioned midway between the market and production, need to lead new product development. QFD renders a powerful arm to engineers as they build a system product development.

Zairi & Youssef(1995) sums the benefits of QFD in their study:

- Unlike other concept, QFD takes customer as a starting point.
- QFD focuses on customers' true requirements which enables the cut down on cycle time
- QFD forces never-ending improvement. It offers the prioritization of customers' own preferences and follows a ranking procedure. If the top priorities are strong enough, companies may be weak at some of these preferences.
- QFD combines efforts which link customer preferences to physical output conversion processes. It forms teams by using input not just from marketing, manufacturing or distribution.
- QFD helps the improvement of customer understanding, internal effectiveness and external competitiveness.
- QFD enables cost,cycle time and waste reduction by experiential learning.
- QFD is an innovation tool because it encourages people to rate their capabilities against competitors

There are also few drawbacks of QFD mentioned in the study like unmanageably large and confusing tables of QFD, the long process of constructing detailed HOQ etc. In Mizuno &Akao (1994), the drawbacks of QFD are explained as follows:

- It's a Japanese based technique, so there can be problems when applying QFD within the western business environment and culture.
- Customer perceptions are found by market surveys. If the surveys are performed poorly, then the whole analysis may not be beneficial or may do harm to firm.
- The customer needs and requirements are too complex nowadays, they can change so quickly. Adaptation of this technique to changed market needs may be complex.

Mizuno &Akao (1994) also mentions the conditions to adopt QFD which are:

- The market survey results should be accurate
- Customer needs can be documented and captured efficiently. Also, they should remain stable during the whole process.

The basic concept of QFD is to translate the desires of customers into engineering characteristics, and subsequently into parts characteristics, process plans and production requirements.

In order to establish these relationships, QFD usually requires four matrices each corresponding to a stage of the product improvement cycle. These are product planning, part deployment, process planning, and production/operation planning matrices, respectively.

The product planning matrix translates customer needs into engineering characteristics; the part deployment matrix translates important engineering characteristics into product/part characteristics; the process planning matrix translates important product/part characteristics into manufacturing operations; the production/operation planning matrix translates important manufacturing operations into day-to-day operations and controls (Shillito, 1994).

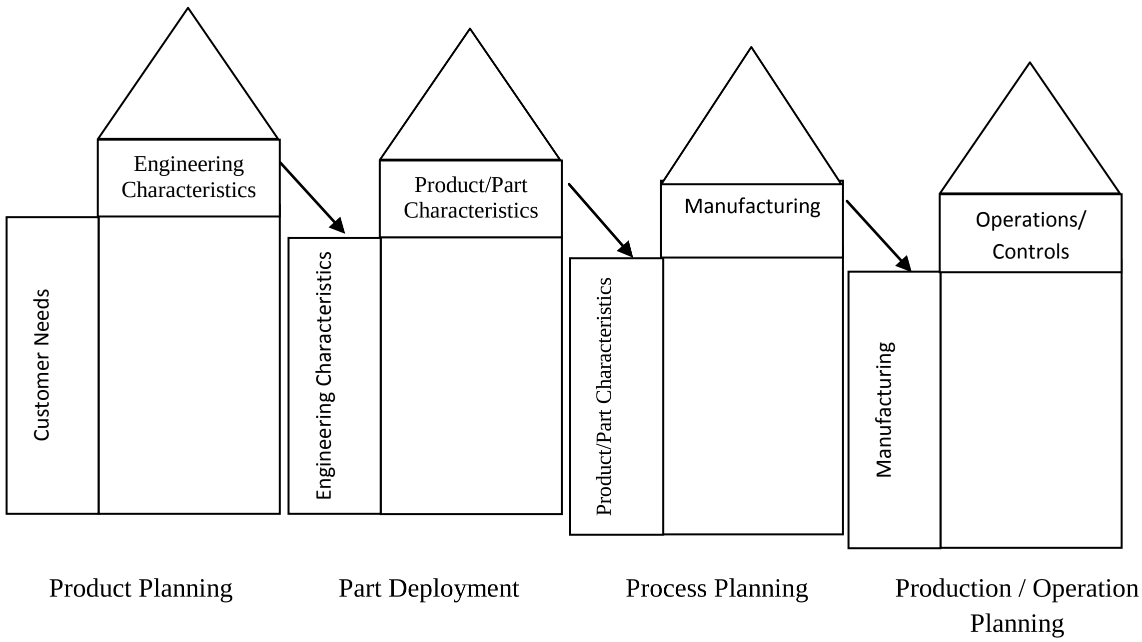

Figure 2.1: Stages of product development cycle

The first of the four matrices, called the house of quality (HOQ), is the most frequently employed matrix in QFD. With this concept, we can identify customers, their needs, design requirements of the product, priorities of them and correlations between these needs and requirements. The majority of the QFD applications end when the HOQ is built. Han et al.(2011) state that many companies, such as Volvo, have found that a great deal of benefit can be achieved from just completing the first matrix.

House of quality and steps of its construction can be seen in a simple way below:

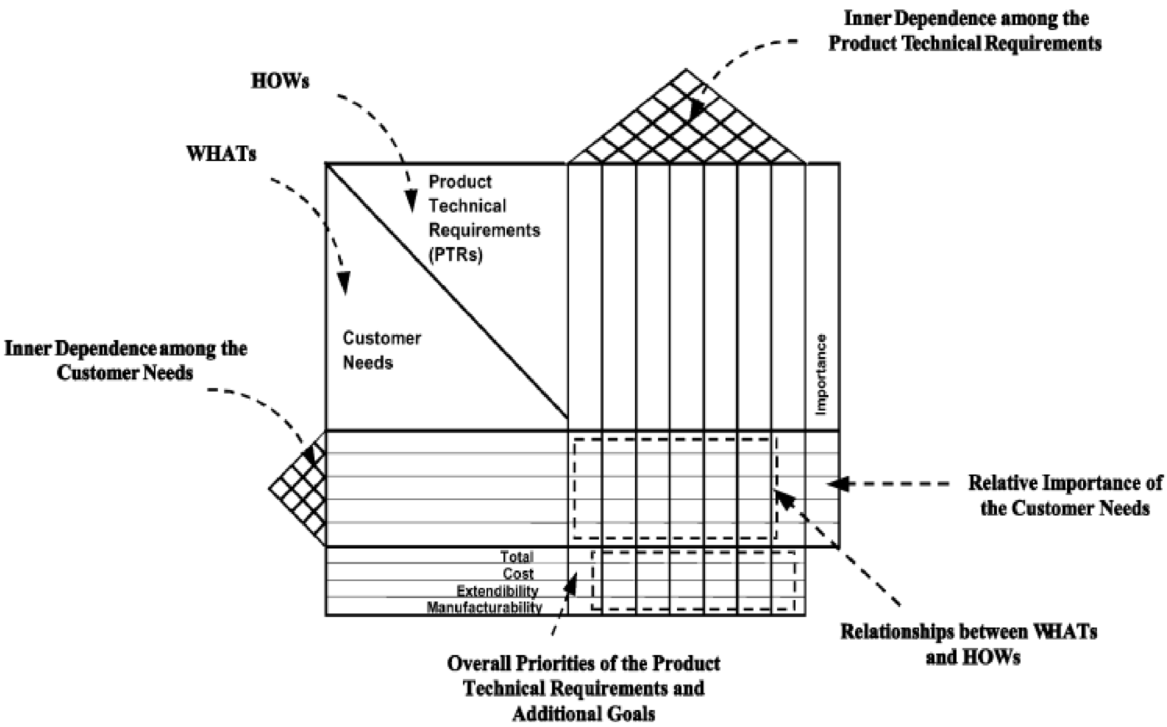

Figure 2.2: House of Quality (Karsak et al., 2002)

Karsak et al. (2002) and Blanchard (2002) mentions in their studies the meaning of each sub matrice and the methods to find them in a detailed manner:

1. Identification of customer requirements (WHATs)

   They are known as the voice of the customer which highlights the important product characteristics. These customer needs are usually collected by focus groups or individual interviews and they should be expressed in customers' own phrases

   One-to-one interviews are the most efficient ones, mail or telephone surveys should be avoided due to the difficulties in controlling the scope of responses.

   During the phase of translation and interpretation, which is a hard process, affinity diagrams can be used to gather large amounts of data and sub grouping them. Cluster analysis is also a recent way to gather the data (Karsak et al., 2002).

2. Identification of engineering characteristics(HOWs)

   These are engineering attributes, quality characteristics and ‘‘the voice of the company’’. They describe the product in the language of the engineer.The selected design-dependent parameters should be tangible, describe the system configuration in measurable terms, and directly affect customer perceptions. In essence, they guide the analysis and evaluation of design concepts during the conceptual, preliminary and detailed design phases (Karsak et al., 2002).

3. Rank assignment of customer requirements

   The data collected from the customer is so complex and there are too many needs to deal with. The solution to this problem is to rate them. Each customer surveys each customer requirement using 1 to 10 scales.
   In contrast of Step 2 of the HOQ construction, a large number of people should be surveyed, surveys through mail are more effective (Karsak et al., 2002).

4. Correlations among the customer requirements and engineering characteristics

   This correlation matrix shows how each design requirement affects each customer requirement. This step should be via numbers and symbols, not with qualitative variables (Karsak et al., 2002).

5. Interrelations among the customer requirements

   To show the trade-offs among customer requirements, this matrix is constructed. The trade-off means supporting and conflicting property of the requirements (Karsak et al., 2002).

6. Interrelations among the engineering characteristics

   This is the HOQ roof matrix which provides a basis to calculate the extent of change in one feature affect the other features. This affection can be positive or negative. The correlations help to indicate the trade-offs and impacts (Karsak et al., 2002).

7. Priorities of HOW: Rank assignment of engineering characteristics

   The results obtained from preceding steps are used to calculate the final rank of the engineering attributes. Additional metrics such as cost, manufacturability can be used to determine the areas of improvement (Karsak et al., 2002).

3. LITERATURE REVIEW

3.1 QFD

It can easily be said that in literature, there are a huge diversity of papers. Firstly, there are some basic QFD papers which are guide to most of the papers in literature. At this point, it is necessary to show some crucial publications of QFD mentioned.

One of the main QFD papers is undoubtly the paper of Akao (1997) in which he talks about early stages of QFD, its current status, the future expectations and possible challenges. The foundation and development stages of QFD is explained in details with the indication of some well-known but incorrect historical facts about this concept like “QFD is originated with Toyota”, “the origin of the term QFD” etc. We can easily say that more progress is expected from QFD which will be the most important area of Total Quality Management concept. He also indicated that QFD will be positioned as an effective tool for quality assurance of systems in the information age and for these goals, QFD method needs to be standardized and incorporated in the ISO (International Organization for Standardization).

Hauser & Clausing (1988) is also another main paper of QFD in which the authors explain briefly the history of HOQ, its development processes. Then, step-by-step procedure of HOQ construction is explained in a simple way with examples from everyday life. Subsequently, the usage of the HOQ is indicated with an illustrative example. The application areas and the advantages are mentioned with the VOC concept in manufacturing processes.

In Karsak et al. (2002), the QFD methodology is used with a multi-criteria decision making process, ANP and goal programming methodologies. In this important paper, each matrice of HOQ is explained in details. The subject of the paper is QFD in product planning processes in which the decision approach aims to consider the interdependence between customer needs and product technical requirements and the inner dependence within themselves. Expert opinions are also used in this paper. The application is demonstrated with an illustrative example for better understanding of the methodologies used.

Here are some QFD literature review papers which can guide many authors:

In the study of Prasad (1998), there is a brief review of the papers from 1980s to late 1990s. It reviews literature firstly then explain briefly historical developments of QFD and extended HOQ concepts which are necessary for product, process and production planning information and processing customer requirements. In the second part of the paper, other deployment techniques are mentioned with examples from literature. Data analysis are also made via affinity diagrams and tree diagrams.

In the detailed literature review of Chan et al. (2002), QFD is decribed as a tool to analyze and collect the ‘‘voice of the customer’’ and to develop products with higher quality to meet or surpass the customer’s needs. So, it can be eaisly said that, the main functions of QFD are product improvement and quality management. In this study, a brief review of QFD’s historical development and a categorical analysis of QFD’s functional fields, applied industries and methodological development are reviewed to facilitate the reference needs of QFD researchers. This research includes papers from 1970s to 2001.

Carnevalli & Miguel (2008) made a classification, review, analysis and codification of related literature of QFD with papers between 2002 and 2006. There are two main classes observed in this paper: conceptual research and empirical research. This study is beneficial for researchers who search for a specific type of QFD papers. The classifications are made in terms of methodologies, difficulties, type, journal etc.

Lastly, here are some example QFD papers observed during the subject and methodology selection of this thesis:

Firstly, the product improvement process function of QFD can be seen in Matzler&Hinterhuber(1998). The paper has theobjective of showing how the Kano's model and customer satisfaction concepts took place in QFD concept. Their importance are also shown in details in a fuzzy environment. The methodology presented in the study can be used in product development with the advantages of a systematic and beneficial deroulement.

For automative industry, Yadav &Goel (2008) indicates customer satisfaction attributes found by some analysis and these attributes are transformed into engineering characteristics The main aim is to augmente vehicle behavior and ease product improvement.

Zhang et al. (1999) proposed a novel life cycle approach for QFD. The paper emergs Life Cycle Costing and Life Cycle Assessment to evaluate different product concepts and create a Green Quality Function Deployment methodology.

This framework is an efficient tool for product development or improvement by virtue of improving quality, reducing costs and minimizing environmental impacts. The purpose is to have a environmental-friendly manufacturing system.

Secondly, the quality management aim of QFD can be seen in Radharamanan & Godoy (1996) with the adaptation of QFD to health care system. Using quality deployement charts, ‘‘the voice of the customer’’ and their requirements are analysed in a detailed manner.

The customer-oriented quality management approach type of QFD is also explained in details in Jeong&Oh(1998). Their paper focused on service management issues in hospitality industry. External and internal problems are discussed.

In addition, the QFD functions can be expanded to many fields including customer needs analysis, decision making, planning, product design, teamwork etc.

Recently, the customer needs analysis function of QFD can be observed in Chen &Ko(2007)with the usage of Kano’s model. A fuzzy linear model is proposed to find the performance indicators which are crucial for customer satisfaction. The applicability of the model is proven with an illustrative example.

Kim et al. (2000) published a paper about the decision making approach of QFD. They stated that the customer satisfaction flexibility is directly related with design improvement and flexibility. The proposed methodology which eases this trade-off can be applied to multiple design criteria cases and independent, uncertain functional relationships.

Lastly, the product design function of QFD can be observed in Wang (1999), who proposes a new fuzzy outranking approach to prioritize design requirements recognized in QFD. The paper tries to handle the evaluation results with linguistic terms to prioritize the design requirements recognized in QFD. It aims to achieve not only customer satisfaction but also the balanced design of a product.

3.2 Fuzzy QFD

There is a wide range of studies related to ‘‘fuzzy QFD’’ subject. Because of this reason, to narrow the research, this paper continued the study of Abdolshah&Moradi (2012) and made a literature review of the papers between 2011 and 2014.

In this part of the review, “fuzzy” and “QFD” keywords are used in the advanced search parts of databases: Science Direct Journals, Wiley Online Library, Web of Science, Taylor & Francis Online Journals, Google Scholar and precised the 2011-2014 interval in each database. The table below classified all of the papers obtained from this research in terms of purpose of the study, sector/industry, investigation, technique and contribution. A researcher can easily benefit from this table when searching for a paper from a specific attribute mentioned above. A diversity of sectors can be seen in papers like manufacturing, service, banking, logistics etc. It can be said that approximately half of the papers used illustrative example and half of them used case study to show their methodologies. In majority of the studies Multi criteria decision-making (MCDM) methodology like AHP, ANP or TOPSIS is used but programming, simulation, clustering can also be seen in some papers. The contributions obtained from the studies are differed according to their methodology and aim but it can be said that mostly, the papers focused on methodologies which can be used in companies for better understanding of the customers.

Below, the summary table of the literature review can be observed with the classifications of industries, methodologies, contributions etc.

Table 3.1: Literature Comparison Table

AUTHOR	PURPOSE OF THE STUDY	TYPE OF SECTOR/INDUSTRY	TYPE OF INVESTIGATION conceptual or empirical(case study/survey/illustrative ex.)	APPLIED TECHNIQUES	CONTRIBUTIONS
Bevilacqua et al. (2011)	The method uses house of quality approach and transforms it to a supplier selection problem which is strategic for a company.	clutch coupling manufacturing	empirical(case study)	fuzzy logic	This method can objectively identify and continually measure the performance of the suppliers.
Chen et al. (2011)	In this paper, evaluation of the technical factors in aviation safety is aimed with the usage of pairwise comparisons and relationships between criterias.	aviation industry	empirical(case study)	fuzzy AHP	Over-valued and under-valued factors demonstrated by conventional AHP can be better predicted with integrated fuzzy AHP(DEMATEL based) and QFD models.
Jiang et al.(2011)	The aim is to optimize process plan selection in the presence of wide-ranging alternatives.	lathe remanufacturing	empirical(illustrative example)	fuzzy linear regression	A decision-making methodology that integrates process quality characteristics is more effective and beneficial than other approaches.
Yuen (2011)	Proposed hybrid approach aims to eliminate the limitations of criteria evaluation and analysis in QFD.	IT sector	empirical(illustrative example)	fuzzy cognitive network process, fuzzy clustering	The method proposed can be used in new product development.
Wang (2012)	The selection of the optimal alternative is aimed with the criteria weighting taken into consideration.	banking sector	empirical(illustrative example)	fuzzy MCDM	This method is useful because the computation is easy and multiplicaiton of fuzzy numbers is unnecessary.
Dursun and Karsak (2013)	A fuzzy MCDM methodology for supplier selection is proposed which identifies the features purchased product should have.	not mentioned	empirical(illustrative example)	MCDM,fuzzy weighted average	The model considers inner dependences among supplier asessment criteria.
Yan et al. (2013)	The approach proposed in the study aims to prioritize design requirements under uncertainties.	flexible manufacturing	empirical(case study)	fuzzy linguistic approach, fuzzy preference relations	The methodology omits the lack of information caused by approximation processes which implies information loss.
Dat et al. (2014)	The paper proposed a new integrated fuzzy QFD technique to enhance market selection and evaluation.	trading service and transportation industry	empirical(case study)	fuzzy TOPSIS	The proposed fuzzy QFD approach is found out to be more efficient by comparing to another approach.
Zaim et al. (2014)	The purpose is to present the relationships between customer requirements and technical characteristics.	pipe manufacturing	empirical(case study)	fuzzy ANP	The paper considers fuzzy logic to better show subjective evaluations of experts.
Zhong et al.(2014)	Fuzzy chance constrained programming model is aimed which minimizes the fuzzy expected cost for determining the values of engineering characteristics.	automobile industry	empirical(case study)	fuzzy simulation,hybrid intelligent algorithm	The methodology takes into consideration customer requirements and engineering characteristics.
Haq and Boddu (2014)	The aim is to enhance the leagility of the supply chain by finding the enablers by coping well with the vagueness of judgements required in HOQ.	food industry	empirical(case study)	fuzzy TOPSIS and AHP	The proposed methodology eases to exploit the most influential enablers to achieve the desired degree of leagility.

AUTHOR	PURPOSE OF THE STUDY	TYPE OF SECTOR /INDUSTRY	TYPE OF INVESTIGATION conceptual or empirical(case study/survey/illustrative ex.)	APPLIED TECHNIQUES	CONTRIBUTIONS
Iranmanesh et al.(2014)	The paper seeks to find a methodology based on fuzzy inference system in order to capture information through house of quality.	education sector	empirical(illustrative example)	fuzzy inference system	Comparing other approaches, this model makes more accurate and reliable results and make sure that findings would not have a harmful effect on other characteristics of product.
Jovanovic & Delibasic (2014)	The proposed method allows an integration of requirements of different stakeholders in supplier selection.	electronics industry	empirical(case study)	fuzzy AHP	The result of the study gives the most stable,relaible supplier with good experience in terms of customers.
Kamvyski et al. (2014)	An effective academic course design is purposed by finding and prioritizing the student requirements.	service industry	empirical(case study)	linear programming, fuzzy AHP	The model augmented the quality of the offered service with the combination of two different techniques.
Li et al. (2014)	A new MCDM methodology is proposed to ease the selection and evaluation of Knowledge Management System.	aviation industry	empirical(illustrative example)	fuzzy TOPSIS	With this proposed method, it is easy to look from the users perspective.
Liao and Kao (2014)	An innovation in operational system is intended with the proposed approach.	logistics and customer service industry	empirical(case study)	fuzzy extended AHP and multi-segment goal programming	This model accomplishes many goals required in logistics and supply chain management.
Liu et al. (2014)	In this paper fuzzy linear regression model is proposed which has an objective h value.	packing machine production	empirical(illustrative example)	fuzzy linear regression	The model proposed is more reasonable which can lead to an effective product design planning and marketing strategies.
Roghanian & Alipour (2014)	Purpose of the study is to combine competitive advantages, lean attributes, and enabling factors to determine the most appropriate one.	automative industry	empirical(case study)	fuzzy AHP, Promethee	Compared to other methodologies, the technique applied in this study is dynamic and compatible in terms of composition and structure.
Roy et al. (2014)	Relative importances are calculated based on product and process characteristics. Also a score is obtained with shape features and materail caracteristic combinations.	manufacturing	empirical(case study)	fuzzy AHP	the variations in process capability are taken into consideration for better results.
Upadhyay et al.(2014)	The study focuses on the leanness of the supply chain and show the applicability of QFD.	liquor industry	empirical(case study)	fuzzy logic	The main purpose is to link the lean attributes with the link enablers with the usage of linguistic judgements.
Pelsmaeker et al. (2015)	The study shows possibilities and limitations of HOQ for food products in terms of consumer preferences,processing parameters,sensory attributes.	food industry	empirical(case study)	HOQ with sensory and instrumental analysis	The limitations of HOQ are found:difficulty of collecting and working with large amount of data, presenting the findings from HOQ to other people etc.
Yu et al. (2015)	Improving end-of-life performance of a product is the main purpose with three important attributes:product variety, reusability and recyclability.	household manufacturing sector	empirical(case study)	fuzzy clustering method	Results in the study shows that QFD can help to design better eco-modular drivers and improve the end-of-life issues.

3.3 Multiple Objective Programming & QFD

Many studies in literature have an objective of customer satisfaction but some of the papers in literature contain multiple objectives like cost minimization and technical difficulty minimization. Multiple objective programming is an optimization technique which is used to deal with multiple and conflicting objectives. In the past decade, we can see many examples of this programming method with the combination of QFD. Here are some important examples of the studies possesing multiple objectives:

Erol & Ferrel (2003) have the objective of minimizing cost and maximizing customer value. Their approach assists decision-makers when dealing with both qualitative and quantitative factors.

Karsak (2004) had the objective of minimizing technical difficulties and extendibility of design requirements. Researcher used fuzzy Delphi method with the multi-objective programming method, where objective's membership functions and their importance degrees are included. The approach is proven with a pencil design example.

The same objective of Karsak (2004) can be observed in Erginel (2010),who uses failure matrix and two-phase method to choose the best quality attribute. Like Mehrjerdi(2012), failure mode and effects analysis is also used with an illustrative application.

The paper of Kang and Lee (2009) considers a color filter replenishment problem in LCD manufacturing process with the considerationof storage space, yield rate, quantity discounts and multiple suppliers.

Firstly, the color filter replenishment problem is formulated as a fuzzy multiple objective programming, and then a fuzzy multiple objective programming with assigned weights for objectives based on experts' opinions is proposed. An example including four cases is given to illustrate the practicality for empirical investigation. Those case studies demonstrate the simplicity of the proposed models in achieving the best satisfaction under multiple goals, which are minimizing total cost, maximizing yield rate and fixing the replenishments to a desired number.

In Sener & Karsak (2010), there are many conflicting objectives: maximizing customer satisfaction, extendibility and minimizing technical difficulty of engineering characteristics. The usage of fuzzy multiobjective goal programming in QFD with linear regression is proposed. The methodology is supported with an illustrative example.

In the paper of Amin & Zhang (2012), a novel integrated mathematical model is proposed for supplier selection, order allocation and closed loop network configuration. The network presented in the paper consists of manufacturer, disassembly, refurbishing, and disposal sites. The methodology consists of two phases: In the first phase, fuzzy sets theory is used to overcome the uncertainty in assessment of eligible suppliers. With the aid of this phase, the importance of suppliers can be calculated. Then, multi objective mixedintegerlinear programming model is constructed to optimize the supply chain network.

Yang & Lin (2013) have the aim to develop an interactive two-phase method that can help the Project Manager with solving the fuzzy multi-objective decision problems. The paper constructs a multi-objective programming model, with the assumption that each objective work has a fuzzy goal.

Then, for reaching the objective, the detailed illustrative example is presented to show the feasibility of applying the proposed approach to Project Manager decision problems.

The main aim is to increase satisfaction degree and attempt to minimize total project costs, total completion time and total crashing costs.

3.4 Goal Programming & QFD

Goal programming is a rare approach used by many researchers. The method deals with goals which are conflicting and the deviationsbetween these goals and set of constraints with the aspiration levels are to be minimized rather than maximizing or minimizing directly the objective function. Here are some samples of the papers including this approach:

Fung et al. (2005) uses least squares regression and the fuzzy regression to show the relationships between engineering characteristics and design requirements. After that, fuzzy expected value-based goal-programming model for product planning was proposed to show the ambiguous results.

Chen & Weng (2006) also have similiar same objective with Fung et al. (2005). Theyproposed several fuzzy goal programming models to determine the fulfilment levels of product design requirements. Researchers also used fuzzy coefficients in the model in order to expose the fuzziness of the linguistic information. The model also considers business competition and the pre-emptive priorities between goals.

Wang & Chin (2008) propose a simple priority method for fuzzy AHP which utilizes a linear goal programming (LGP) model to derive normalized fuzzy weights for fuzzy pairwise comparison matrices.

The proposed LGP priority method is tested with three numerical examples including an application of fuzzy AHP to new product development (NDP) project screening decision making. The methodology that they suggested is simple to make computations and rational in terms of weights.

Apart from other studies, Yılmaz & Dagdeviren (2011) has a novel approach in which zero-one goal programming method is used together with F-PROMETHEE method. This method deals with the fuzziness of the data presented in the study. The main aim is to minimize the overall deviations in the objective function with various goals from zero-one Goal Programming and weights of criteria from F- PROMETHEE and the objectives. The application is denoted with a case study about equipment selection.

Mehrjerdi (2012) has a more theoric approach related to this programming methodology. A method is proposed where multiple objective chance-constrained goal programming and failure mode and effects analysis are made. This methodology aims to ease the optimization of a model including multiple objectives and risk factors.

However, in Bakshi et al. (2012), multi-criteria decision making approach AHP-QFD model is used with the fuzzy goal programming model. The framework is adapted to a project selection process using triangular numbers. After GP, the optimal criteria maximizes the goal is found.

Liao & Kao (2013) provides a novel approach for customer service management. The goal programming method is used together with QFD and fuzzy extended Analytic Hierarchy Process. Both customer expectations and service provider’s perception are used for this methodology. With the fuzzy extended AHP, the uncertainty of the human judgement is omitted. Subsequently, the consideration of multi-objective with multi-segment aspirations levels are madeby goal programming method.

Subulan et al. (2014) wrote a paper including a case study about lead acid battery supply chain. A fuzzy goal programming model is constructed to plan strategically the problem. Different importance and priorities are considered. Flexibility is also introduced in this model which is a novel approach. The main aim is to minimize cost and maximize collection of returned batteries and also, maximize total volume flexibility. Like Liao & Kao (2013), fuzzy AHP method can also be seen in this paper to obtain weights of the decision-makers.

4. PROPOSED DECISION APPROACH

4.1 Description of the proposed approach

In this study, the proposed framework differs from existing fuzzy QFD models and approaches in which customer complaints are used instead of customer expectation. The aim is to minimize customer complaints, in other words, minimize the dissatisfaction of the customers (maximize the satisfaction). This can be shown with this formulation:‘‘*max (z) = min (-z)*’’

The customer expectation data is hard to collect and to identify. Because of this reason, using customer complaint data is more realistic and helps to get better results. The customer complaints are recorded in all companies and the customers do not hesitate to share their complaints via Customer Complaint Platforms on Internet. The selected application area of the study is the product development process which is crucial for organisations to augment their profit and their customer satisfaction.

The proposed methodology of the paper starts with the identification of customer and engineering data. In order to be effective, real customer complaints, retrieved from a complaint platform (www.sikayetvar.com) , are used. The percentages of these complaints are calculated and the most common ones are formed the customer complaint data of the study.

Then, the selections of the main technical attributes are made. With the help of the experts in the sector and using the information written on company’s websites, the selection is made in a most logical manner.

Five decision-makers evaluated those data with surveys. The first DM(decision maker) works in the household sector for 15 years as a specialist, second DM works in a repair service for an important company in this sector for many years, third DM is an engineering masters student, fourth DM is a human resources specialist in this sector and finally thelast DM is a housewife who uses frequently household appliances. So, it can be clearly indicated that the first two DMs have a higher expertise than the others. Each survey is prepared in Turkish in order to have a better understanding of the proposed questions. During those surveys, experts evaluated how each technical attribute affect another and how each how each technical attribute affect each customer complaint. The surveys from five decision-makers are collected and written in linguistic terms.

At this point, fuzzy numbers used to be realistic and to show better the vagueness of the written information that the customers gave. The weights of technical properties are constructed with this transformation of linguistic data to fuzzy numbers. Moreover, the evaluations of how each technical attribute affect another and how each how each technical attribute affect each customer complaint are used to form the correlation matrix. For this part, the process of transformation the linguistic data to fuzzy numbers is also made. Then the correlation matrix for technical properties is constructed. Finally, the final scores of technical properties are calculated with the defuzzification technique.

With the usage of those scores, the most crucial technical attributes in the development of a product are found.

The paper than used the method of Goal Programming (GP) to create a model with the most important technical properties found via HOQ in the frame of the solution space of the goals determined.

In other words, this paper has two proposed frameworks in product improvement process differing from existing studies: Fuzzy QFD which is the most important one, and Goal Programming. Below, the detailed information about each method and the reasons why they are applied in the study can be understood:

4.2. FuzzyLogic& Fuzzy Set Theory in QFD

The concept of fuzziness that was first introduced by Zadeh (1965) has been effectively employed in modeling systems where human estimation is influential. As Zadeh (1965) indicates in his study: "the notion of a fuzzy set provides a convenient point of departure for the construction of a conceptual framework which parallels in many respects the framework which provides a natural way of dealing with problems in which the source of imprecision is the absence of sharply defined criteria of class membership rather than the presence of random variables."

For a long time, probability theory and statistics have been the predominant theories and tools to model uncertainties of reality. These theories are hard to test during its application to reality. There are many uncertainty theories developed and fuzzy set theory is one of them. It's an extension of dual logic and classical set theory. During the last decades, it has been developed in the direction of a powerful fuzzy mathematics (Zimmermann, 2010).

The first publications of the fuzzy set theory show the intention to generalize the classical notion of a set and a proposition to accommodate fuzziness in the sense that it is contained in human language, that is, in human judgement, evaluations and decisions. This theory provides a strict mathematical framework in which vague concepts can be precisely and rigorously studied. In other words, it can also be considered as a modelling language, well suited for situations in which fuzzy relations, criteria and phenomena exist (Zimmermann, 2010).

In a decision-making process, people face with different types of uncertainty and inaccuracy. The decision-maker cannot precisely express his preferences, evaluations and opinions because they are expressed with linguistic terms. To overcome with this problem, fuzzy logic is used. The logical tools that people can rely on are ‘‘yes/no, true/false’’ type but the problems posed by real-life situations and human thought processes and approaches to problem-solving are not that type. Fuzzy logic consists of fuzzy sets which don’t possess a predefined boundary between the objects which are or are not members of the set (Bevilacqua et al., 2006).

Kazançoğlu & Aksoy (2011) indicate that fuzzy sets are characterized by membership functions which have a range between zero and one. It can be represented with notations like: (α,β,γ) or $\left(\frac{\alpha}{\beta},\frac{\beta}{\gamma}\right)$. In these notations “α’’ represents the lowest value, “β’’ represents the most promising value and ‘‘γ’’ represents the highest value. Thelinguistic terms are used to identify human thoughts and those terms have corresponding fuzzy scores. For instance; linguistic term ‘‘VERY HIGH’’ represents a fuzzy score (8, 9, 10).

Tringular Fuzzy Number Operations retrieved from Karsak, E.E. (2004):

Two example fuzzy numbers with:

$A_1 = (a_1, b_1\ c_1)$ where $a_1 \leq b_1 \leq c_1$

$A_2 = (a_2, b_2, c_2)$ where $a_2 \leq b_2 \leq c_2$

- Summation

$$A_1 + A_2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2)$$

- Multiplication

$$K\ x\ A_1 = \begin{cases} (Ka_1, Kb_1, Kc_1) & \text{if } K > 0 \\ (Ka_2, Kb_2, Kc_2) & \text{if } K < 0 \end{cases}$$

Some advantages of fuzzy logic mentioned in Albertos & Sala(1998):

- Flexible
- Easy to make computations
- Validation of consistency,redundancy,completeness
- Combination of regulation algorithms and logic reasoning

Fuzzy logic also has some disadvantages. For example, there are many unclear options in this concept which depend on conjunction, disjunction, implication and defuzzification choices.

The QFD tables consist of entries from questionnaires and interviews. This condition arises the uncertainty in the quantification of the information.

To deal with this uncertainty and vagueness, fuzzy logic is used together with QFD concept (Kazançoğlu & Aksoy, 2011).

4.3. Goal Programming

This is an optimization technique found by Charnes& Copper in 1960s. This technique handles decision problems with a single goal and multiple sub goals or multiple goals with multiple sub goals concerning the decision-maker. This programming type is flexible. These goals are conflicting goals and the deviationsbetween these goals and set of constraints with the aspiration levels are to be minimized rather than maximizing or minimizing directly the objective function. So, it can be clearly indicated that, the objective function of a goal programming contains deviational variables which symbolises each goal or sub goal (Na & A-da, 2007). The key element of a GP model is the achievement function that represents a mathematical expression of the unwanted deviation variables (Liao & Kao, 2014).

According to Orumie & Ebong (2014), the key steps of the goal programming structure can be explained as follows:

1. Goals are discovered and converted to constraints by introducing deviational variables.
2. The goals are examined to determine the exact deviational variables needed
3. The goals are ranked according to the order of importance and pre-emptive priority factor assigned to each of them.
4. In case of ties in priority, weights are assigned to each of the deviational variables in the priority.

There are three mostly-used goal programming models: Pre-emptive Goal Programming, Weighted Goal Programming and Prioritized Goal Programming.

Pre-emptive Goal Programming is called ‘‘Lexicographic Goal Programming’’. In this method, the decision maker ranks each goal according to his/her relative importance and the aim is to concentrate on the most importance goal. The objective functions are also constructed with the help of this prioritization. In Weighted Goal Programming method, each objective has a corresponding weight. Lastly, Prioritized Goal Programming is the combination of two methods (Orumie&Ebong, 2014). It concerns the same attributes of the two programming types explained above.

The proposed framework of the methodology can be summarized with this flow chart:

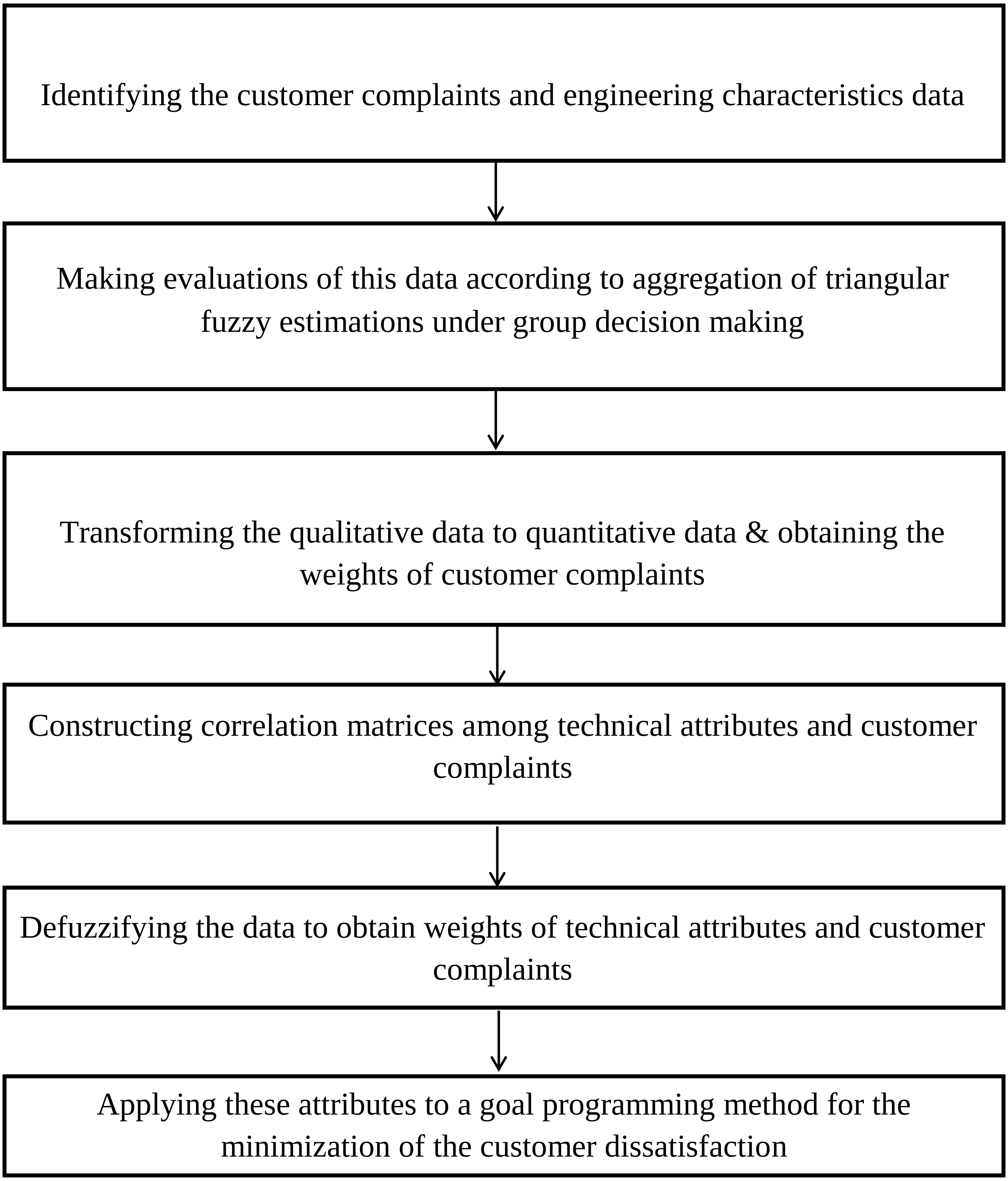

Figure 4.1: Flowchart of the proposed methodology

5. APPLICATION

This paper uses fuzzy QFD methodology proposed by Bevilacqua et al.(2006). In their study, the authors first identify the technical properties and tries to establish supplier assessment caracteristics that the product should have. It came up with the ranking of suppliers.

On the other hand, their paper adapts the paper of Bevilacqua et al.(2006)for a product quality improvement. It aims to find the ranking of the technical properties in terms of importance for a new product. The industry selected in this paper is the household appliance industry.

5.1. Household Appliance Industry

The household appliance industry is a billion dolar industry with a fast-growing property. Many appliances like air conditioning, ovens, refrigerators, washing machines, hair dryers etc. are membersof this industry. Turkey has a large household appliance market with many leading local manufacturers like Vestel, Arcelik, Profilo, Beko.

Vacuuming regularly houses is crucial to keep the houses neat. This enables the requirement of a vacuum cleaner. There are a huge diversity of cleaners on the market.

A significant growth in this market in Turkey can be observed with the affordable and easy-to-use products. In this study, one of the leading brands are selected for the vacuum cleaner product. This brand aims to show the methodology used with the help of a case study.

5.2. Materials used in the study

Customer complaints of the vacuum cleaner from a specific brand are retrieved from popular customer complaint platforms of Turkey. Most common complaints in these platforms are taken into consideration (especially www.sikayetvar.com). In those complaint platforms, the researchs are made using the keywords “household” and “vacuum-cleaner”. The complaints are classified into some categories and the percentage of each category is calculated. By looking at the percentages of each category, the most written criterias(categories) are picked and used in this study as the customer complaints qualitative data:

Customer Complaints of the Vacuum Cleaner

- Corruption,short life span (CLS)
- Low performance, suction(low power, low battery) (PS)
- Usability,form,affordability (price,usefulness, not have an easy-handling) (F)
- Misinformation and attitude of the store (dealer) or call center (MA)
- Repair service problems (duration, supply of spare parts, staff approach) (RSP)
- Product return or change (PRC)
- Contract problems (shortness, scope, unvalid contract) (CP)

Table 5.1: Percentages of the complaints

Complaints	Approximate percentages % of the complaints in customer complaint platform
CSL	7.90%
PS	12.70%
F	9.50%
MA	10.60%
RSP	34.90%
PRC	9.60%
CP	14.80%

In addition, most important engineering characteristics are identified by a detailed literature review and these data are used as qualitative data of technical properties in this paper:

Technical Properties

1. Product life span(PLS)
2. Product quality(PQ)
3. Number of workers in repair services(NW)
4. Number of repair services(NRP)
5. Sleight of the procurement of spare part(PSP)
6. Contract scope and duration(CSD)
7. Support&help of call centers(SHCC)
8. Service quality of the workers (SQ)
9. Shipping time and accuracy(STA)

5.3 Numerical part of the study

Five decision makers are picked: The first DM (decision maker) works in the household sector for 15 years as a specialist, second DM works in a repair service for an important company in this sector for many years, third DM is an engineering masters student, fourth DM is a human resources specialist in this sector and finally the last DM is a housewife who uses frequently household appliances. Decision makers one and two have more importance than the other decision makers because of their area of expertise and their well-experienced feature. With "E" reffers to the expertise level of a decision-maker:

Table 5.2: The level of expertise of each decision-maker

	DM1	DM2	DM3	DM4	DM5
Level of expertise	2E	2E	E	E	E

These experts evaluated the importance of customer complaints with the linguistic terms''VH,H,M,L,VL'' which have triangular fuzzy quantities (functions). Each of them corresponds to a fuzzy scale set which are triangular.

Fuzzy sets are used to omit the impression or vagueness. A triangular fuzzy distribution is a distribution which treats vague data as a possibility distribution. In triangular fuzzy numbers, a decision maker indicates the possible maximum point, the maximum possible point and the possible minimum point in comparing each alternatives.

In other words, these can be denoted as upper bond, median value and the lower bound of a triangular fuzzy numbers respectively (Liu et al., 2014).

As Liu et al.(2014) also indicates, triangular fuzzy numbers are more natural and logical than making precise judgement in a decision–making. These type of sets are scaled as a fuzzy scale. In this study, five class scale is used to have better precision of the opinions of the decision maker.

Table 5.3: The linguistic terms and corresponding fuzzy scales used by the experts

Linguisticterm	FuzzyScale
VL	(0, 0,2.5)
L	(0,0.25, 0.5)
M	(0.25, 0.5, 0.75)
H	(0.5, 0.75, 1)
VH	(0.75, 1,1)

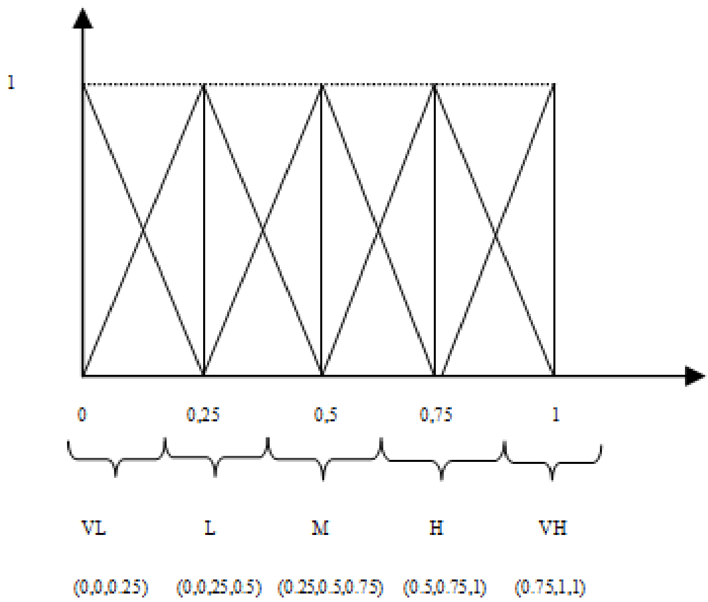

Figure 5.1: Triangular fuzzy term set used in the study

The fuzzy QFD methodology is selected to obtain which technical attributes that should be focused mostly in making necessary improvements of a vacuum cleaner. It enables the translation of customer complaints and requirements into real numerical data and engineering targets (Tapke, J., et al., nd).

After defining the market segment, experts are selected and surveys are made in order to collect the necessary data. In other words, the numerical part of the paper begins firstly bythe expertevalautions which are the ranking of the most popular customer complaints with the linguistic scores by their viewpoint. The results can be seen below:

Table 5.4: Evaluation of the customer complaints by the experts

Complaints	DM1	DM2	DM3	DM4	DM5
CSL	VH	VH	VH	VH	VH
PS	VH	H	VH	VH	VH
F	VH	VH	VH	VH	VH
MA	M	M	H	L	M
RSP	H	M	M	M	H
PRC	H	H	M	M	M
CP	M	VH	H	M	L

For instance, first decision-maker thinks that corruption and short life span (CSL) has a very high importance.

Then each expert evaluated the customer complaints on how they effect the technical properties. This is made via aggregation method of fuzzy estimations under group decision-making. In this method, as described in Tsabadze(2014), each expert expresses their subjective estimations denoted by a type of a fuzzy number. In our case, triangular fuzzy scores are used. The following table represents the resulting scores of the evaluation. The decision makers evaluated higher linguistic variables for the properties which can lead to customer dissatisfaction or customer loss.

Table 5.5: The linguistic scores given by the experts on how each technical property effects each customer complaint

	PLS					PQ				
	DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5
CSL	VH	VH	VH	VH	VH	VL	VH	VH	H	M
PS	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH
F	VL	VL	VH	VL	VL	VL	VL	H	VL	VL
MA	VL	L	VH	VL	VL	VL	L	VH	VL	L
RSP	VH	L	VH	L	VH	L	L	VH	H	H
PRC	VH	H	VH	H	VH	M	VL	H	L	H
CP	M	L	VH	VL	VH	M	L	H	VL	VH

	NW					NRP				
	DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5
CSL	VL	H	VL	H	VH	M	L	L	VL	VL
PS	H	H	VH	VH	VH	L	M	M	VL	H
F	VL	L	H	VL	VL	VL	VH	M	L	VH
MA	VL	L	M	VL	VL	H	H	VH	L	H
RSP	H	L	H	H	VL	H	VL	M	M	VL
PRC	L	L	H	L	VL	L	L	M	L	L
CP	L	L	VH	VL	M	VH	VH	M	VH	VH

	PSP					CSD				
	DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5
CSL	H	VL	H	L	VH	L	L	M	VH	VH
PS	H	L	H	VL	VH	VH	H	VH	VH	VH
F	H	VH	M	VH	VH	M	L	H	H	VH
MA	H	VH	M	L	VH	H	L	VH	H	VL
RSP	H	L	H	H	VH	M	VH	VH	M	M
PRC	H	L	M	L	VH	VH	H	VH	H	VH
CP	VH	L	H	H	VH	M	H	H	VH	VH

	SHCC					SQ				
	DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5
CSL	M	VL	M	H	VH	VL	VL	VH	VL	VH
PS	M	H	H	M	M	VL	VL	H	VL	L
F	VL	VL	M	VL	M	VL	VL	VH	VL	VL
MA	L	L	H	L	VH	VH	VH	M	VH	VH
RSP	H	VL	M	VL	VH	M	H	H	VH	VH
PRC	VH	VH	VH	VH	VH	M	L	H	H	L
CP	M	L	L	L	VH	VL	L	L	L	VL

	STA				
	DM1	DM2	DM3	DM4	DM5
CSL	VL	L	L	VL	VL
PS	VL	VL	VL	VL	VL
F	VL	VL	VL	VL	L
MA	H	VL	VL	H	VH
RSP	H	H	L	VH	VL
PRC	H	VH	VH	VL	VH
CP	H	L	L	VL	L

For example, fourth decision-maker believes that repair service problems (RSP) have a high importance effecting product quality, number of workers in repair services and procurement of spare parts.

The linguistic scores are then transformed into quantitative variables. These are triangular numbers with alpha, beta and gamma (α, β, γ). For table 5.4, each linguistic score given for each complaint are summed up by triangular number summation method. For first and second decision makers, the triangular numbers are multiplied by 2.Then their averages are taken as a triangular fuzzy number. For table 5.5, the procedure is the same for each customer complaint affecting each technical property. The triangular fuzzy scores can be seen on tables below (5.6 and 5.7).

Table 5.6: The triangular fuzzy scores of the customer complaints given by the experts

Complaints	α	β	γ
CSL	0.75	1	1
PS	0.68	0.86	1
F	0.75	1	1
MA	0.25	0.5	0.75
RSP	0.36	0.6	0.86
PRC	0.39	0.64	0.89
CP	0.39	0.64	0.89

For each complaint the sum of the fuzzy score corresponding to the fuzzy linguistic variable multiplied by weight of the decision maker and the averages are taken. For instance, PRC= $\frac{2(0.5,0.75,1)+2(0.75,1,1)+3(0.25,0.5,0.75)}{7}$ (0.39, 0.64, 0.89)

Table 5.7: The triangular fuzzy scores of how each technical property effects each customer complaint

	PLS			PQ			NW		
	α	β	γ	α	β	γ	α	β	γ
CSL	0,75	1	1	0,43	0,64	0,82	0,32	0,46	0,68
PS	0,75	1	1	0,75	1	1	0,61	0,86	1
F	0,1	0,14	0,32	0,07	0,11	0,36	0,07	0,18	0,43
MA	0,1	0,21	0,43	0,11	0,25	0,46	0,04	0,14	0,39
RSP	0,43	0,68	0,78	0,25	0,5	0,71	0,29	0,5	0,75
PRC	0,57	0,78	0,86	0,21	0,39	0,64	0,07	0,29	0,54
CP	0,28	0,5	0,68	0,25	0,46	0,68	0,14	0,36	0,58

	NRP			PSP			CSD		
	α	β	ɣ	α	β	ɣ	α	β	ɣ
CSL	0,07	0,25	0,5	0,32	0,5	0,7	0,25	0,5	0,68
PS	0,18	0,39	0,64	0,32	0,54	0,75	0,54	0,93	1
F	0,36	0,54	0,68	0,61	0,86	0,96	0,32	0,57	0,71
MA	0,46	0,71	0,93	0,5	0,75	0,89	0,32	0,54	0,75
RSP	0,21	0,36	0,61	0,39	0,64	0,86	0,46	0,71	0,86
PRC	0,04	0,29	0,54	0,46	0,71	0,86	0,64	0,89	1
CP	0,68	0,93	0,96	0,46	0,71	0,86	0,43	0,75	0,93

	SHCC			SQ			STA		
	α	β	ɣ	α	β	ɣ	α	β	ɣ
CSL	0,29	0,46	0,68	0,21	0,29	0,46	0	0,11	0,36
PS	0,36	0,61	0,86	0,07	0,14	0,39	0	0	0,25
F	0,07	0,14	0,39	0,07	0,11	0,36	0	0,04	0,29
MA	0,18	0,43	0,64	0,68	0,93	0,96	0,32	0,46	0,68
RSP	0,29	0,43	0,64	0,5	0,75	0,93	0,39	0,61	0,82
PRC	0,75	1	1	0,21	0,46	0,71	0,57	0,79	0,89
CP	0,18	0,43	0,64	0	0,14	0,39	0,14	0,36	0,61

The calculation procedure of this table(5.7) is the same with the previous table.

Table 5.8: The final linguistic scores of technical attributes

PLS			PQ			NW			NRP			PSP		
α	*β*	*ɣ*	*α*	*β*	*ɣ*	*α*	*β*	*ɣ*	*α*	*β*	*ɣ*	*α*	*β*	*ɣ*
0.24	0.48	0.67	0.17	0.37	0.62	0.13	0.31	0.58	0.13	0.35	0.63	0.22	0.50	0.76

CD			SHCC			SQ			STA		
α	*β*	*ɣ*	*α*	*β*	*ɣ*	*α*	*β*	*ɣ*	*α*	*β*	*ɣ*
0.21	0.52	0.77	0.15	0.36	0.63	0.10	0.26	0.53	0.07	0.21	0.49

In the table 5.8, tables 5.6 and 5.7 are columnwise multiplied with each other the average of each column is taken. For instance, the calculation of $\alpha$of PLS:

$$\frac{(0.75*0.75)+(0.75*0.68)+(0.1*0.75)+(0.1*0.25)+(0.43*(0.36)+(0.57*0.39)+(0.28*0.39)}{7}$$

The deffuzzification technique used in the study is $\frac{\alpha+4*\beta+\gamma}{6}$ which is retrieved from Raju & Kumar (2010). For each technical attribute, the final defuzzification scores are calculated. Than the ranking of the technical properties are made beginning with the highest score.

Final scores of the defuzzification and the corresponding rankings are:

Table 5.9: The resulting scores and ranking of technical properties

Technical Property	Defuzzification Result	Ranking
PLS	0.47	3
PQ	0.38	4
NW	0.32	7
NRP	0.36	6
PSP	0.5	2
CD	0.51	1
SHCC	0.37	5
SQ	0.28	8
STA	0.23	9

The final ranking of the technical properties, we can conclude the HOQ procedure by saying that the properties with the highest scores (CD, PSP, PLS) are the most important among others. In other words;

$$CD > PSP > PLS > PQ > SHCC > NRP > NW > SQ > STA$$

Where ‘‘>’’ means “have a higher importance than”. For instance, PSP has a higher importance than SQ.

Using the final results of the HOQ construction, we found the technical attributes who depend mostly on the customer complaints. These can be considered as the most important technical attributes.

With the usage of these results, a modelling with multiple goals can be easily constructed. In this paper, an illustrative example is provided to show how the procedure of goal programming and how the most important technical attributes can be used for finding the best solutions. The improvement of these technical attributes can lead to a minimization in terms of customer complaints and also minimization of the customer dissatisfaction.

In Goal programming, the main aim is to find a solution in the area of the optimums of functions and goals. The tolerance limits existe in objective functions and goals. This means that, the goals must be accomplished in best manner. The tolerance limits should not be negative and for each upper & lower limit one of them will be 0.

The main thing to keep in mind while constructing a goal programming is to know that, if the goal constraints ‘‘≥’’ direction , the unwanted limit is the lowerbound limit if the direction ‘‘ ≤’’ , the unwanted limit is the upperbound limit. In addition, if the goal constraint is ‘‘=’’ type, both of the limits are unwanted.

The goal programming which has goals with equal importance weights are selected as a goal programming type. If that is the case, the addition of the unwanted tolerance limits will be the objective function and the objective function should be minimized (Yiğit, 2014).

The constraints are made firstly by obtaining the necessary information from Internet and from the selected household firm. With the usage of these approximate values, the goals and the objective function are constructed in a logical manner. The general technique for multi-attribute goal programming model formulation is as follows:

d_i^+ with i=1…n : upper tolerance limit for i th goal

d_i^- with i=1…n : lower tolerance limit for i th goal

g_i (x) : goal constraints

f_i (x) : goal constraints without deviational variables

$$\min \sum_{i}^{n} d_i^+ + d_i^-$$

$$f_i(x) + d_i^- - d_i^+ = g_i(x)$$

$$d_i^-,\ d_i^+ \geq 0 \text{ with } i = 1..n$$

In the illustrative example of this study, we have one objective and three goals to accomplish with two constraints. Based on the information above, here is the model constructed:

With t_1 : product life span

t_2 : contract duration

t_3 : additional contract duration

y_i^+ with *i*=1,2,3 : upper tolerance limit for *i* th goal

y_i^- with *i*=1,2,3 : lower tolerance limit for *i* th goal

Goals in our model:

- $t_1 = 5$ years
- $t_2 \geq 3$ years
- $t_3 = 1$ year

It is aimed that the product life span should be equal to 5 years which is also aimed in many companies in this sector. The contract duration should be equal or bigger than 3 years, which also shows that the longer the contract life the better the trustfullness of a company. Additional contract duration is an optional tool to be benefited from the original contract. The companies gain money when they extend the additional contract duration. In a vacuum-cleaner there can be a one year additional contract duration.

To put them in another way, the goals can be demonstrated as:

- $t_1 - y_1^+ + y_1^- = 5$
- $t_2 - y_2^+ + y_2^- = 3$
- $t_3 - y_3^+ + y_3^- = 1$

System constraints in our model:

1. $t_1 \geq 2\, t_2$
2. $t_2 + t_3 \leq \frac{2}{3} t_1$

The first constraint shows that the product life span should be equal or bigger than 2 times the contract duration. In many products, the estimated life span should be much bigger than the contract duration to prevent loss in a company.

In the second constraint, it is estimated that 3 times the summation of the contract durations should be less than 2 times the product life span. This constraint also supports the first constraint in which the product life span should be longer in order to prevent loss and to augmente thequality and the trustfullness.

All the deviational variables and the durations should be non-negative to obtain logical results. Here are the non-negativity constraints:

$t_{i \in 1,2,3} \geq 0$

$y^{+}_{i \in 1,2,3} \geq 0$

$y^{-}_{i \in 1,2,3} \geq 0$

As explained earlier, according to the general methods of goal programming with equal weight constraints, the objective function is constructed as follows:

Min z = $y_1^+ + y_1^- + y_2^- + y_3^+ + y_3^-$

Using MS Excel Solver, these approximate results can be easily found.

t_1 = 6 years

t_2 = 3 years

t_3 = 1 year

Z = 1 year

The result is 1 years with product life span 6 years and contract duration 3 years. The additional contract duration is 1 years as precised in the goals of our model.This illustrative model can be diversified by adding different goals and constraints, or changing the existing ones.This result can ideally minimize the customer complaints and also minimize the customer dissatisfaction.

6. CONCLUSION

This study proposes a novel approach of fuzzy QFD, in which the real "voice of the customer" data is used which is customer complaint data instead of vague customer requirement data used in many studies in literature. The companies should aim to make sure that the VOC is completely understood and act accordingly.

The objective is to minimize the dissatisfaction which also is an innovative approach. Constructing the basic matrices of HOQ is also an novel approach. Firstly, the main customer complaints and technical attributes are found with a brief analysis of literature and Customer Complaint Platforms. After that, the indication of the relationships and interrelations among customer complaints and technical attributes by the decision-makers with an aggregation method of triangular fuzzy estimations under a group decision-making methodology is made.

The results of the HOQ construction lead the reader to find important engineering characteristics. With the proposed goal programming method, an illustrative application area of these important characteristics can be seen. The best result can be found to minimize the dissatisfaction of the customers.

The formulations in this study can allow making assessments by the related teams of the company. They can serve as an important tool to take proper actions in product improvement processes of a company. The framework can help the companies identify the customer opinions and complaints systematically. This methodology cannot be effective in companies which already have database systems to analyse the customer complaint data.

The same methodology used, which is fuzzy QFD, can be done with real recorded data of a specific company. In addition, the modelling part can be done with fuzzy goal programming technique which considers all the technical properties cited in the paper. Besides, the constraints of the model can be varied by adding some constraints like cost constraint or budget constraint. The goals and the objectives can be changed accordingly.

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BIOGRAPHICAL SKETCH

Ece Öztürk is a manufacturing systems and industrial engineer. After graduating from a French high school naming Saint-Joseph, she decided to have an engineering degree because of her interest in numerical and scientific lessons. She went to one of the reputable universities in Turkey, Sabancı University. Obtaining her industrial engineering degree, she decided to narrow her area of expertise in industrial engineering and started Masters Degree in Logistics and Financial Management in Galatasaray University.

During her academic life, she had an internship in a pharmaceutical company to become familiar with this sector as a manufacturing planning and logistics intern. During this internship, she had the chance to practice SAP and Excel in a detailed manner and augmented her material planning skills. She has fluency in both French and English, with the summer camps; she has the chance to practice her speaking skills in both languages.

She currently worksas a junior purchaser in a multi-national company PSA Peugeot Citroen in global purchasing department where she practices French language, SAP and learns key notions of the purchasing department.

She wrote aproceeding paper with ZeynepSenerentitled‘‘a QFD-Based Decision Model for Ship Selection in Maritime Transportation.” It’s about selecting the convenient ship during maritime transportation and the paper proposes a decision approach, QFD. The data used in the study contains company needs and ship attributes. Their correlations and interrelations among them are found and used during the application of the methodology. The paper concluded with simple additive method. The paper is published in the proceedings of the 5th International Conference on Management and Service Science, ICMSS 2015 in Rome, Italy.