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**FORECASTING THE FUTURE NEEDS OF
CUSTOMERS FOR NEW PRODUCTS**

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DECLARATION

I hereby declare that this master's thesis titled as "**Forecasting the Future Needs of Customers for New Products**" has been written by myself in accordance with the academic rules and ethical conduct. I also declare that all materials benefited in this thesis consist of the mentioned resources in the reference list. I verify all these with my honour.

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ABSTRACT

Master's Thesis

Forecasting the Future Customer Needs for New Products

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The way of doing business and being successful in it evolves within time. With the increasing speed of technological developments, innovation has become a more important topic than it ever was. Competition in markets has become tougher due to globalization. Product life cycles have become shorter due to the race among companies to produce the better and newer product. Making customers happy has become a differentiating factor in business. As a result of these developments, business environment demands high customer satisfaction rate for success in long term. Thus to be successful, there is a need for companies to know what customers expect from them. A sector in which the technology is changing very fast, also needs faster adaptation or for a better chance, requires companies to be a leading innovator. However, with each innovation, customers' expectations are also effected. So, companies need not only understand their customers' needs but they should also anticipate the change in their needs in future. Thus, there is a need for combining a forecast system that is able to detect the changes in customer needs, extracted from a QFD study or similar analyses.

This study primarily focuses on finding a conceptual framework which can be used to predict the weights of future customer requirements (CR) of the target market segment for new product development. The lack of historical data is a problem for forecasting when it comes to new products, so existing forecasting methods are carefully examined. QFD tools are used in the first step to understand the different categories and importance of customer

requirements. The, Kano questionnaire is applied to use Kano categories to modify weights and predict the changes of states for each CR. A modified version of Kano questionnaire is conducted; that can be analyzed to find out transition probabilities between Kano categories. With the help of Markov Chain, the probabilities of states for each CR are predicted to generate four data points. Grey Theory Forecasting is a suitable tool, as it only requires four data points for a robust forecast. GM (1,1) methodology is applied to the data to predict the change in weight of customer requirements.

The suggested framework has been applied with a case study, in which the target product was selected as notebook. Customer requirements have been forecasted for four periods. The results indicate that importance of CRs do change within time for customers. In fact, 20 out of 24 CRs selected for this study changed in importance rankings after four periods. This highlights the necessary effort on companies' behalf to be able to predict future importance of CRs, especially in the early design phase to produce more successful products.

The output of this model can be much valuable for management or decision makers, in the process of design for engineers. This will also help preventing unnecessary R&D efforts and budget spending on features which can become obsolete in future; while directing the energy to an area which will be more valuable in the eyes of the customers.

Keywords: Statistical Forecasting, Markov Chain Model, Grey Model, Kano Model, Quality Function Deployment, Customer Requirements, New Product Development

ÖZET

Yüksek Lisans Tezi

Yeni Ürünler için Gelecekteki Müşteri İhtiyaçlarının Tahminlenmesi

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İş yapma yöntemleri ve iş piyasasında başarılı olmanın yolları zamanla değişmektedir. Artan teknolojik gelişme hızı, inovasyonu daha önce olduğundan çok daha önemli bir kavram haline getirdi. Pazardaki rekabet, globalizasyonun da etkisiyle çok daha kızıştı. Üreticiler arası en iyi ve en iyi ürünü üretme arışı, ürün yaşam döngülerinin kısılmasına yol açmıştır. Müşterileri mutlu edebilmek, şirketler için bir adım öne çıkma fırsatı, diğerlerinden ayrılma fırsatı olmuştur. Bu sebepler dolayısıyla, şirketlerin uzun dönem başarısı, müşterilerini tatmin etme zorunluluğunu ortaya çıkarmıştır. Bunun yolu da, şirketler için müşteri isteklerini anlamaktan geçmektedir. Teknolojinin daha hızlı evrildiği bir sektörde başarılı olabilmek için şirketlerin bu hıza ayak uydurabilmesi, hatta sektöründe yenilikleri lokomotif olarak bizzat ortaya çıkarması gerekmektedir. Ancak, her eklenen yenilikle müşteri beklentileri de değişmektedir. Bu nedenle, şirketlerin müşteri ihtiyaçlarını sadece o dönem için anlaması yetmemekte; aynı zaman bu müşteri ihtiyaçlarının zamanla değişimini de ön görebilmeleri gerekmektedir. Bu yüzden; hem müşteri ihtiyaçlarının belirleyip hem de bunları geleceğe yönelik tahminleyebilecek bir birleşik yöntem belirlenmesine ihtiyaç vardır.

Bu çalışma asıl olarak, yeni ürünler için hedef müşteri kitlesinin ihtiyaçlarının tahminlenmesini sağlayabilecek bir yapı kurmaya odaklanmıştır. Yeni ürünler için geçmiş dönem verilerinin olmaması, literatürdeki tahminleme yöntemlerinin daha detaylı incelenmesini gerektirmektedir. İlk aşamada müşteri ihtiyaçlarının belirlenmesi için Kalite Fonksiyon Göçerimi araçları

kullanılmıştır. Kano Model'in entegresi ile müşteri ihtiyaçlarının önem ağırlıkları düzeltilecektir. Kano Anketi ufak bir değişiklik ile uygulanarak, Kano kategorileri arasında zamanla geçiş olasılıkları hesaplanmıştır. Markov Zincirleri kullanılarak, bu her bir müşteri ihtiyacı için hangi Kano kategorisine ait olduğunun dört dönem olasılık hesabı yapılmıştır. Daha sonra Gri Tahminleme (1,1) kullanılarak müşteri ihtiyaçlarının ağırlıklarının değişimi tahminlenmiştir.

Önerilen yapı, hedef ürünün "diz üstü bilgisayar" olarak seçildiği bir örnek olay çalışması üzerinden gösterilmiştir. Müşteri ihtiyaçları dört dönem bazında tahminlenmiştir. Sonuçlar, müşteri ihtiyaçlarının öneminin zamanla değiştiğini göstermektedir. Listedeki 24 müşteri ihtiyacından 20'si önem sıralamasında dördüncü periyot sonunda, ilk sıralamasından farklı bir yerde olarak tahminlenmiştir. Bu sonuçlar; şirketlerin müşteri ihtiyaçlarının önem ağırlıklarının gelecekteki durumlarının tahminlenmesi için gerekli eforu sergilemesinin önemini altına çizmektedir. Bu kabiliyete sahip olmak, özellikle erken tasarım aşamasında daha başarılı ürünler piyasaya sunabilmede önemli bir faktör olabilir.

Bu modelin çıktısı; yönetici ve karar vericiler için ve ya tasarım aşamasında mühendisler için değerli olacaktır. Ayrıca, sonuçlar doğru yorumlanırsa gelecekte önemsiz hale dönüşebilecek ürün özelliklerini geliştirmek için harcanacak para, efor ve zaman; daha değerlendirilecek özelliklere aktarılarak daha rekabetçi bir ürün ortaya çıkarılması sağlanabilir.

Anahtar Kelimeler: İstatistiksel Tahminleme, Markov Zincirleri, Kano Modeli, Gri Model, Kalite Fonksiyon Göçerimi, Müşteri İhtiyaçları, Müşteri Gereksinimleri, Yeni Ürün Geliştirme

FORECASTING THE FUTURE NEEDS OF CUSTOMERS FOR NEW PRODUCTS

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ABBREVIATIONS

A	Attractive
AHP	Analytic Hierarchical Priority
CN	Customer Needs
CR	Customer Requirements
DI	Dissatisfaction Index
EC	Engineering Characteristics
ER	Engineering Requirements
GM	Grey Model
HoQ	House of Quality
I	Indifferent
LCD	Liquid Crystal Display
M	Must be
MAPE	Mean Absolute Percentage Error
O	One Dimensional
PLC	Product Life Cycle
Q	Questionable
QFD	Quality Function Deployment
R	Reverse
R&D	Research and Development
SI	Satisfaction Index
TM	Technical Measurements
VoC	Voice of Customer

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INTRODUCTION

Fast changing environment and conditions of 20th century in political, technical and scientific areas has led to many structural differences on how the business today can run its course and make profit. After Industrial Revolution with the availability of new machines that are capable of larger production capacity and integration of energy sources into industry, came the area of “mass production and standardization”. Especially after Second World War, companies have achieved the freedom to do business overseas and compete for market share. Thus, companies, in both service and production sectors were competing on a level trying to provide acceptable quality with the lowest prices as possible, approaching the customer collectively rather than seeing them as individuals having different mindsets, except from niche segments. However, in 70’s, individualism trend has become popular and from then on, customers started to desire and demand the products tailored to their specific needs. Also, customer satisfaction has gained importance as a subject in marketing departments and academics as well. The success of a product is considered to be dependent upon how much it satisfies customer; so “true quality” was started to taken as how much it satisfies the customer base (Akao, 1997: 2). As a result of this change, companies have started to invest on projects to measure their potential customers’ needs, wants and desires and analyze them. A successful example was Quality Function Development (QFD); which was developed during this period and became central to business management (Akao, 1997: 1).

Status quo in business has further changed greatly with the development of Internet, later WEB 2.0, e-marketing, social media and this change goes on with each new technological development that is integrated into daily life and gained acceptance from large customer groups. Globalization enabled logistic chains to cover almost all-around world. The cost to acquire information significantly decreased due to rising Internet usage. Product life cycles have become shorter. Innovative products started to get customers’ attention. The fast changing pace of technology which brought out the need for continuously improving the firms’

products or service offerings to keep its customers satisfied and happy (Bhattacharya, 2014: 50).

This all resulted in competition getting very tough in markets and market leaders could only make differences due to small advantages they have. As a result of these developments, business environment demands high customer satisfaction rate for success in long term (Matzler & Hinterhuber, 1998: 26). A sector in which the technology is changing very fast, also needs faster adaptation or for a better chance, requires companies to be a leading innovator. So, companies need not only understand their customers' needs but they should also anticipate the change in their needs in future. Thus, there is a need for combining a forecast system that is able to detect the changes in customer needs, interpolated from a QFD study or other analysis.

In this study, the possible ways to forecast customer needs, wants and demands in future will be analyzed, in which QFD tools will also be relied upon. The aim of this research is to develop a model which can forecast the changes in customer needs and general market trends with minimum error rate. The focus of this will be on "new products"; so the existing literature on forecasting methods for new products will be analyzed alongside QFD methodology. This is also important as it has potential to contribute to literature in both fields.

The application of forecasting techniques to predict future customer needs in literature are actually rare but there is an increasing interest on this area. While there is an abundance of diffusion models, forecasting with time series; the combination of QFD and forecasting methods are still limited.

One of the applications of this combination has taken place in software industry (Purohit & Sherma, 2015). Their idea of forecasting customer requirements stemmed from the dynamic nature of customer requirements and the lag between QFD data collection phase and actual product launch. Thus, in today's rapid changing world, the actual product will not be able to satisfy customers; hence forecasting is a necessity for QFD (Purohit & Sherma, 2015: 208). They have used data mining forecasting techniques in their process. While the main aim of this study is not to explain how this process would work but designing a software database and

simplifying it; it is important because forecasting of customer requirements found out by QFD is described as critical.

A paper has reviewed and developed a model of new service popularity (Vrdoljak et al., 2012). They have used Service Life Cycle growth models and Bass Model to predict how the new clip will gain popularity among viewers. They have used semantic similarity to gather input parameters to use in Bass Model to forecast growth. Certain new features of a product can be modeled with Diffusion Models if a similarity between historical product requirements can be established. This would, in return, make the forecast error smaller.

Forecasting the future trends is also closely related to the purpose of this study. An example was found in cell phone industry, where the researchers have analyzed customer reviews on similar products on web and identified positive or negative trends (Tucker & Kim, 2011). Using the data that has emerged from their analysis; they stated that the positive trends, which means they are being demanded by users, actually correspond to “Attractive Quality” in Kano’s Model. This information can help design engineers to enhance the new cell phone or the next version of the cellphone. Product features, which a negative trend has been found for, can be similarly eliminated or substituted for the next time period. The technique used here is called Holt-Winters exponential smoothing method and accuracy of the forecast is evaluated by Maximum Absolute Percent Error (MAPE). This study is important in that the input for forecasting obtained from publicly available customer review data and easy to collect.

Another paper, where data mining techniques have been used for QFD in order to predict future customer requirements (CR) for computer designers and manufacturers was published in Taiwan (Hsu et al., 2012). Based on a huge amount of data collected by a Taiwan manufacturer with sales questionnaires, time series based data mining cycle techniques have been applied to predict future CRs. Having access to data of the last four periods, the weights of CRs, consequently engineering requirements (ER) are calculated. It has been suggested that this technique provides an effective procedure of identifying the trends of CRs and enhances customer relationship management in the computer marketplace (Hsu et al., 2012: 8).

Raharjo et al. (2010) carried out a time series analysis of historical data about customer needs from Kano questionnaires. Using compositional double exponential smoothing, the results for each Kano category, which are in percentage data form, are forecasted. Then, the importance rankings for customer needs are derived from Kano results and integrated into QFD model for better product success in market. Integration of Kano's Model into QFD to better identify Voice of Customer (VoC) is critical and is related to the topic of this thesis. The life cycle of attributes for CRs described by Kano is highly dynamic and the results from this paper reflect this. According to this paper, application of multiple time series forecasting techniques doesn't only make QFD input more robust but also useful for implementing future strategies in the context of customer driven innovation.

Use of fuzzy logic for new product specification has also been applied in literature (Jeddi, 2016: 105). Usually, the input variables in forecasting have been assumed to be numerical however this will not be the case for customer requirements. The authors suggest that incorporation of fuzzy set logic can be an answer to confront this question (Jeddi, 2016: 112).

Markov Chain modeling and Grey forecasting methods have also become a point of interest for analyzing and predicting customer requirements. Wu et al. (2005) proposed a model implementing GM (1, 1) method using the periodical QFD outputs; such as the weights of customer requirements; the relationship between CRs and technical measurements (TM), to forecast the weights of CRs for the 5th period based on the four data points observed historically. Forecast error percentage was low and organized graphics can be of help to monitor the changes. The relation of CRs with TMs could give companies a direction to check and plan which processes are important for customer satisfaction and how that can change in upcoming periods.

The use of Markov Chain is not limited to predicting the weight of customer trends in literature. In a later study, researchers applied Markov chain model to analyze the relationships between TMs and CRs from a probabilities point of view in case of incomplete information and data (Wu & Shieh, 2008: 670). It is stated in another study that drawing of the relationship matrix between TMs and CRs is a vital part of each QFD practice since the final analysis and key decisions heavily depends

on it (Wu H. H., 2006: 1279). When designing a House of Quality, this relationship usually takes the name of “the relationship between WHATs and HOWs”; WHATs refer to CRs and HOWs refer to TMs. This relation is assumed to be known by members of the team that is leading the QFD practice, usually a cross-functional team covering up different areas. However, in real life situations, the experience of the team may not be enough and/or due to limited information, it might be difficult to assess the relationship correctly. Thus, use of Markov Chains in this part of the QFD analysis, could approach it with a probabilities point of view (Wu & Shieh, 2008: 672). The paper also makes an illustrative example of how their models work. For simplicity, the example only includes two CRs and one TM. After the assumption of the weights of relationship between CRs and TM, as strong, medium and weak respectively, for the initial probability matrix; the probability matrix of the change of relationships from state to state is calculated. Calculation of the new weights after one, two and three transitions as well as a steady state weights is done. The results are plotted on a graphic for each CR including after transition weights. Also, the output of the model could be used to monitor the importance trend of TMs and the model is flexible enough to update for whenever new data becomes available. The prioritization of TMs can be possible with this model for decision makers.

A Chinese study investigated the customer requirements analysis with two sub-sections; first clustering CRs with TMs, then implementing a trend analysis for CRs to see how their importance will change in future (Chen & Wang, 2008: 325). They tested their method with data from an electrically powered bicycle manufacturer, as the demand for such bicycle had been growing and the company is eager to know future importance of bicycle features to help them with decision-making to implement feature in their new products. With historical data from the company for the last four periods, GM (1,1) forecasting method is applied to predict near future. The dynamic nature of CRs (and the related TMs) is noted by scholars and trends of each CR are plotted on a graphic to visualize the data. It has been suggested that this forecasting method will help company to satisfy or even exceed customer requirements, keeping their customers satisfied which will in turn increase the company’s competitive power in marketplace.

This study primarily focuses on finding a conceptual framework which can be used to predict the future customer needs (CN) and related customer requirements (CR), of the target market segment for new product development. Customer requirements are built upon customer needs; they are rather formal form of customer requirements (Sari et al., 2001: 2). It was also mentioned (Xie et al., 2003: 12) that customer needs are translated to customer requirements in one of the first steps while constructing the House of Quality (HoQ), a part of QFD methodology. Hence, CRs will be used to represent the customer needs.

Designing of new products and forecasting the demand for such products by already accepted qualitative and quantitative methodologies will serve as a base to the predictive framework suggested with this thesis. QFD tools will be used in the first step to understand the different categories and importance of customer requirements. Classification of CRs will be done with Kano Model Questionnaire and their importance weights will be adjusted according to the results. Then, Markov Chain Matrices will be formed from the data collected from questionnaire results. Markov Chain Model will be used to generate inputs for the main forecasting model in this study, which was chosen as Grey Forecasting Model – GM (1,1). Thus, the weights of CRs can be forecasted. This contributes to the efforts to overcome the scarcity of literature on this topic; while suggesting a brand new framework including combination of models.

In the first chapter, background information about QFD methodology and use of related QFD tools are examined. Second chapter includes forecasting methods that exists in the literature, which could be of use for the purposes of this study. Extracted from this knowledge base, a framework on forecasting the future of CRs will be suggested in third chapter. Fourth chapter includes a case study for demonstration purposes of the suggested framework. The results will be analyzed and possible short comings will be interpreted. Further advice from the study will be given for future works.

Main objective of this thesis is to help companies to be able to have a better success rate in market with their new products; with combining QFD tools and forecasting methods to produce a framework to understand customer requirements in

future, which will be very valuable information especially early in the new product development phase.



CHAPTER ONE

QUALITY FUNCTION DEPLOYMENT

QFD is a total quality management tool which was developed in Japan, aimed to ensure consumer satisfaction during this development stage of the new products. Before this technique; quality tools and usual quality strategy among firms was dependent on finding product defects during production or after customers bring the unnoticed defects after they had made the purchase (Akao, 1997: 6). It can be said that previous techniques, attempted to raise general quality levels and customer satisfaction, was not adequate and thus QFD started to get more attention and became widely used around the world (Hsu et al., 2012: 2).

Of course; changing dynamics in production, design development, customer behavior, new marketing techniques and customers' desires to obtain a more individualized product led to changes and improvements in QFD methods. The specifics of the theory; its applications worldwide and generated benefits will be covered in next sections.

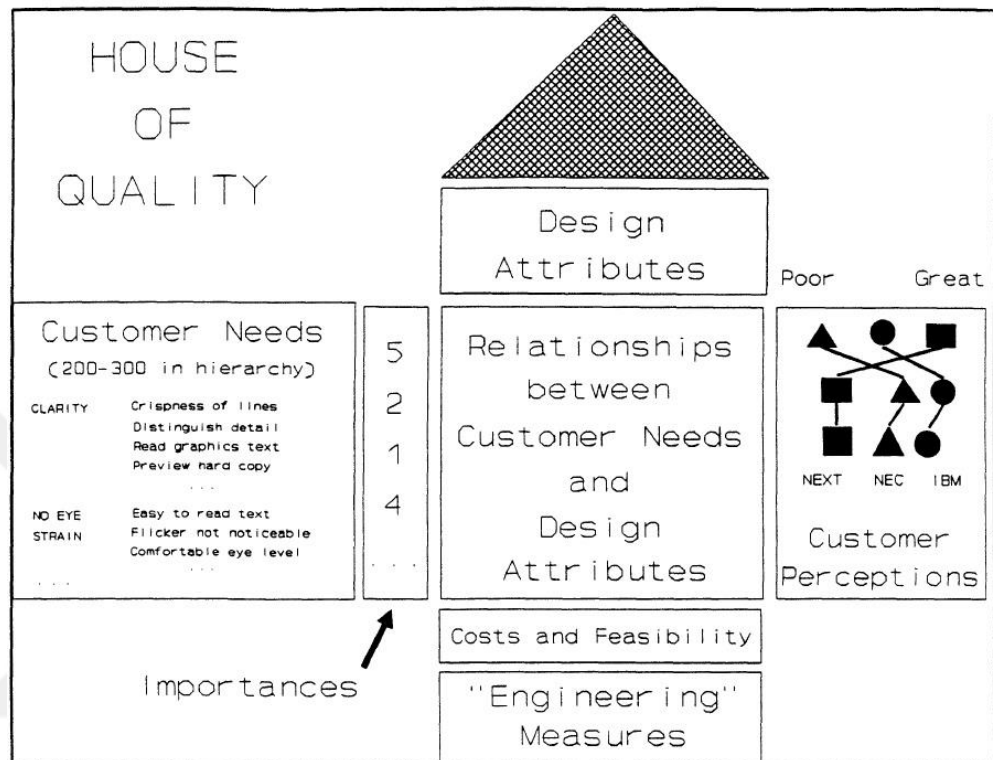
1.1. THEORY AND HOW IT WORKS

QFD, nowadays, is a necessary process in product development; it starts with understanding customers' needs and translating these needs into engineering specifications, to be applied and tested before the actual production starts. These product specifications; which are reflecting customers' demands from the producer company, are called "quality characteristics" (ReVelle et al., 1997: 3). They are substitute characteristics for customers' demands from a product; the ones which are fitted and understood more easily by production engineers. These criteria also serve as control points before production in mass scale starts (ReVelle et al., 1997: 3); if certain characteristics are not satisfied, it would have a negative impact on the success of the launch of the product.

The listing of customers' demands and engineering characteristics; meaning that how they relate to technical measurements, are depicted in a chart called "House

of Quality” (Griffin & Houser, 1991: 8). The structure of House of Quality (HoQ) needs to be explained in order to understand how QFD works for a new product in its design phase. An example of HoQ is given in the Figure 1.

Figure 1: House of Quality



Source: Griffin & Houser, 1991: 4

HoQ consists of several parts; hence it is called a house, it has several walls, an area of living space which connections happen and a roof. Traditionally, on the left side, the customers’ needs and demands are written (Griffin & Houser, 1991: 5). These are listed items that have come up in prior marketing research for the product and customer needs. Customer needs can be generated by different techniques; Gemba visits, questionnaires, focus groups, in depth interviews, lead user analysis, sales force recommendations, customer reviews in web (Mazur, 2000: 3; Özdağoğlu et al., 2018: 1546). These attributes are then prioritized by customers, showing the relative importance of each attribute; a quantitative value is given for each one.

On the right section, an analysis of competitors takes place. This area gives the ability to do a mini benchmark for our product and enables us to get an idea of where our end product will stand to next to other competitors’ products. An

assessment of how the competition stand regarding satisfying current customer needs can be extracted by the information which is collected by the questionnaires (Xie et al., 2003: 16).

Third part of HOQ is the engineering (or design) characteristics (EC). This is located on the top of the main body. Purpose of this section is translate customer attributes, as they verbalize their needs and come up with technical terms to describe what is actually needed questionnaires (Xie et al., 2003: 13). For an example; a customer attribute for an LCD TV complaining about blurry image translates to an EC as higher definition of screen, meaning more pixels in the same size of the screen. As can be imagined, there could be several reasons or engineering characteristics that are related to the solution or innovation to satisfy a customer demand.

Fourth part of the HOQ deals with the relationships between these two dimensions of CRs and ECs and takes place in the main body of the house (Griffin & Houser, 1991: 7). The relationships in question can be negatively or positively correlated and the strength of the relationship can change from very weak to very strong on a scale.

The fifth part shows a prioritization analysis about which of ECs, company's focus should be directed and which one of those are more valuable for the ultimate customer satisfaction (Xie et al., 2003: 17). Quantitative techniques are used here in order to calculate the importance. In this part, target values for each component should also made clear for the upcoming engineering work.

The roof of the House of Quality shows the relationships between ECs themselves. There can be cases where satisfying one attribute causes a hindrance to another one (Xie et al., 2003: 15). To what degree one will be satisfied depends on the customers' selections that are extracted from the data we have collected on importance according to customers.

It should also be noted that QFD, hence the design of HoQ also evolved with time; as modern tools are adapted into QFD methodology. Determinations of target values, competitive benchmarking tools are incorporated into HoQ modifying its initial origin (Xie et al., 2003: 26).

1.2. APPLICATIONS AND BENEFITS

QFD and quality charts have become common tools for companies to use worldwide after the initial development in Japan. A wide array of industries has applied QFD and saw improvements in their measurements. If we are to classify quality characteristics into “negative” and “positive” variants; QFD deals with finding out the unspoken demands that would assure quality in the perception of the customer (Akao, 1988: 4). This exact reason makes the use of QFD a critical part in new product development and applicable to a wide array of industries; from manufacturing to service. The value is given customers’ needs as it is a customer driven approach.

The most important benefit of QFD applications is that, this method is preemptive in its efforts to ensure quality. By understanding what customers demand in a product early in design phase and the importance they assign to each demand, a solid plan can be built for product’s success (Griffin & Houser, 1991: 3).

QFD application involve the cooperation of several departments; from marketing, sales, design engineering, research teams, production, planning. The information flow and analysis of such information may cause trouble at the very start; yet at the very least it shows a direction to follow for all members of the company (Mazur, 2010: 4). Also over time a structure and knowledge base appears which makes further developments in new products, giving the company an expertise in doing so.

The benchmarking part allows to the companies where their current products stand in competition and which level to they should improve it (Xie et al., 2003). Consequently for new products, it gives a target value to achieve adjusted to importance weight given by customers. When used as main building block; it eliminates the further need to change the design in later phases, thus reducing the level of costs associated with product development. Trial and error would drive up the costs and needs to be avoided. Similarly, the design development and engineering teams save time by focusing on features that really matter in terms of sales and product success; not giving time to unnecessary functions, which is another cost saving benefit of implementing QFD.

1.3. FOCUSING ON VOICE OF CUSTOMER

Voice of Customer (VoC) is a term where customers report their experiences or expectations from a product they have already used or where they state their opinions of a product in design phase. It is described as a product development technique which produces a detailed set of what customer needs and wants, which are organized into a hierarchical structure and then prioritized in terms of relative importance and satisfaction with current alternatives (Griffin & Houser, 1991: 6). This Griffin & Houser (1991: 3) article also states it has its origins ultimately in QFD process, in which customer needs are linked with performance measures; however this paper gives a more focused explanations on how it can be implemented and what are the exact sub features VoC consist of. Despite further discussions about VoC, its scope is mostly limited as current requirements.

According to Griffin and Houser (1991: 8), the process leading to acquiring a solid VoC is primarily a qualitative approach. According to them, in depth interviews with between 10-30 customers is typical and enough to generate 75-150 phrases which can be further grouped as entities. It is very important that during the interviews, customers are using their own language as opposed to using company jargon and technical terms. The nature of these research task is that they are experimental and focus on customers own experiences.

Collecting VoC and clarifying the customer needs, which may be vague, is a difficult task. When asked directly customer may have trouble with coming up with their real needs. Therefore, it is suggested that practitioners must look into hidden needs of the customers by analyzing customer complaints and problems. They may also have trouble about weighting the importance of new attributes or new requirements they may have but not realized yet (Sauerwein et al., 1996).

It has been also true that VoC have a quantitative dimension as well. If the qualitative dimension is about what customers want and need; the quantitative dimension is a representation of how customers value those different needs hierarchically (Xie et al., 2003: 31). Quantitative part is as important as gathering customer needs; wrongly calculated importance ratios can be the cause of badly adjusted product designs. End design, however, doesn't only depend on customer

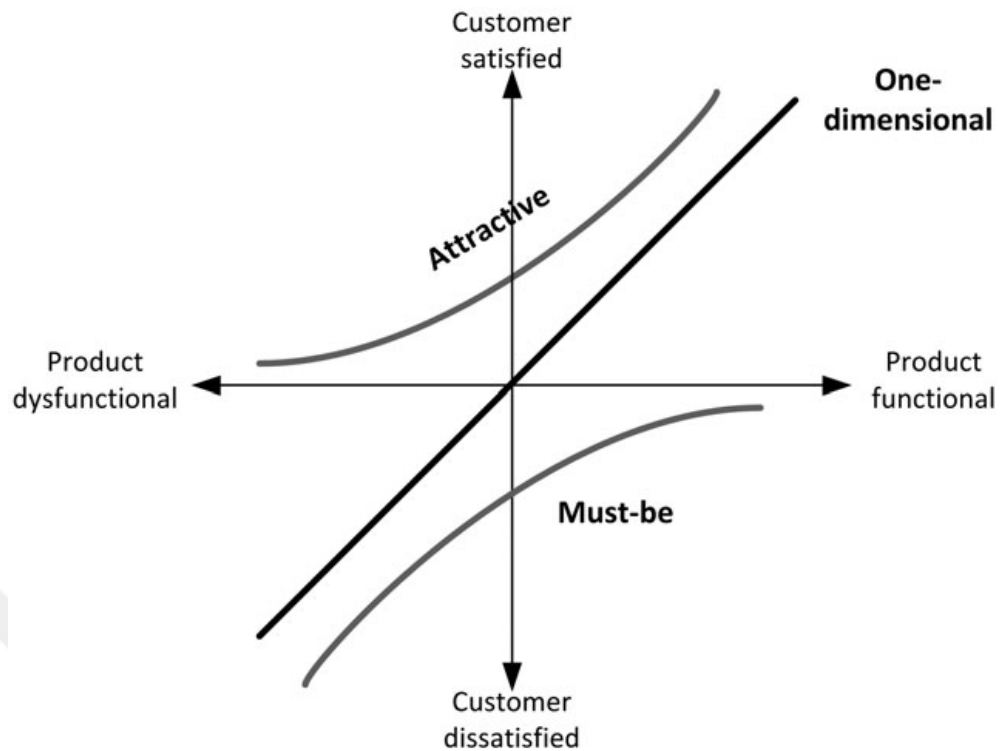
evaluations; but company's technical capabilities, market situation and product positioning are also factors to consider. Also, cost-benefit analyses of making improvements for the product; direction from management as the decision makers are also critical in product development.

To further analyze the CRs; their importance and characteristics, there are other tools that can be implemented. Analytic Hierarchical Priority (AHP) method, used for prioritizing the customer requirements have been widely used as a decision making tool. Fuzzy set theory and artificial intelligence are some of the other methods that have used with QFD (Xie et al., 2003: 30). Most important one, generally used along with QFD, is called Kano Model. According to this model; different types of customer demands effect their satisfaction in different ways and these demands are dynamic, meaning they change with time and technology.

1.4. KANO'S MODEL

The Kano Model, originally developed by Professor Noriaki Kano, classifies customer requirements under different categories according to how strong they are related to overall customer satisfaction. The classical assumption is that the relationship between customer satisfaction and quality attributes are linear; meaning the higher quality, higher customer satisfaction. Kano in his paper (1984, as cited in Kametani et al., 2010: 316) argues for this is not the case for all attributes and the impacts of such attributes can be greater or lesser depending on where they fall in spectrum. A better understanding of such relationship can be demonstrated by Figure 2.

Figure 2: Classification of Attributes According to Kano Model



Source: Ji et al., 2014: 6337

“Must-be” (M) attributes are definitely expected to be present by customers. Their absence can cause huge dissatisfaction and disappointment with the product (Matzler & Hinterhuber, 1998: 28). The absence of such attributes usually gives the product a cheap feeling and hinders other attributes, which may be really successful on its own. Car industry can be used to give a suitable example for such attribute; when a customer purchases a new car, he expects the paint to be scratch free. Defects in painting usually incline customers to question the company’s capability, causing a sort of bad reputation for the remainder attributes. The relationship between these attributes and customer satisfaction can be summarized as “absence of such features definitely causes dissatisfaction however fulfilling these don’t guarantee satisfaction.” Hence, they are called as “must be” characteristics.

“One dimensional” (O) attributes, also called as “Satisfier”, show the relationship between customer satisfaction and presence of the attribute, in line with what classical approach to quality expects, as they are more or less linearly and positively related the customer satisfaction. The more fulfillment of these

characteristics lead to better satisfaction rates; their absence or bad performance on such criteria dissatisfaction. From the same industry; fuel efficiency of cars (or gas mileage) can be given as a CR example that falls under “One dimensional” category. Customers do expect that their car to be fuel efficient and better the mileage then better the customer satisfaction (Berger et al., 1993: 4). Although there may be exceptions to these cases, such as sports cars where other criteria such as acceleration or top speed are more important.

“Attractive” (A) attributes, or sometimes called as “Delighters” as well, can be described as attributes that sets the product part from competitors. However, their absence doesn’t cause dissatisfaction in the customers’ eyes (Ji et al., 2014: 6336). They can be the tangible results of extensive R&D efforts, a technological improvement or simply a novelty that has not been marketed before. These are the attributes, where aggressive marketing strategies may be based upon to differentiate the product from the others. Automatic folding side mirrors, driver seat heating in a small non luxury car can be given as examples to attractive quality. They cause a great level of satisfaction when present; in this case these attributes are directly oppositional to must-be attributes.

There are three other categories which a CR may fall into after analyzing the questionnaire results; namely “Indifferent” (I), “Questionable” (Q) and “Reverse” (R). “Indifferent” is the category; when customers are not interested in if that feature is present or not, it doesn’t affect their satisfaction either way. “Reverse” is the situation, when the feature is present, customers satisfaction is negatively affected. It indicates that, customers actually don’t want this feature. “Questionable” comes up when questionnaire results show a contradictory pattern for that (Berger et al., 1993). This may be due to a faulty design of the questionnaire, misunderstanding of some questions by participants or just that they haven’t paid enough attention.

These categories are found out by a questionnaire format that asks customers a pair of questions for each CR. As suggested by Kano, first one of the pair tries to evaluate customers reaction when the feature is present in the product, called “functional form”; while the second question asks about customers reaction if the feature is not present, also called “dysfunctional form” (Berger et al., 1993: 5). Combining these two answers; the category which that certain CR or product feature

belongs can be classified. The results for combination are given in the table below; showing its Kano category.

Table 1: Kano Model Evaluation Table

Product requirement → ▼		Dysfunctional form of the question				
		1. I like it that way	2. It must be that way	3. I am neutral	4. I can live with it that way	5. I dislike it that way
Functional form of the question	1. I like it that way	Q	A	A	A	O
	2. It must be that way	R	I	I	I	M
	3. I am neutral	R	I	I	I	M
	4. I can live with it that way	R	I	I	I	M
	5. I dislike it that way	R	R	R	R	Q

Source: Matzler & Hinterhuber, 1998: 32

While the Kano categories are definite; sometimes results may not be as clear cut. In his work; Berger et al. (1993: 18) states that Kano questionnaire implementers may come across with cases, where answers may be spread out to different categories. Timko, an experienced user, then came up with an index to better quantify the results of the questionnaire (Berger et al., 1993: 15). According to him, a feature with %65 of responders consider “Attractive” must be different than another one with %90 selection rate. Also, he wanted to know the cost of not including that feature and potential satisfaction of including the same one, thus getting one positive and one negative value for each CR. The initial formulas for these are given below; later named as “Satisfaction index” (SI) for positive and “Dissatisfaction Index” (DI) for the negative value (Chaudha et al., 2011: 692).

$$SI = \frac{A + O}{A + O + M + I} \quad (1)$$

$$DI = \frac{O + M}{A + O + M + I} \quad (2)$$

Further developments are made to better integrate Kano Model categories into a QFD work and how these categories can be quantified into CR weights. A model has been proposed by Chaudha et al. (2011: 693), which adjusts the weights of CRs according to Kano category it belongs to achieve higher customer satisfaction rates. The adjustment ratio is an inherent part of QFD, manipulated by sales target and competitor's situation but that doesn't include the effect of Kano categories. The critical part of this work is that they also include all Kano data and also "Indifferent category" in their adjusting function, which was generally ignored before. The function (IR_{adj}) is given as follows.

$$IR_{adj} = (1 + m)^k \times IR_0 \quad (3)$$

IR_0 is the original improvement ratio. The value of " m ", represents the maximum value of the DI and SI pair; while k is the value given according to the determined Kano category. The values are taken as "0", "0.5", "1", "1.5" for indifferent, must be, one dimensional, attractive category, respectively. According to authors, including indifferent category due to its potential to evolve into innovative features and placing more weight on attractive features will make product more desirable and competitive as this can actually exceed customer expectations (Chaudha et al., 2011: 693).

Another way to integrate Kano model into QFD by assigning quantitative values to Kano categories has been suggested by Tontini (2003: 109). His suggestion, modifies the Kano questionnaire to calculate the customer satisfaction rate for a certain CR; asking them if the product doesn't have a certain feature, how would customers feel, same as the original Kano questionnaire, however the scale here is different and ranges from "-5" to "5", "5" being the most satisfying reaction. "SI" is calculated by summing up of all positive answers lying on the positive side of

the scale and dividing them by 5; while “DI” is calculated by doing the same method but for the negative side of the scale. Then, the maximum value between these two values is taken and summed with 1 to get the adjustment factor (Tontini, 2003: 113). Adjustment factor is multiplied by raw weights of CRs for final importance weight.

While classifying attributes into such dimensions, it must be taken into consideration that; they are dynamic, both with time and market segment (Löfgren et al., 2011: 238). The exact same attribute can be considered as attractive or one-dimensional or even in extreme cases must-be according to class segment. A customer who is willing to pay more than 50000 Euros for a car will classify attributes very much different than another customer looking for cars around 20000 Euros price range. This is why highly differentiated products exist in different segments of market and broad analysis aiming to capture customer voice for a new LCD TV for example; is not specific enough in its scope and target segment so random questionnaires may throw off real expectations from the specific product.

Voice of customer also changes over time, especially current situation of reduced time for new product introductions. New technologies are being adopted and getting acceptance by a broader user base (Xie et al., 2003: 31). An attractive attribute at first launch, if successful, will be demanded more within time. Also further down the production, costs are reduced so product price will become lower, making the attribute accessible to larger customer bases. A recent example is that smart features in cellphones, at first used and adopted rarely has today become so mainstream that even elderly people have to buy them even if they will not be able to take advantage of its full features. The change in state of a certain CR within time is possible for other categories as well.

CHAPTER TWO

FORECASTING METHODS

2.1. DEFINITION OF FORECASTING

Forecasting can be broadly defined as a process of estimating a future event by the help of past data with a systematic approach (Hyndman, 2009: 1). Different types of forecasting technique exist in literature in various situations depending on the purpose of the forecast and what is being forecasted. A generalized distinction is where these techniques are separated as qualitative and quantitative techniques.

Quantitative forecasts are more suitable when forecasters have access to historically correct and extensive numerical data (Armstrong & Green, 2017: 11). A sales forecast of a product is usually of this nature of forecast. Most widely known and used methods which are classified within this type of forecast are “Naive methods”, “Moving Averages”, “Exponential Smoothing”, “Regression Analysis”, “Econometric Modeling”.

On the other hand, qualitative forecasts usually depend on the decision maker/forecasters intuition, experience and brainstorming of ideas with other experienced individuals. Common ones are “Executive Opinions”, “Delphi Technique”, “Sales Force Polling” and “Consumer Surveys” (Mas-Machuca et al., 2014: 5). As one can imagine, the inputs from actual potential customer and the sales department are influential factor for Sales Force Polling and Consumer Survey techniques. Forecasting by analogy is also used by experts as a qualitative method (Green & Armstrong, 2007: 368).

Another forecasting method for especially new products is “Diffusion Models” (Meade & Islam, 1995). Under this title; Gompertz Model, Bass Model and Logistic Model has achieved acceptance in literature. These models work assuming product life cycle is an S shaped curve and calculating certain parameters; they give an estimation of how the sales will go down in future. These sales figures depend of the penetration of the new product into market and how its acceptance by customer base/target market in time will realize.

2.2. QUALITATIVE METHODS

Qualitative methods in forecasting are sometimes also called as judgmental methods. Their usage is appropriate when there is a lack of historical data which makes the usage on quantitative methods not probable (Armstrong J. S., 2009: 7). There are four common qualitative methods used in wide array of fields in business, technology and sales.

First one is “Jury of Executive opinions”. This method depends on the subjective views from different areas of business; sales, production, purchasing, finance (Kahn, 2006; as cited in Kaperi, 2011: 22). Their forecasts are usually averaged and maybe tailored again by management according to their point of view. This method can work with any need for historical data; although their existence could help give executives better idea, hence it is favored by most managers.

Second method is called “Delphi Technique” and it is similar to jury of executive opinions method however more systematically implemented (Armstrong & Green, 2017: 7). The participant experts are given formal questionnaires; their responses are analyzed by another group and given feedback. The purpose of this method is to reach a consensus at the end of the process about the forecast. The responses remain anonymous throughout the process to eliminate the possibility of biases which can be caused by strong names in the field. Each iteration ends with a feedback and this loop continues until a consensus on the forecast is reached.

Third method is Sales force polling in which the sales people who are interacting with customers on a daily basis are asked of their opinions. This method is subject to biases; depending on the sales person, their area, recent sales history, personal characteristics (Gilliland & Guseman, 2010, as cited in Kaperi, 2011: 22). However the opinions of the sales manager and sales force can help to provide a basic forecast and help identify a couple of key trends. It is often more suitable for short term forecasting as the participants usually don't have required qualifications for the long term trend prediction.

Using analogies are another method for forecasting. As described by Green & Armstrong (2007), at the beginning, the case is defined and explained to experts by the administrator. Experts are selected due to their experience related to the

forecasting issue at hand. Experts then describe many analogies considering the target situation and rate similarity of the each analogy. Administrator derives a forecast from these analogies.

Lastly, a survey for customer about their expectation can be implemented. According to survey based on 168 companies; together with jury of executive opinions, these two are actually the most commonly used technique by companies (Singh, 2006: 18). The data can be obtained via telephone calls, face to face interviews, questionnaires, social media comments. After the data is obtained, more detailed analysis can lead to forecasting results.

2.3. DIFFUSION MODELS

Adaptation of innovation by market has been a research topic since 1960's. Starting with this period several diffusion models have been developed and applied in several industries (Meade & Islam, 2006: 520). There most widely used models have been named before, in this section, further explanations about the models will be given.

All of these models assume S-shaped curve of the cumulative diffusion of the innovation. There is a point of inflection and as the market goes towards saturation point, the curve starts to get flattened (Jahanbin et al., 2013: 14). Gompertz model has the following equation;

$$N_t = M \times e^{-ae^{-bt}} \quad (4)$$

where “a” and “b” are coefficients that effect the initial purchases and growth speed of the innovation. Coefficient “M” represents the market saturation level and “ N_t ” represents the number of adaptors at “t” moment. In this mode, the slope of the curve shifts before half of the market adapted the innovation which translates into slower diffusion rate in the first phase and longer diffusion period (Meade & Islam, 1995: 200).

Logistic Model differs from Gompertz Model as it assumes symmetrical saturation level. This subsequently means that market growth will slow down after half of the market adapted the innovation or product in question (Jahanbin et al., 2013: 14). It can be given as;

$$N_t = \frac{M}{1 + ae^{-bt}} \quad (5)$$

Gompertz Model and Logistic Model are very similar to each other except the rate of diffusion and turning point of the slope. They are more appropriate when the innovation is assumed be growing in a closed market, where the interaction and competition with other services is ignored by the model.

Bass Model classifies market as into innovators and imitators. “ p ” is the coefficient of innovators and “ q ” represents coefficient of imitators (Jahanbin et al., 2013: 15). The equation is given as;

$$N_t = pM + (q - p)N_{t-1} + \left(-\frac{q}{M}\right)N_{t-1}^2 \quad (6)$$

In Bass Model, the shape of the curve is different and always shifted down on y-axis (Vrdoljak et al., 2012: 457). It assumes that; the imitators are influenced by initial purchasers, who are also called as “innovators” and diffusion rate depends on this.

2.4. MARKOV CHAIN MODEL

Markov Chains are a specific type of stochastic models, in which the probability of a change happening depends upon the initial state of the model. First discovered by A.A. Markov in 1907, it is named after its discoverer. The model is applied across a variety of fields; such as inventory management, predicting changes

in market shares, stock prices, QFD projects, health services and so on (Wu & Shieh, 2006: 142).

To describe the model further; we can assume a set of ‘ n ’ states in $S = [s_1, s_2, s_3, \dots, s_n]$ and the process starts in a certain state at $t = 0$. The state, which the process starts, depends on the initial probabilities. Markov Chain Models has basically two elements and one of them is this initial probability vector, called “ Q ”. This Q vector contains probabilities of each states at the time $t=0$. It can be represented as; $Q = [p_{(s_1)t=0}, p_{(s_2)t=0}, \dots, p_{(s_n)t=0}]$ and each of the probabilities can be called as “ Q_n ”. Let’s say that in our case, it starts at s_1 at $t = 0$. The change of states of the process within each time limit is called ‘step’. From s_1 , the probability for it to move to s_2 is accepted as known and assumed to be fixed for each step. When the transition probabilities are steady state or stationary, the Markov chain can be used to forecast future values (Wu & Shieh, 2006: 143). However; the state of the system doesn’t need to change; it can also stay as s_1 . The probabilities of these state changes are called as ‘transition probabilities’ and denoted by p_{12}, p_{11}, p_{13} and so on. A square array can be created from using these transition probabilities and called as ‘transition matrix’, usually called.

In the transition matrix, each of the elements should be at least zero and the sum of numbers each row must equal to 1. Numbers in “ n ”th row in P matrix, connote the probabilities of changes to other possible states, when the initial condition is ‘ S_n ’. For a simple example, we can think of flipping a coin. There are only two probabilities; ‘heads’ and ‘tails’; each having an equal weight of “0.5”. The probabilities of each side of the coin, when tossing it will not ever change so they are fixed for each step of the way. Thus, we can create P matrix for given example as;

$$P = \begin{bmatrix} 0.5 & 0.5 \\ 0.5 & 0.5 \end{bmatrix} \quad (7)$$

An important function of Markov Chain Models is that, they can be used for obtaining probability results after n step transitions. When obtaining values for our steady state system after a known number of transitions; both Q vector and P matrix

must be used. Since our transitional probabilities' matrix is stationary; taking the “ n ”th power of the matrix would give us the “ n ”th period probabilities of each state depending on the previous state, after “ n ” steps. Q vector is used to specify the state the process is in at the time $t = 0$. This means, to calculate the state probabilities whichever the system is in, at the period “ n ”, the following equation can be used (Zhang, 2010: 47);

$$Q * P^n \quad (8)$$

Meaning scalar multiplication of “ n ”th power of the probability matrix and Q initial probability vector would give the state probabilities after n steps (or time periods) have passed (Wu & Shieh, 2008: 671). This feature of Markov Chain Modeling would be beneficial when forecasting the probabilities of the Kano categories that CRs belong to.

2.5. GREY MODEL

Julong Deng (1982), a professor researching at Chinese Huazhong University of Science and Technology, in his attempts to find solutions for problems under uncertainty, whether it's due to discrete data, lack of historical data or small sample size had come up with an interdisciplinary approach called as “Grey System Theory”. It has immediately attracted the interest many scholars worldwide and extensively researched, as it was an alternative approach to fuzzy methods. Since then, it has been applied across different industrial or social fields to find solution for complex problems. Common usage areas are analysis of relation between different systems, modeling, forecasting and decision-making problems.

It has been modified for the area it is intended to be used and is usually classified under four categories; grey relational analysis, grey modeling, grey decision making and grey forecasting, the last two being of special interest for the purposes of this study. The Grey Relational Analysis is a system analysis tool that identifies the relationship between one main factor and other factors in a system (Deng, 1989: 2). The Grey Decision Making is used to choose the decision with optimal effect from multiple decision and objectives, given that decision information

has grey elements (Zhang et al., 2014: 2). Grey Model is a dynamic differential model with a group of differential equations. It creates the base for Grey Forecasting; Grey Forecasting uses Grey Model to know where and how the events to be forecasted would appear (Deng, 1989: 10). Usage areas of Grey Model - Forecasting from literature include water demand prediction (Li et al., 2016), personal selection (Aplak et al., 2013), prioritization of expected defects (Turgut, 2013), analyzing dynamic customer requirements (Chen & Wang, 2008) and forecasting fire accidents (Mao & Sun, 2011). It has been used to quantify the uncertainty and is able to produce results where stochastic or fuzzy methods may be inefficient.

The main contrast between traditional forecasting methods and forecasting with grey models is that grey model forecasting doesn't require large amounts of historical data. Actually, only four data points are needed to implement a grey model forecast (Deng, 1989: 8). Grey Model is suitable for smaller amounts of data and this attribute of the model makes it a good candidate when dealing with processes such as new product forecasting when historical data is limited by definition (Wu et al., 2005: 1243).

Another critical feature of grey forecasting method is that, it approaches the original data and transforms the data linearly so that the variation of the original series is reduced, thus generating new grey series. There are two common ways to generate grey series; the accumulating generating operation (AGO) and the inverse accumulating generating operation (İAGO). When the AGO is applied to a series lacking regularity; the new series is a monotonically increasing one with reduced randomness, increased smoothness (Wu et al., 2005: 1243). This operation is also called as whitening method for a grey series. The mathematical expression of such operations is given below:

$$x_0 = (x_0(1), x_0(2), \dots, x_0(n)) \quad (9)$$

$X_{(0)}$ represents the original series to be worked with grey method. Then, let x_1 be AGO series of x_0 . x_1 can be defined as;

$$x_1 = (x_1(1), x_1(2), \dots, x_1(n)) \quad (10)$$

The relationship between $x_{(1)}$ and $x_{(0)}$ is given by equation 11;

$$x_{(1)}^n = \sum_{m=1}^n x_{(0)}^m \quad (11)$$

The inverse accumulating generating operation is used for returning the whitened grey series back to its original form. In the example above; $x_{(0)}$ is the IAGO of the $x_{(1)}$.

To convert original series to a whitened state to work with GM (1,1) model, further calculations are needed. GM (1,1) is the most common used Grey Model (n,m); where “ n ” indicates the order of the grey differential equation and “ m ” indicates the number of the variables (Shih et al., 2011: 1315). First whitened values need to be formed, represented by $z_{(1)}(k)$ with the help of adaptive value, α , usually taken as 0.5 (Wu et al., 2005: 1243). Then, coefficients of a and b ; called developing coefficient and grey input respectively are to be calculated. The equations to continue with GM (1,1) method are given in Equation 12 and Equation 13:

$$x_{(0)}(k) + az_{(1)}(k) = b \quad (12)$$

$$z_{(1)}(k) = ax_{(1)}(k) + (1 - \alpha)x_{(1)}(k - 1) \quad (13)$$

To find out GM (1,1) equation and calculate the coefficients a and b ; equation is written with a matrix format;

$$\begin{bmatrix} x_{(0)}(2) \\ x_{(0)}(3) \\ x_{(0)}(n) \end{bmatrix} = \begin{bmatrix} -z_{(1)}(2) & 1 \\ -z_{(1)}(3) & 1 \\ -z_{(1)}(n) & 1 \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} \quad (14)$$

To simplify; the matrix equation above can be denoted as $Y = Bv$. Then v can be calculated with;

$$v = (B^T B)^{-1} B^T Y \quad (15)$$

Extracting coefficients a and b from the equation above, formulas for each one respectively;

$$a = \frac{\sum_{k=2}^n z_{(1)}(k) \sum_{k=2}^n x_0(k) - (n-1) \sum_{k=2}^n z_{(1)}(k) x_0(k)}{(n-1) \sum_{k=2}^n [z_{(1)}(k)]^2 - [\sum_{k=2}^n z_{(1)}(k)]^2} \quad (16)$$

$$b = \frac{\sum_{k=2}^n [z_{(1)}(k)]^2 \sum_{k=2}^n x_0(k) - \sum_{k=2}^n z_{(1)}(k) \sum_{k=2}^n z_{(1)}(k) x_0(k)}{(n-1) \sum_{k=2}^n [z_{(1)}(k)]^2 - [\sum_{k=2}^n z_{(1)}(k)]^2} \quad (17)$$

When the formula is revised again with the predicted values of a and b , GM (1,1) takes the form of;

$$f_{(1)}(k) = \left(x_{(0)}(1) - \frac{b}{a} \right) e^{-a(k-1)} + \frac{b}{a} \quad (18)$$

In the equation above k represents the forecast step, while $f_{(1)}(k)$ is the general solution for the grey equation. Calculation of $f_{(0)}(k)$ will give the final forecasted values for periods. To calculate $f_{(0)}(k)$, we need to take IAGO series of $f_{(1)}(k)$. The formula for $f_{(0)}(k)$ is given in Equation 19;

$$f_{(0)}(k) = f_{(1)}(k) - f_{(1)}(k-1) \quad (19)$$

The resulting series is the forecasted values for given period; k .

CHAPTER THREE

METHODOLOGY

3.1. OVERALL DESCRIPTION OF PROPOSED FRAMEWORK

The main objective of this thesis is to create a quantitative model which can predict the importance of customer needs and the trend they show for future concerning new products; meaning that the product or service in question doesn't have any historical data which can be analyzed. Thus, the suggested framework will consist of two main parts; as the first one determining the customer needs for a new product by using QFD and related methods; the second one forecasting the future importance weights of the customer needs based on the initial values from the first part of his model.

In the first part of the thesis; QFD means and Kano Model will be used in order to collect customer data. While QFD means are to be used for identification of CRs and the weights of them, determination of which Kano category each CR belongs will be determined by specially designed questionnaires. The outputs from these models will be input to forecasting techniques.

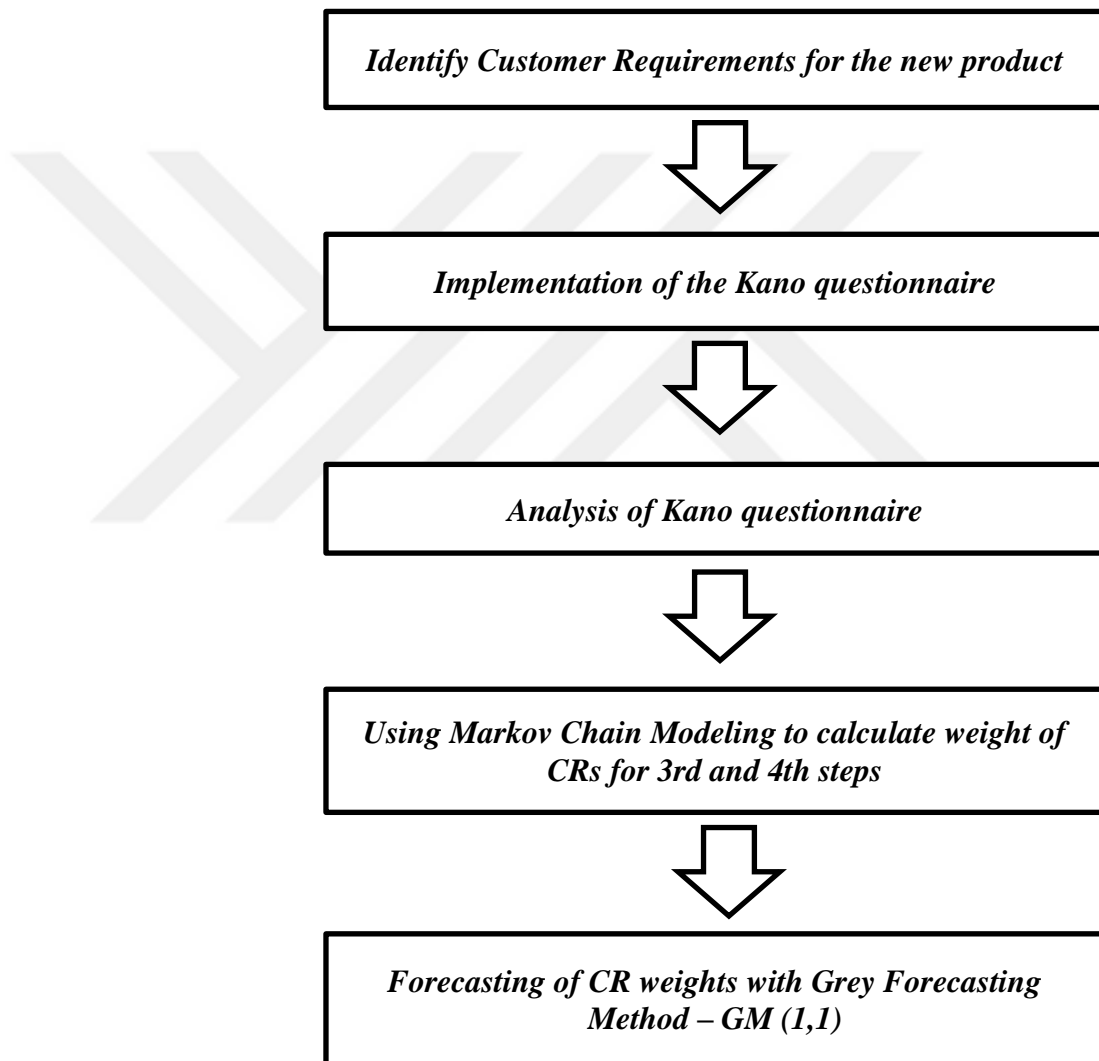
Second part is where the forecasting the future needs of customers takes place. Since new products are considered in this study, it shouldn't be expected that there is historical data at hand to be relied upon. Therefore, more traditional quantitative methods such as simple moving average or exponential smoothing cannot be used. As mentioned, methods that don't require much data such as Grey forecasting model or Markov chain probability models have been proposed in literature before. There has been an interest in this topic in literature recently however, a combination of such methods; namely Markov Chain Model and Grey Forecasting Method and a case study showing how it can work hasn't been done. This study differs from others as it shows fully integration of Markov Chain Modeling and Grey Forecasting in the context of analysis of future customer needs for enriching QFD practices.

The output of this model can be much valuable for management or decision makers, in the process of design for engineers; serving as a step to bullet proof the

product/service for changes in customer perceptions and what they want by purchasing this product/ service in future. This will also help preventing unnecessary R&D efforts and budget spending on features which can become obsolete in future; while giving a chance to canalize the energy and time for getting a competitive advantage in an area which will be more valuable in the eyes of the customers.

The overall framework of the methodology is represented in Figure 2 below.

Figure 3: Suggested Framework



3.2. IDENTIFYING CUSTOMER REQUIREMENTS

The framework starts with identifying customer requirements for a certain product or product idea which may include new features, where the product selection depends on who is employing this method. There are two sources to gather data; primary and secondary (Hox & Boeije, 2005: 593). Secondary data depends on outside sources and statistics, therefore not very useful in QFD studies as listening to the pure voice of customer (VoC) can only be accomplished when they use their words.

“Gemba visit” is one of the most common ways to collect VoC. In practice, it means going to the sight, where interaction between customers and product/service is taking place and observing them. The research team takes notes of what’s happening and can come across unexpected customer needs. This way may reveal otherwise unvoiced customer desires or some potential innovative solutions to exceed customers’ expectations (Mazur, 2012).

Another common way is to interact with customers. This can be done by focus groups or one on one interaction. Usually, the administrator asks about a certain product and customers give their comments on it (Hauser & Griffin, 1991: 9). It may also be a conversation style of interview or the participants may discuss with each other as well, sharing ideas and brainstorming. This is usually voice recorded to be listened again and analyzed by experts in future. Surveys can be also be implemented with open ended questions where customers write down their expectation or complaints.

Text mining has also been used to extract customer needs. Labor intensive work to be done by experts can be almost impossible when it comes to analyzing large amounts of data, such as online customer reviews (Özdağoğlu et al., 2018: 1546). Text mining, referring to deriving high quality information from text, can help QFD practitioners to save time and discover hidden needs of customers.

All of these data gathered are later analyzed and grouped together by experts. Customer Voice Table is one of the most important tools for extracting the true customer needs. Here, exact customer verbatim is interpreted by experts. Verbatim that may contain more than one need is broken down further. Missing or potential needs are added by experts during interpretation. They may come up with some

secret needs, extracted from words and sentences customers used. Some of the needs will be short-listed, usually due to number of customers who reported or the intensity of reaction by customers. Interpretation process continues until need items are found and most of these items start to repeat. The final list will include the more important customer needs for that specific product (Kapucugil et al., 2006).

While the methods above are very common for QFD studies; in practice for new products with innovations or new features, they may come up short, customers lacking ground knowledge of industry capabilities. This is where interviews with industry experts, technology providers may help. Interactions with lead users, constructing a test market environment to observe how they behave is another method to gain knowledge. There are technology fairs in which companies introduce their innovative ideas to business leaders and pioneering thinkers, for example the one organized by Consumer Technology Association, from which some ideas and innovative features can be integrated into products. Some of the promising features from there can be included in these questionnaires in order to see if they are desired by potential customers and observe the trends they may show.

3.3. COLLECTING CUSTOMER PREFERENCES

This study assumes that customer requirements for a certain product changes over time, which is based upon various studies and articles, referred in previous chapters. This phenomenon can be more easily observable, when it comes to an area technological changes happen frequently, thus shortening Product Life Cycle (PLC). In literature; the diffusion models are used for estimating the spread of new products. In this case, the new feature can be analogous to new product.

The Kano Model takes a similar perspective on the change of customer requirements and it arranges them under different categories. However, the categories are not stable and expected to change over time; similar to views explained in PLC articles. The new feature (or product) is barely noticeable by customers at first; then becomes the center of attention but not easily reachable; over time with production costs are declining becomes more widespread; loses its initial

charm and then falling out of customer's attention. The comparison table of certain stages between new features and products is given in Table 2.

Table 2: Comparison of Stages in PLC and Attributes in Kano Model

PRODUCT LIFE CYCLE	KANO CATEGORY
Development (R&D), Introduction	Indifferent
Introduction, growth	Attractive
Growth, Maturity	One Dimensional
Maturity, Decline	Must be
Later stages of Decline	Indifferent

In this thesis, Kano model and a modified Kano questionnaire will be used for gathering customer preferences data about product features. As implemented by two studies on this topic (Wu et al., 2005: 1244; Wu & Shieh, 2008: 640), modifying the questionnaire with asking customers about their last time purchases will be useful if an analogous or similar products already exists on the market.

In addition to classic Kano questionnaire, which consists of a pair of questions for a CR, a self-stated importance rating questionnaire will be used to understand the importance of CRs. This is also advised by literature and used commonly in practice along with Kano questionnaire (Berger et al., 1993: 12). This form is rather straight forward; asking customers how important would it be if a product has certain feature that can satisfy the CR. The scale used here, is a 9 point "Likert Scale" the same one suggested in the study of Berger et al. (1993: 12), ranging from "Not at all important" to "Extremely important".

3.4. KANO CATEGORIES AND MARKOV CHAIN MATRICES

The purpose of this step is to assign the CRs to Kano categories and calculate the transition probabilities between Kano categories for each CR. To each CR, a "before and now" Kano category will be assigned, for each participant. After

analyzing the data collected by questionnaires; the initial probability vector and transformation matrix will be formed; as suggested by Wu and Shieh's study (Wu & Shieh, 2008: 640). The formulation for the creation of these matrices is Table 3.

First step is to classify the CRs under Kano categories according to the answers concerning preceding timeline. Total number of participants who choose (CR - number i) CR_i as "attractive" is n_1A . " n_1 " refers to previous period. This is the "before" Kano category for that specific CR. Then, these same participants' answers are checked for the following timeline. After second analysis, some people will still think this is an "attractive" attribute, some may decide that it is now "one dimensional", while other people may become "indifferent" to it. The probability for this CR to change into new S_i state from initial S_A state can be calculated with;

$$n_{2(A \rightarrow i)} / n_1A \quad (20)$$

where n_2 represents the preceding timeline and ($A \rightarrow i$) refer to the customers whose opinion for that specific CR changed from A to I. This probability is dependent on the condition that, this CR is classified under "A" category for the first time interval (i.e. "before" category). It fits within rules for Markov Chain Modeling. All probability calculations for this CR to change are given in the table below. It can be noted that the sum of these probabilities should be equal to 1.00 in all cases.

Table 3: Calculation of Transition Probabilities for Changes in CRs

Before category	After category	Formula/Calculation	Transition probability
A	A	$n_{2(A \rightarrow A)} / n_1A$	$P_{(A \rightarrow A)}$
A	O	$n_{2(A \rightarrow O)} / n_1A$	$P_{(A \rightarrow O)}$
A	M	$n_{2(A \rightarrow M)} / n_1A$	$P_{(A \rightarrow M)}$
A	I	$n_{2(A \rightarrow i)} / n_1A$	$P_{(A \rightarrow i)}$
		n_1A	1.00

After completing this step for “before category - A”, the calculation is repeated for each Kano category for this CR. So, for each CR, a transition matrix will be calculated and filled out accordingly.

Another piece of information is needed for Markov Chain modeling, which is initial probability vector. This vector only depends upon the initial state probabilities of CRs, which is collected by the help of the questionnaire as well. The probabilities for this vector can be calculated as follows;

$$p_A = n_{1A} / n \quad (21)$$

where p_A refers to initial probability for the CR to belong to A category in Kano Model. “ n ” refers to the total number of participants.

Then, initial probability vector will be consisting of;

$$Q = [p_A, p_O, p_M, p_I] \quad (22)$$

3.5. PREDICTION OF KANO CATEGORIES WITH MARKOV CHAIN

After the construction of initial probability vector (Q) and transition matrix (P), future Kano states of CRs can be predicted. According to Equation 8, the multiplication of Q with “ n ”th power of P will give results for probabilities of which Kano state the CR will be in. The result for each period will be in the format of Q , a 1x4 vector, each number referring to probabilities. This format will allow us to calculate SI and DI values as well; so adjustment vector can be calculated.

$$Q * P = [p_A \quad p_O \quad p_M \quad p_I] * \begin{bmatrix} P(A \rightarrow A) & P(A \rightarrow O) & P(A \rightarrow M) & P(A \rightarrow I) \\ P(O \rightarrow A) & P(O \rightarrow O) & P(O \rightarrow M) & P(O \rightarrow I) \\ P(M \rightarrow A) & P(M \rightarrow O) & P(M \rightarrow M) & P(M \rightarrow I) \\ P(I \rightarrow A) & P(I \rightarrow O) & P(I \rightarrow M) & P(I \rightarrow I) \end{bmatrix} \quad (23)$$

For grey forecasting methods to be implemented, it requires at least 4 data points. This is the reason why Markov Chain predicting will be done until 3th power of P . After this point, there will be enough data to forecast weight of CRs with Grey

Forecasting. However, before using GM (1, 1) method, the weights of customer requirements will be adjusted so that changes in Kano category will be integrated in those results. This next stage will be explained hereafter.

3.6. ADJUSTING THE WEIGHTS WITH KANO CATEGORIES

Prediction of future states with Markov Chain is not enough to make a forecast for the weights of customers' requirements. The problem here is that; Kano states correspond to a qualitative category, while the weights of customer requirements are quantitative. There have been numerous studies which try to integrate qualitative Kano categories into quantitative QFD analysis. The model suggested by Chuadra et al. (2011: 693) bases this effect of states on two indexes; the Satisfaction Index (SI) and Dissatisfaction Index (DI) and adjusts the weights according to Kano questionnaire results.

A simple change has to be made to calculate SI and DI for this study. In original model, indexes are calculated according to the number of people who selected certain categories for the CR. In this study, only data for two periods can be obtained directly; however the probabilities of each state for period 3 and 4 can be calculated. The probabilities can be substituted in for the number of people; the result won't change as no unit is changed and actually the original model also calculates the ratio which can be also found with probabilities. Thus, the formulas for SI and DI become as follows;

$$SI = \frac{p_A + p_O}{p_A + p_O + p_M + p_i} \quad (24)$$

$$DI = \frac{p_O + p_M}{p_A + p_O + p_M + p_i} \quad (25)$$

The first point in our dataset when adjusting according to Kano categories will be based upon the number of people from the questionnaire. For evaluation of a

certain CR, let's assume CR1, the average weight from self-stated questionnaire results will be found. This can be done by summing up all the weights from respondents, then dividing the number to total number of participants.

Next step is to calculate adjustment factor, which is the maximum value of DI or SI for that particular CR, summed with 1. Then the raw weight is multiplied by this adjustment factor. This step is repeated for each data point in Markov Chain prediction for how the states would change. Then the whole process will be repeated for other CRs.

At the end of this step, four data points will be generated for all CRs, which will be taken as input values for Grey Forecasting model.

3.7. FORECASTING WITH GREY METHOD

GM (1,1) Grey Forecasting Method has been widely used in literature especially with limited amounts of data or incomplete data because of its practicality. Due to nature of new products lacking historical data; it is used after Markov Chain to forecast the change of the weights of CRs. After multiplied by adjustment ratios; there would be weights for four different time periods of each CR. These points will be the input for this method, as it requires at least four points to give robust results.

Before moving on with Grey Forecasting, the data set structure needs to be checked for compatibility (Özdemir & Özdağoğlu, 2017: 83). The smoothness and exponentially of the data can be tested with Equation 26 and Equation 27.

$$\rho_{(k)} = \frac{x_{0(k)}}{x_{1(k-1)}} \quad (26)$$

$$\sigma_{1(k)} = \frac{x_{1(k)}}{x_{1(k-1)}} = 1 + \rho_{(k)} \quad (27)$$

for values of $k \geq 2$, the results should satisfy $\rho_{(k)} \in [0, 0.5]$, thus satisfying the condition of quasi-smoothness. If $x_{0(k)}$ is quasi-smooth, then $x_{1(k)}$ is also said to be quasi exponential. When $\rho_{(k)} \in [0, 0.5]$; according to Equation 27, $\sigma_{1(k)} \in$

[1, 1.5], thus satisfying the law of quasi-exponentially. This will allow the GM (1,1) to be built directly.

The original series will be given as in Equation 28 as $x_{0(CR_n)}$, where each element of the series representing the adjusted importance weight of the CR for each time period, totaling four. “ CR_n ” specifies on which customer requirement the process has been done.

$$x_{0(CR_n)} = (w_{CR_n}(1), w_{CR_n}(2), w_{CR_n}(3), w_{CR_n}(4)) \quad (28)$$

Then, AGO series of $x_{0(CR_n)}$ will be calculated. This series is named as “ $x_{1(CR_n)}$ ”. The relationship between these two series is given as;

$$x_1^n = \sum_{m=1}^n x_0^m \quad (29)$$

Thus turning $x_{1(CR_n)}$ into;

$$x_{1(CR_n)} = (w_{CR_n}(1), w_{CR_n}(1) + w_{CR_n}(2), w_{CR_n}(1) + w_{CR_n}(2) + w_{CR_n}(3), w_{CR_n}(1) + w_{CR_n}(2) + w_{CR_n}(3) + w_{CR_n}(4)) \quad (30)$$

To whiten the series, z_1 series also needs to be calculated; as it represents the whitened values. The series is whitened to smooth the randomness of the original series and gain a clear rule (Slavek et al., 2015: 8225). The formula for z_1 , is given by Equation 31;

$$z_1(k) = ax_{(1)}(k) + (1 - \alpha)x_{(1)}(k - 1) \quad (31)$$

Here, a value is taken as “0.5”, in accordance with the literature (Wu et al., 2004: 1243). k represents the number of forecasting steps.

The original formula for x_0 series can be written as in GM (1,1) format;

$$x_0(k) + az_1(k) = b \quad (32)$$

This Equation 32 can be revised as Equation 33;

$$\begin{vmatrix} x_0(2) \\ x_0(3) \\ x_0(n) \end{vmatrix} = \begin{vmatrix} -z_1(2) & 1 \\ -z_1(3) & 1 \\ -z_1(n) & 1 \end{vmatrix} \begin{vmatrix} a \\ b \end{vmatrix} \quad (33)$$

Then, vector $\begin{vmatrix} a \\ b \end{vmatrix}$ needs to be calculated. “a” is developing coefficient and “b” is grey input. By least square estimation, values for “a” and “b” is estimated from;

$$a = \frac{\sum_{k=2}^n z_1(k) \sum_{k=2}^n x_0(k) - (n-1) \sum_{k=2}^n z_1(k) x_0(k)}{(n-1) \sum_{k=2}^n [z_1(k)]^2 - [\sum_{k=2}^n z_1(k)]^2} \quad (34)$$

$$b = \frac{\sum_{k=2}^n [z_1(k)]^2 \sum_{k=2}^n x_0(k) - \sum_{k=2}^n z_1(k) \sum_{k=2}^n z_1(k) x_0(k)}{(n-1) \sum_{k=2}^n [z_1(k)]^2 - [\sum_{k=2}^n z_1(k)]^2} \quad (35)$$

Grey forecasted series is defined by f_1 and it is calculated as;

$$f_1(k) = \left(x_0(1) - \frac{b}{a} \right) e^{-a(k-1)} + \frac{b}{a} \quad (36)$$

This series is “grey” equivalent to x_1 , which was AGO series of x_0 . To find out the Grey forecast values for original series, IAGO series of f_1 needs to be calculated as given in the following Equation 37.

$$f_{(0)}(k) = f_{(1)}(k) - f_{(1)}(k-1) \quad (37)$$

The resulting series will consist of predicted values of weights of CRs.

CHAPTER FOUR

CASE STUDY

4.1. SUMMARY OF THE APPLICATION

To demonstrate how the suggested framework works, a case study has been carried out for a hypothetical new product. A new product definition usually covers new to the world products, modified or improved products or even imitation products being new only the company (Ulrike, 2001: 170). Due to limitations of time and resources for the purpose of this thesis; improved product category has been selected to analyze instead of new to the world type of new product.

The hypothetical example product is chosen as a notebook modified with some innovative features compared to the existing products on the market. First, the CRs for notebooks have been identified based on previous QFD work on notebooks with innovative ideas as improved features added in. After all CRs have been identified, a modified form of Kano questionnaire; with the addition being another added form, asking participants about their past choices; has been applied with “Self Stated Importance” part as well. Each participant’s survey has been analyzed individually. With the results of the questionnaire, the weight of CRs for current time period and the change rates between Kano categories have been calculated. Also, to integrate Kano categories into CR weights, adjustment factor has been used. Incorporating these values into a transition probabilities matrix and initial probability vector, Markov Chain was taken to 3rd step. This gave CR weight results for four periods, with past choices serving as base, which are minimum required data points for Grey Forecasting Model. Then, the weights of CRs are forecasted with GM (1,1) method.

4.2. IDENTIFYING CUSTOMER REQUIREMENTS

While the notebooks have been in markets since 1990’s, constant improvement in hardware and internet technology makes it a must for the producers to improve their lines, so that their product wouldn’t fail against competition. Apart

from these technological factors; with the rise of tablets in markets, they face completion from them as well, thus requiring both design and functional updates to their features.

Usually, a new version of a notebook is introduced every 6 months to 1 year with changes in design or function or both. In this thesis; a hypothetical improved version of a notebook has been selected to apply the suggested framework. QFD studies on notebooks have been several in literatures and for non-innovative attributes, recent studies have been analyzed to form as a base of CRs.

Ko and Lo applied a green QFD methodology for identifying CRs (2016: 846). The CRs that are related with environmental affinities were not identified in literature before; “Zero environmental pollution” and “Re-cycle for re-use”. Thus, they were assumed to be new CRs and incorporated into the list in this thesis directly. The whole list of CRs is given below:

- Design of appearance
- Convenient portability
- Shock Absorbance
- Display
- Operation time
- Product not scratched easily
- Price
- Memory size
- Hard drive space
- Operation time
- Brand
- Reputation
- Zero environmental pollution
- Re-cycle for re-use

Huang and Chen (2015: 312) suggested using QFD and TRIZ together to solve electromagnetic compatibility related issues early in design phase for notebook products to meet customer demands. This study implemented a consumer survey to

collect customer requirements for notebook PCs. The final list of CRs in term of QFD is given below (Chen & Huang, 2015: 316):

- Fashion and exclusiveness
- Compact and easy to carry
- Damage resistant and low failure rate
- Keyboard and screen are of the proper size and with ergonomic design
- Fast execution speed
- Long battery life
- Continuously pursuing maximized performance/price ratio
- Hazard free materials and operating process
- Featuring wireless networking and powerful I/O port expansion
- Immediate mass production for market launch

Another study investigating ways to integrate Kano model into QFD has also considered notebooks an example (Ji et al., 2014: 6344). It is a modified list from the CRs identified by Wang's previous study and it is composed of seven CRs, listed below:

- Stylish design
- Mobility
- High computing speed
- Large storage
- High network performance
- Solid audio capability
- Powerful graphics solution

A previous study by Wang (2008: 82) states that the CRs for notebooks have been identified by a preliminary work. Focus group interviews, market research on internet as well as market surveys have been used. The identified CRs are given below (Wang, 2008: 83):

- Stylish design
- Light and mobile
- Large screen size

- Multimedia function
- High computing speed
- Large storage
- Wireless LAN
- Remote Control
- Expandable device
- High network performance
- Solid audio capability
- Powerful graphics solution

These are the CRs identified in literature for notebooks. A comparison between studies has been made, represented by Table 4. There were CRs corresponding to the same needs in these studies such as “Design of Appearance- Stylish design”; however others include a couple of requirements as one CR such as “Keyboard and screen are of the proper size and with ergonomic design” which can be too long and technical to be asked directly to the customers in a survey. They are broken down into parts. After needed modifications to CRs, they are included in this study. “ * ” signs represent the CRs which meet more than one CRs identified in literature.

The innovative feature ideas are taken as from the articles from leading websites related to technology and computer hardware; tom’s Hardware (Freedman, 2019), eweek (Enderle, 2019) and techspot (Mayersen, 2019) respectively. These are added to the existing CR list as; CR23 – Flexible (Folding) Display and CR24 – Upgradable. The final is of 24 total CRs.

Table 4: Comparison of CRs by Studies

Application of green quality function deployment and fuzzy theory to the design of notebook computers (2016)	The synergy of QFD and TRIZ for solving EMC problems in electrical products – a case study for the Notebook PC (2015)	QFD optimization with Kano's Model (2008)	Quantification and integration of Kano's model into QFD for optimising product design (2014)	Customer Needs (This study)
Design of appearance		Stylish design	Stylish design	Aesthetic appearance
x	Fashion and exclusiveness	x	x	In line with latest trends
Convenient portability	Compact and easy to carry	Light and mobile	Mobility	Easy to carry
				Smaller space allocation
Shock Absorbance	Damage resistant and low failure rate	x	x	Damage resistant
Display	Keyboard and screen are of the proper size and with ergonomic design	Large screen size	x	Cristal Clear View
x	Keyboard and screen are of the proper size and with ergonomic design	x	x	Comfortable to Use
x	x	Multimedia function	x	Compatible with different media types
x	Fast execution speed	x	x	Very fast execution
Operation time	Long battery life			Long operation time without charging
				Low failure rate
Product not scratched easily	Damage resistant and low failure rate	x	x	Damage resistant*
Price	Continuously pursuing maximized performance/price ratio	x	x	Inexpensive
Memory size	x	x	x	Very fast execution *
x	Fast execution speed	High computing speed	High computing speed	Very fast execution *
Hard drive space	x	Large storage	Large storage	Able to storage large size programs/data
Brand	Fashion and exclusiveness	x	x	x
Reputation (Brand image that has been established to customers)	x	x	x	Increases my reputation
Zero environmental pollution	x	x	x	Zero environmental pollution
Re-cycle for re-use	x	x	x	Re-cycle for re-use
x	Hazard free materials and operating process	x	x	Safe physical interaction
x	x	Wireless LAN	x	Connectivity to the different devices
x	x	Remote Control	x	Commandable without touching
x	x	Expandable device	x	Expandable storage capacity
x	Featuring wireless networking and powerful I/O port expansion	High network performance	High network performance	Connectivity to the different devices*
x	Immediate mass production for market launch	x	x	x
x	x	Solid audio capability	Solid audio capability	Solid audio capability
x	x	Powerful graphics solution	Powerful graphics solution	Powerful graphics solution
x	x	x	x	Flexible (folding) display
x	x	x	x	Upgradable

4.3. IMPLEMENTATION OF THE KANO QUESTIONNAIRE

After identifying the CR list for notebooks, a modified form of Kano questionnaire is designed. As stated in literature (Wu & Shieh, 2006: 144), we can ask about customers' their past choices and preferences, to infer transition probabilities. Thus, using Kano Model, participants are also asked to consider their last purchase of a notebook and answer the questions.

In the design of Kano questionnaires, participants are asked to evaluate their reaction given two situations. The first form of the questions, called functional form, asks about the situation when a CR is met through the product. The second question, called dysfunctional form, asks about when the same CR is not provided or its absence (Berger et al., 1993: 7).

Table 5: Functional and Dysfunctional Forms of the Questions

<i>Functional Form</i>	
How would you feel if a laptop is easy to carry?	I would be delighted to find it that way
	I expect it to be that way
	I am neutral
	I would not like it that way but I can live with it that way
	It must not be that way
<i>Dysfunctional Form</i>	
How would you feel if a laptop is not easy to carry?	I would be delighted to find it that way
	I expect it to be that way
	I am neutral
	I would not like it that way but I can live with it that way
	It must not be that way

Customers last purchases preferences are also asked with the same questions; however an explanation of situation is given as the headline information. The instructions are given as: "Remember the last time you have purchased a new laptop or considered buying one. Please mark the appropriate option on the given scale for following items, as if the whole statement reads as "How would you feel if a laptop has an aesthetic appearance?"

The participants' answers are evaluated to the rules in "Evaluation Table", taken from (Matzler & Hinterhuber, 1998: 32) for each timeline considered. At the end of this part, two choices of customers can be inferred about that particular CR for each participant, a past and current one.

Table 6: Kano Evaluation Table

Product requirement → ▼		Dysfunctional form of the question				
		1. I like it that way	2. It must be that way	3. I am neutral	4. I can live with it that way	5. I dislike it that way
Functional form of the question	1. I like it that way	Q	A	A	A	O
	2. It must be that way	R	I	I	I	M
	3. I am neutral	R	I	I	I	M
	4. I can live with it that way	R	I	I	I	M
	5. I dislike it that way	R	R	R	R	Q

Source: Matzler & Hinterhuber, 1998: 32

This study also made use of "Self stated Importance Questionnaire", usually applied alongside basic form of Kano questionnaire. The participants are asked to evaluate the importance of a CR being present in a notebook, on a Likert Scale, from one to nine. Below is an example of how an item is asked with headline information of "Assume that you are planning to buy a new laptop. Please rate the importance of following items based on your opinion." Figure 4 shows an example of this.

Figure 4: Self-Styled Importance Question Example

Aesthetic appearance

1 2 3 4 5 6 7 8 9

Not at all important Extremly important

Participants' answers to "Self Stated Importance Questionnaire" will be used for calculating raw importance weight for CRs. The average weight is found by the number of participants multiplied by each score category then divided by total participant number.

The questionnaire is formatted with Google Docs and distributed by e-mail. It was sent to people who are either business professionals or had professional experience before. A total of 65 valid responses have been sent back and analyzed for next steps.

4.4. CALCULATIONS FROM KANO QUESTIONNAIRE RESULTS

Responses of 65 participants are examined individually. The raw weights of CRs are calculated according to "Self Stated Importance Questionnaire" results for each CR.

Table 7: Raw Weights of CRs

CR	Raw Weight	Importance %	Order
Aesthetic appearance	6,59	3,78%	19
In line with latest trends	6,80	3,90%	18
Easy to carry	8,09	4,63%	5
Smaller space allocation	7,20	4,12%	15
Damage resistant	8,15	4,67%	4
Cristal Clear View	8,02	4,60%	6
Comfortable to Use	7,70	4,41%	10
Compatible with different media types	7,02	4,02%	16
Very fast execution	8,50	4,87%	1
Long operation time without charging	8,28	4,75%	2
Low failure rate	8,20	4,70%	3
Inexpensive	7,65	4,39%	12
Able to storage large size programs/data	7,35	4,21%	13
Increases my reputation	5,89	3,38%	22
Zero environmental pollution	6,33	3,63%	20
Re-cycle for re-use	6,02	3,45%	21
Safe physical interaction	7,70	4,41%	10
Connectivity to the different devices	7,73	4,43%	9
Commandable without touching	5,70	3,26%	24
Expandable storage capacity	6,88	3,94%	17
Solid audio capability	7,76	4,45%	8
Powerful graphics solution	7,98	4,57%	7
Flexible (folding) display	5,72	3,28%	23
Upgradable	7,24	4,15%	14

Raw weights of CRs are calculated again for the data to be shown in percentages of total importance. Then, each CR has been given a ranking; “CR 9 – Very fast execution” came up as the most important CR, scoring a raw weight of “8.50” and accounting for %4.87 of total importance.

After this step, answers to dysfunctional and functional questions are examined. Using Kano Evaluation Table, each CR has been assigned to Kano categories of Attractive (A), One Dimensional (O), Must be (M), Indifferent (I). After classification, percentages of each category have been found for each CR.

For example; CR 9 has been assigned to One Dimensional category, with percentages of each category “%23.08”, “40.00”, “12.31”, “24.62”, in A-O-M-I order. From these results; SI and DI indexes can finally be calculated. Using SI, DI and adjustment factor formulas given in part 3.6; these values are found and raw weights are adjusted. Final adjusted values are given for first period in Table 8.

Table 8: Adjusted Weights and Rankings of CRs

CR	Raw Weight	Order	Max (DLSI)	Adjustment factor	Adjusted Weight	Adj Order
Aesthetic appearance	6,59	19	0,55	1,55	10,18	15
In line with latest trends	6,80	18	0,44	1,44	9,83	17
Easy to carry	8,09	5	0,47	1,47	11,90	7
Smaller space allocation	7,20	15	0,38	1,38	9,95	16
Damage resistant	8,15	4	0,49	1,49	12,15	5
Cristal Clear View	8,02	6	0,73	1,73	13,85	2
Comfortable to Use	7,70	10	0,45	1,45	11,19	11
Compatible with different media types	7,02	16	0,46	1,46	10,27	14
Very fast execution	8,50	1	0,63	1,63	13,86	1
Long operation time without charging	8,28	2	0,43	1,43	11,81	10
Low failure rate	8,20	3	0,58	1,58	12,96	4
Inexpensive	7,65	12	0,73	1,73	13,22	3
Able to storage large size programs/data	7,35	13	0,48	1,48	10,88	12
Increases my reputation	5,89	22	0,28	1,28	7,53	21
Zero environmental pollution	6,33	20	0,29	1,29	8,19	19
Re-cycle for re-use	6,02	21	0,28	1,28	7,69	20
Safe physical interaction	7,70	10	0,54	1,54	11,84	9
Connectivity to the different devices	7,73	9	0,36	1,36	10,50	13
Commandable without touching	5,70	24	0,26	1,26	7,20	22
Expandable storage capacity	6,88	17	0,29	1,29	8,85	18
Solid audio capability	7,76	8	0,53	1,53	11,87	8
Powerful graphics solution	7,98	7	0,52	1,52	12,12	6
Flexible (folding) display	5,72	23	0,23	1,23	7,02	23
Upgradable	7,24	14	0,29	1,29	9,38	17

The results here imply that Adjustment factor has been effective in changing the importance ranking. CR 6 – Crystal Clear View has jumped from 6th to 2nd; CR 12 – Inexpensive has gained the 3rd ranking. These demonstrate the need for adjustment of raw weights with Kano model.

Another piece of information needed for Markov Chain Matrix is also inferred by comparing participants' answers for their past and present choices. To build the transition probabilities matrix "P", changes of customers perception regarding CRs under which Kano category to be classified is needed. For each participant of the survey, both of their past "Kano choice" and present "Kano choice" is noted. An excel document is prepared for each CR. A 4*4 matrix table has been

created. The rows represent their past choices and columns represent their current one. Here is the example table for CR 9.

Table 9: Changes in Customer Perception for CR 9

CR 9	A	O	M	I
A	9	4	2	
O	1	22	3	
M		1	7	
I	5	6	2	3

To better explain the table, number in the first row, first column (9) represents the number of participant, who classified CR 9 as Attractive in their past and also current evaluation. Fourth row, first column number (5) represents the number of people who classified CR 9 in Indifferent category with their past choices but in their current evaluation changed it into Attractive.

These tables are constructed for each of the 24 CRs. They will serve to calculate transition probabilities. To get this, each section in the table is divided by the sum of the numbers in their respective rows. So for transition probabilities matrix (P), first row first column is calculated with $9/(9+4+2)$; resulting as “0.6”. This represents the probability that for this CR, attractive selection will stay as attractive for the next period with a probability of “0.6”. After the calculation for each section of the matrix; P is inferred for the targeted CR. P_9 is given below;

Table 10: Transition Probability Matrix for CR 9

CR 9	A	O	M	I
A	0,600	0,267	0,133	0,000
O	0,038	0,846	0,115	0,000
M	0,000	0,125	0,875	0,000
I	0,313	0,375	0,125	0,188

To calculate the probabilities of the Kano category that a CR belongs to for each time period/step of Markov Chain, we also need the Q vector, initial probabilities. These are inferred from customers’ past choices. For Q vector, Figure 7 is used again. The sum of the numbers in first column, divided by sum of the all numbers in the matrix $(9+1+5)/(9+4+2+1+22+3+1+7+5+6+2+3)$ gives the initial probability that CR 9 falls under “Attractive” category. Same calculation method for

column 2 represents “One Dimensional”; column 3 “Must be” and column 4 “Indifferent” category.

Table 11: Initial Probabilities for CR 9

	CR 9
0,231	A
0,400	O
0,123	M
0,246	I

After examination of Kano questionnaires’ results, for each CR, there are P matrix, Q vector, and raw weight at hand.

4.5. STEPS WITH MARKOV CHAIN

With the inputs from Kano questionnaire, the probabilities of the Kano categories, that a CR belongs to, can be calculated. Initial probabilities multiplied with the first, second and third power of the P matrix gives the results. Below is given formulas for the probability calculations for each period.

Initial period (Step 0):

$$Q * P^0 = [p_A, p_O, p_M, p_I] \quad (38)$$

First period (Step 1):

$$Q * P^1 = [p_A \quad p_O \quad p_M \quad p_I] * \begin{bmatrix} P(A \rightarrow A) & P(A \rightarrow O) & P(A \rightarrow M) & P(A \rightarrow I) \\ P(O \rightarrow A) & P(O \rightarrow O) & P(O \rightarrow M) & P(O \rightarrow I) \\ P(M \rightarrow A) & P(M \rightarrow O) & P(M \rightarrow M) & P(M \rightarrow I) \\ P(I \rightarrow A) & P(I \rightarrow O) & P(I \rightarrow M) & P(I \rightarrow I) \end{bmatrix} \quad (39)$$

Second Period (Step 3):

$$Q * P^2 = [P_A \ P_O \ P_M \ P_I] * \begin{bmatrix} P(A \rightarrow A) & P(A \rightarrow O) & P(A \rightarrow M) & P(A \rightarrow I) \\ P(O \rightarrow A) & P(O \rightarrow O) & P(O \rightarrow M) & P(O \rightarrow I) \\ P(M \rightarrow A) & P(M \rightarrow O) & P(M \rightarrow M) & P(M \rightarrow I) \\ P(I \rightarrow A) & P(I \rightarrow O) & P(I \rightarrow M) & P(I \rightarrow I) \end{bmatrix}^2 \quad (40)$$

Third Period (Step 4):

$$Q * P^3 = [P_A \ P_O \ P_M \ P_I] * \begin{bmatrix} P(A \rightarrow A) & P(A \rightarrow O) & P(A \rightarrow M) & P(A \rightarrow I) \\ P(O \rightarrow A) & P(O \rightarrow O) & P(O \rightarrow M) & P(O \rightarrow I) \\ P(M \rightarrow A) & P(M \rightarrow O) & P(M \rightarrow M) & P(M \rightarrow I) \\ P(I \rightarrow A) & P(I \rightarrow O) & P(I \rightarrow M) & P(I \rightarrow I) \end{bmatrix}^3 \quad (41)$$

For calculation of Markov Chain Steps, a Microsoft Excel template was used. It was taken from courses material from website of University of Massachusetts (Dynamic Facilities Layout and Simulation Modeling Laboratory, 2018). Screenshots of results for CR 9 for each step are given in Figure 5, Figure 6 and Figure 7.

Figure 5: Markov Chain Step 1 Results for CR 9

State	Absolute (1-step)	Steady state	Mean return time
A	0.2315	0.047985	20.839977
O	0.51085	0.479847	2.0839984
M	0.21015	0.472169	2.1178844
I	0.0475	0	infinity

Figure 6: Markov Chain Step 2 Results for CR 9

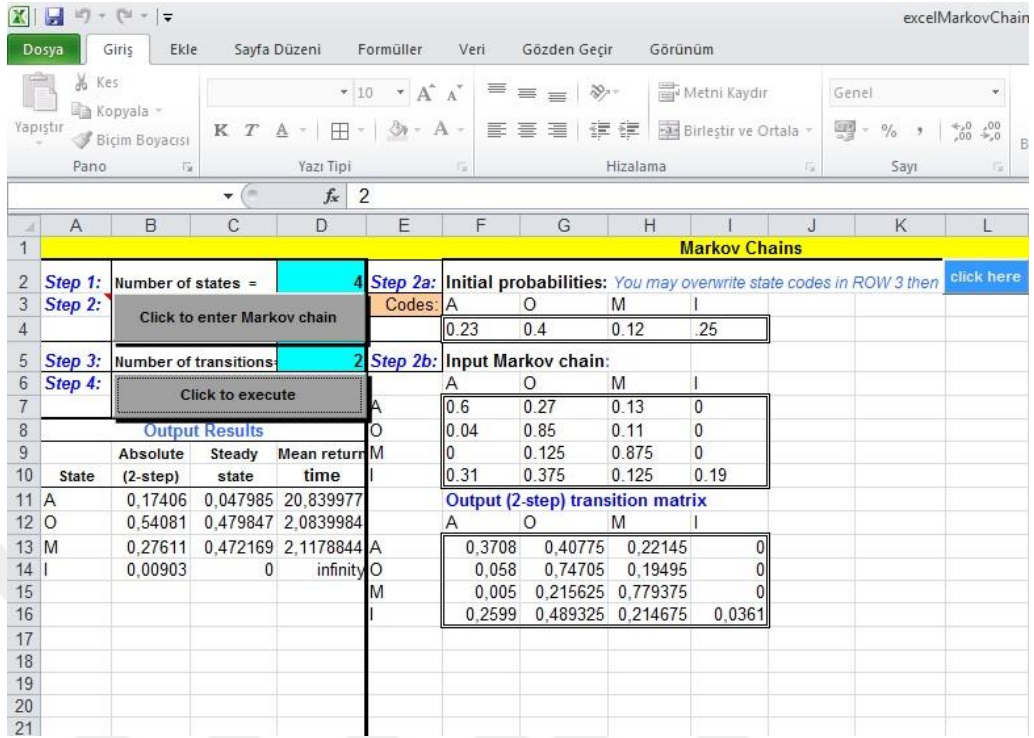
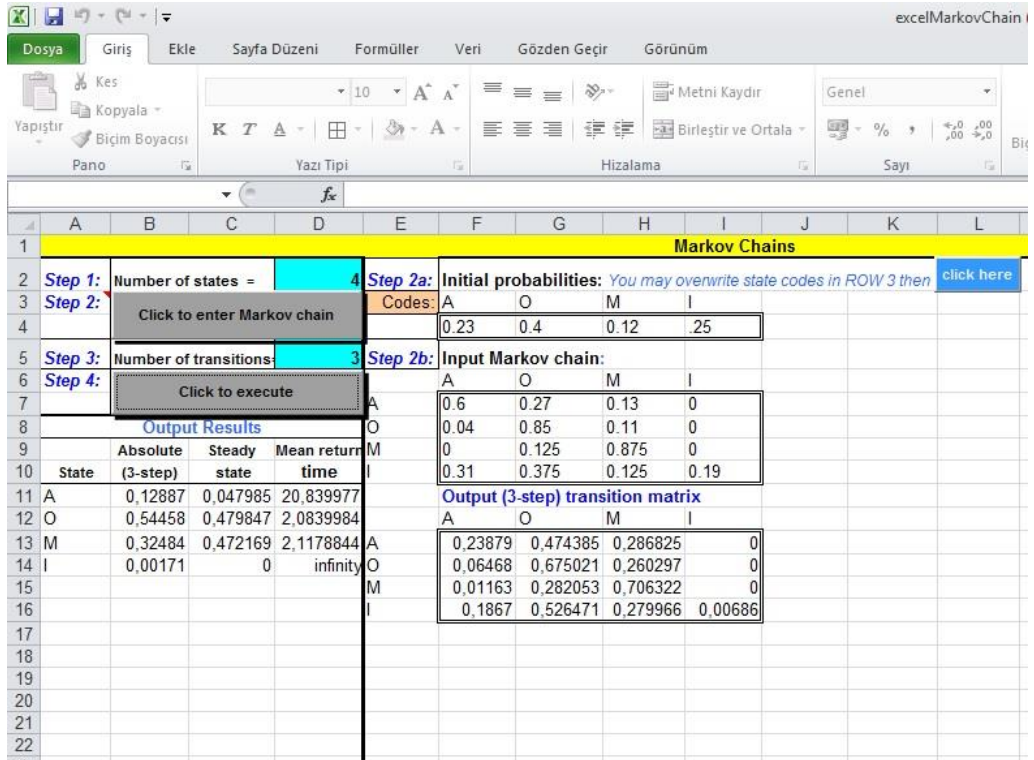


Figure 7: Markov Chain Step 3 Results for CR 9



“Output Results” in the figures above give the probabilities of Kano categories at the given period for CR 9. This process is repeated for all other CRs in the list. All of the matrices can be found in the appendix.

The change of probabilities for Kano categories affects the used adjustment factor. Thus, for all periods, a new value for adjustment factor needs to be calculated. The formula for it stays the same for all periods.

These calculations are made in Microsoft Excel. Here are the results for CR 9 with respect to periods 1, 2, 3 and 4.

Table 12: Probabilities of Kano Categories and Adjusted Weights of CR 9

	Time Periods			
CR9	1	2	3	4
A	0,231	0,231	0,174	0,129
O	0,400	0,511	0,541	0,545
M	0,123	0,210	0,276	0,325
I	0,246	0,048	0,009	0,001
SI	1	2	3	4
	0,63	0,74	0,71	0,67
DI	1	2	3	4
	0,52	0,72	0,82	0,87
max (SI,DI)	0,63	0,74	0,82	0,87
Adjustment factor	1,63	1,74	1,82	1,87
Predicted weights for CR9	13,86	14,81	15,44	15,89

This operation gives values for four different time periods of the weights of CRs. These values, named “Predicted weights for CR9”, will be used as inputs for GM (1,1) Forecasting in the next step.

4.6. FORECASTING WITH GM (1,1)

After acquiring the much needed four data points, a forecast can be made with GM (1,1) model as explained in methodology. In order to facilitate the required calculations, the instructions given by Li & Li (2016: 89) are used in Microsoft Excel. Exactly all steps have been implemented to have a template to make the forecasting. According to Liu et al. (2014: 769), the suitability test for GM (1,1) to be built directly can be checked for $k > 3$, a criteria which all of the input values for all twenty four CRs satisfy the conditions for.

To further illustrate how GM (1,1) works, calculations for CR 9 is shown below. First, the predicted weights from the results of Markov Chain Modeling are taken as x_0 series. Then following steps, as explained in part 3.7 according to GM (1,1) equations, are carried out.

$$x_{0 (CR 9)} = (13.86, 14.81, 15.44, 15.89) \quad (42)$$

$$x_{1 (CR 9)} = (13.86, 28.67, 44.11, 60.00) \quad (43)$$

$$z_{1 (CR 9)} = (22.06, 36.39, 52.05) \quad k \geq 2 \quad (44)$$

By solving the general GM (1,1) equation " $x_0(k) + az_1(k) = b$ " with least square estimation method, values for a and b are obtained as "-0.06888" and "13.8556" respectively. The solution of $f_1(k)$ can be calculated as shown by the Equations 45, 46, 47 and 48.

$$f_1(k) = \left(x_0(1) - \frac{b}{a}\right) e^{-a(k-1)} + \frac{b}{a} \quad (45)$$

$$f_1(4) = \left(x_0(1) - \frac{13.8556}{0.06888}\right) e^{0.06888(4-1)} + \frac{13.8556}{0.06888} = 60.03 \quad (46)$$

$$f_1(3) = \left(x_0(1) - \frac{13.8556}{0.06888}\right) e^{0.06888(3-1)} + \frac{13.8556}{0.06888} = 43.57 \quad (47)$$

$$f_1(2) = \left(x_0(1) - \frac{13.8556}{0.06888} \right) e^{0.06888(2-1)} + \frac{13.8556}{0.06888} = 28.20 \quad (48)$$

To forecast the values for the original series, Equation 49 is used.

$$f_{(0)}(k) = f_{(1)}(k) - f_{(1)}(k - 1) \quad (49)$$

$$f_{(0)}(4) = f_{(1)}(4) - f_{(1)}(3) = 16.46 \quad (50)$$

$$f_{(0)}(3) = f_{(1)}(3) - f_{(1)}(2) = 15.37 \quad (51)$$

$$f_{(0)}(2) = f_{(1)}(2) - f_{(1)}(1) = 14.34 \quad (52)$$

For CR 9, forecasted results until 8th can be seen in Table 13.

Table 13: Forecasted weights for CR 9

Period	GM (1,1)
1	13,86
2	14,34
3	15,37
4	16,46
5	17,64
6	18,89
7	20,24
8	21,69

The results of GM (1,1) for other CRs can be found in appendix.

Results indicate that with the GM (1,1) method, expected weights can exceed theoretical possible limit of 18 for long time periods. The raw weight scale is between 1 and 9. Adjustment factor changes between 1 and 2; as SI and DI can be 0-1 according to nature of the formulas. Therefore, results over 18 are unrealistic with given scales.

Given that GM (1,1) is more suitable for short term predictions (Liu et al., 2014: 770) when the α value is between 0.3 and 0.5 (taken as 0.5 in this study); a cut of point for forecasted periods needs to be set. In this study, it is set at 5th period as; there is no forecasted value that falls out of original scale until this point.

The changes in the weights of CRs are given in the Figure 8 and Figure 9.

Figure 8: Forecasted Values for CRs 1-12

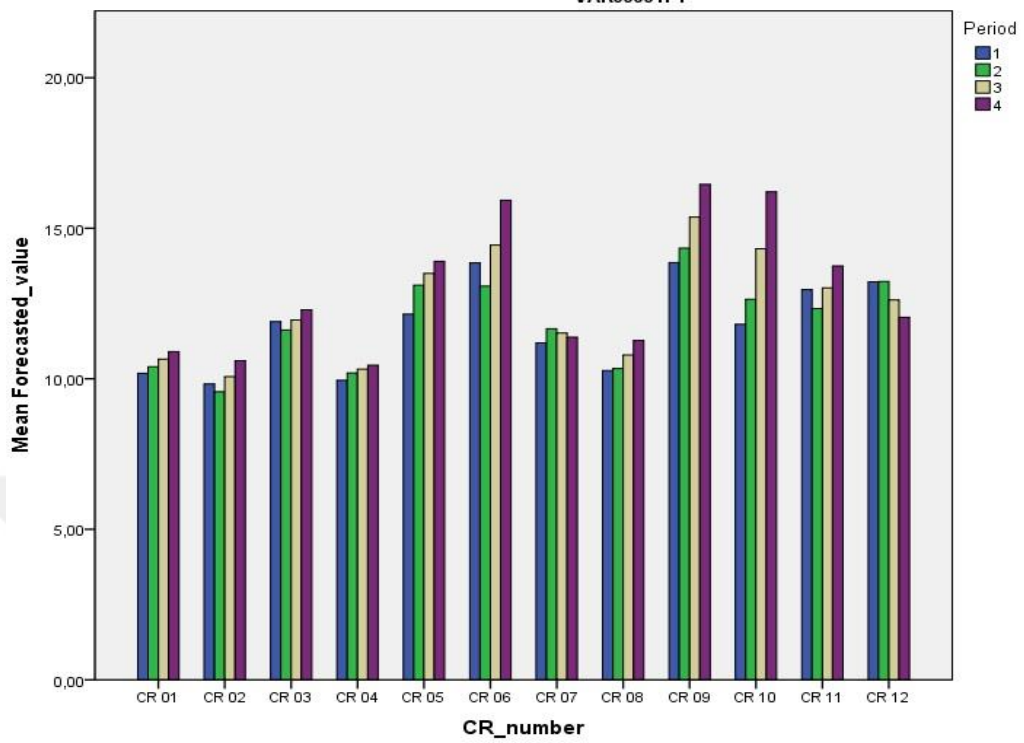
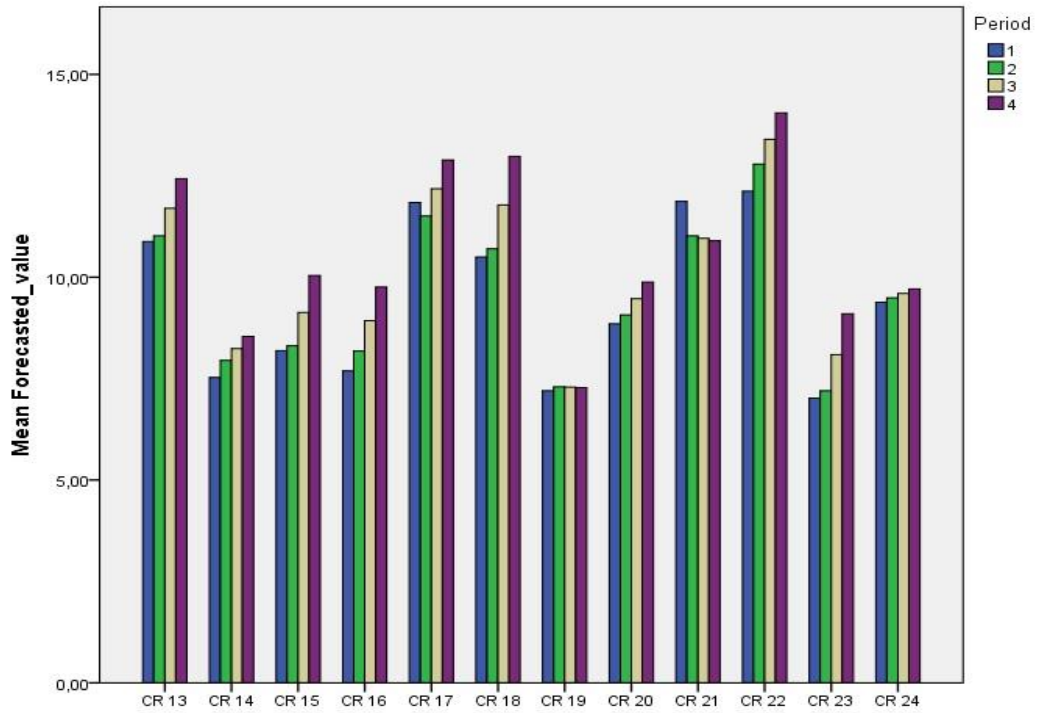


Figure 9: Forecasted Values for CRs 13-24



Finally another list of ranking of the CRs is made for the end of the forecasting period (period 4). The changes in rankings can be seen in Table 14.

Table 14: Final Importance Ranking for 24 CRs

CR	Adjusted Weight Period 1	Adj Order	Period 4 weights	Period 4 order	Trend
Aesthetic appearance	10,18	15	10,90	15	↔
In line with latest trends	9,83	17	10,60	16	↓
Easy to carry	11,90	7	12,29	10	↓
Smaller space allocation	9,95	16	10,45	17	↓
Damage resistant	12,15	5	13,90	5	↔
Cristal Clear View	13,85	2	15,93	3	↓
Comfortable to Use	11,19	11	11,38	12	↓
Compatible with different media types	10,27	14	11,27	13	↑
Very fast execution	13,86	1	16,46	1	↔
Long operation time without charging	11,81	10	16,21	2	↑
Low failure rate	12,96	4	13,75	6	↓
Inexpensive	13,22	3	12,04	11	↓
Able to storage large size programs/data	10,88	12	12,43	9	↑
Increases my reputation	7,53	21	8,54	23	↓
Zero environmental pollution	8,19	19	10,04	18	↑
Re-cycle for re-use	7,69	20	9,76	20	↔
Safe physical interaction	11,84	9	12,89	8	↑
Connectivity to the different devices	10,50	13	12,98	7	↑
Commandable without touching	7,20	22	7,28	24	↓
Expandable storage capacity	8,85	18	9,88	19	↓
Solid audio capability	11,87	8	10,90	14	↓
Powerful graphics solution	12,12	6	14,05	4	↑
Flexible (folding) display	7,02	23	9,10	22	↑
Upgradable	9,38	17	9,71	21	↓

A drastic change can be observed for CR 10 – Long operation time without charging. It jumps from being 10th in the first list but forecasted to be second most important CR from a notebook in future. This result may stem from the characteristics of the targeted notebook users, in this study our target group was business people, hence they need to be mobile and still need to be operating on their notebooks. As business requires more mobility, they need to more operation time from their notebooks.

CR 21 – Solid audio capability however have a decreasing trend for importance. This may be due to the fact that the quality of headphones has been rising so they don't need their notebooks to have good speakers.

From the new features, CR 23 and CR 24, the results show that they don't show to be quite important in near future. Trend for CR 24 – Upgradable is negative; it seems that customers actually show less interest in having such feature in their notebooks. CR 23 – Folding display, on the other hand has move up one spot in importance ranking list. That's not an impressive climb compared to CR 10 but still that attribute has potential to become more valuable in future because it shows a positive trend. If a decision is to be made between CR 23 and CR 24 to spend resources, it could be better to focus on CR 23. This also proves that forecasting the weight of CRs and trends is really important as in the first list CR 24 is more important but for future it looks to be a dead end.

CR 9 – Inexpensive also shows a huge decrease in rankings. This may be due to again our target groups' characteristics but it may also show that a higher pricing is becoming more acceptable for customers which can have a serious impact on marketing decisions.

Green CRs, CR 15 and 16, don't show any significant negative or positive trend. That means at least for our focus group, effect on environment is a second thought when in market for buying a notebook and their position will probably stay the same in near future.

4.7. LIMITATIONS

There were several limitations while conducting this study. First is the number of participants. While it is enough to infer customer preferences, more data would yield more realistic results. Also, the questionnaire is only applied on working individuals. The notebook market's reach is far greater than that and includes students, travellers, home users etc.

The questionnaire is demonstrated on Internet. The Google Docs, while free and practical, has some problems. Although no questionable results were found when examining answers; a simple wrong click could result in a different Kano categorization, which will impact the results.

The scope of forecasting was also limited by GM (1,1). As mentioned in part 4.6, this model is more suitable for short term forecasting. There are some modifications to GM (1,1) for better accuracy of forecast results which were not applied here because of the complicated calculations.

It is also assumed that transition probabilities between categories will stay same. While this assumption may be true for short term; unexpected economic changes or important technological advancements can change the results. Also over long term, transition probabilities will change.

Also, due to time limitation, the reliability of this method could not be checked on a real world product example.

CONCLUSION

Due to recent developments in technology and business, product life cycles have become shorter and achieving success has become more dependent on customer satisfaction. The way to customer satisfaction lies in not only meeting their needs, but also exceeding them. For this, companies need to understand customers' future needs in addition to their current needs. Thus, there is a need for combining a forecast system that is able to detect the changes in customer needs, interpolated from a QFD study or other analysis.

Wang and others (2004: 1244) have used GM (1,1) model to deal with this problem but that four periods of historical data was required. Wu and Shieh (2008: 674) has applied Markov Chain modeling to predict future weights of CRs however they classified the importance of CRs as High, Medium and Low and attaining them weights of 5, 3 and 1 respectively.

This study aimed to find a conceptual framework which can be used to predict the future customer requirements (CR) of the target market segment for new product development. This will help companies in their decision making and design phases of new products to better utilize their resources. Due to lack of historical data for new products; companies usually relied on judgmental methods, which can be biased.

It is proposed with this study that with the combination of QFD tools and Kano model, a detailed analysis about customer preferences can be extracted. The change rate between Kano categories is calculated with Markov Chain matrix to produce input for GM (1,1) to forecast the weights of CRs. Suggested qualitative method is the first in literature for laying out a framework for forecasting of customer requirements for new products, which tried to integrate Markov Chains and Kano Model categories together.

Upcoming studies on this topic should look into validation of the suggested framework. This requires close cooperation with companies who actually use QFD practices from the start of the new product development projects and with the implementation of periodical Kano Questionnaires gathering data different time periods, depending on products assumed life cycle.

Another distinction of this study is; it has gathered real world customer preference data on a product. Other studies relied on hypothetical datasets to demonstrate their models. In this way, it also contributed to literature on customer requirements of notebooks.

From the results in Figure 9 and Figure 10; it can be seen that the importance of CRs do really change with time. Our results indicate that both positive and negative trends can emerge within time. This is line with previous literature that some features can become obsolete for customers (Löfgren et al., 2011: 242).

Table 14 shows the importance that this study has. There is significant difference between both rankings, between initial phase and after fourth period. In fact out of the listed 24 CRs, only four of them stayed in their previous order after forecasted values have been found out. Eight of the CRs has moved up in the ranking and surpassed other CRs in importance. Drastic change of CR 10 is eye catching. The prediction of such case would be really important in design phase of the new products.

Comparing the rankings of the initial adjusted weights and the weights at the end of period four, it can be seen that the top three importance rankings have been changed. “CR 9 – Very fast execution” is still the most important attribute being at the first place; however “CR 10 – Long operation time without charging” has taken the second place of “CR 6 – Crystal Clear View”, which in turn fell down to third place. “CR 12 – Inexpensive” has fallen down to eleventh place; which shows that customers anticipate seeing price as less important in future when buying notebooks. However, a fast computer with a good bright screen with high definition that can last longer without charging is going to be desirable in market. It can be inferred that better specs for the main features of notebooks (screen, CPU, battery) will become more important and notebook producers may invest more R&D efforts into hardware rather than design characteristics. CRs related to design and trends, CRs related to new features such as flexible display or green CRs relating to environmental causes don’t seem to be increasing in importance at least in near future. Connectivity will also have an increasing trend. These results may stem from the characteristics of study’s target group, working professionals. Different results can be expected if this questionnaire has been answered by a group of gamers or if this study was conducted

in a society where environmental concerns are deemed more important, concerning green CRs.

This study laid out a foundation method to be improved for future work. With the methodology known, a better implementation of the suggested framework with follow up work to check for the accuracy of predictions can be made. Also, to better understand constantly changing customer preferences, these questionnaires should be followed upon and repeated periodically. With the new data feed, the accuracy of model can be better. Especially, for transition probability matrix in Markov Chain, this is crucial as it is not expected to stay same.

Also instead of the basic GM (1,1) model, its modifications with better accuracy and a longer horizon can be incorporated into the model. There have been several studies on this topic (Xinping & Deng, 2001: 3; Madhi & Mohamed, 2016: 14).

To better understand the preferences change, a test market can be implemented. This may yield better results for transition probabilities inferred from customers past and current choices; first questionnaire is implemented before they take part in experimental test market and one (corresponding to current choices one in this study) after their experience.

The framework proposed in this study is valuable to test in a better structured experiment. It contributes to literature on Kano's Model and QFD; serves as an example to implement Markov Chains into Kano's model and shows that GM (1,1) can be used for predicting the weight of customer requirements. The initial results with limited data shows promise in the field as, it can be valuable for companies due to its rather practical implementation.

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APPENDICES

A Survey on Identifying and Categorizing Customer Needs for a New Laptop Product

This survey is a part of a masters thesis on the topic of forecasting the importance of customer needs for new products. What customers want and desire from a product might change with time, this is especially true for a sector, where rate of innovation is high and product models are renewed frequently. The example product is chosen as "laptop", since every year new models/products has been served to market by producers.

The survey will consist of three parts. In the first section, you are expected to rate the importance of different attributes which a laptop may have on a scale of 1 to 9; 1 having the least importance and 9 having the highest.

Second part asks you about how you would react/feel when given attribute is present or not on a laptop, considering you are in the market to purchase a laptop at time being. Please note, this is not a linear scale and try to mark the closest option to your opinion.

Third part requires you to think of the last time you bought a laptop (or were in market to buy one). Again, you are expected to mark the option closest to how would you have felt according the written statement. This part is the same as second part; but asks you about your last preferences.

Whole questionnaire will take about 10-15 minutes of your time. Thank you for your participation .

NEXT

Categorizing Customer Needs for a New Laptop Product

Prioritization of the Customer Needs

Assume that you are planning to buy a new laptop. Please rate the importance of following items based on your opinion.

Aesthetic appearance

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

In line with latest trends

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Easy to carry

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Needs less space allocation

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Damage resistant

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Crystal clear view

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Comfortable to use

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Compatible with different media types

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Very fast execution

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Long operation time without charging

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Low failure rate

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Inexpensive

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Increases my reputation

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Zero environmental pollution

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Recyclable for re use

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Safe physical interaction

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Connectivity with other devices

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Commendable without touching

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Expandable storage capacity

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Solid audio capabilities

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Powerful graphics solution

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Flexible (folding) display

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

Up gradable

1 2 3 4 5 6 7 8 9

Not at all important Extremely important

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NEXT

A Survey on Identifying and Categorizing Customer Needs for a New Laptop Product

Assessment of Functional (Positive) and Dysfunctional (Negative) Forms of the Customer Needs for Today

Assume that you are evaluating laptop alternatives for your purchase. Please mark the appropriate option on the given scale for following items as if the statement starts with "How would you feel if a laptop ...". For example; for the first item, the complete statement should be thought as; "How would you feel if a laptop has an aesthetic appearance?".

How would you feel if a laptop ...

	I would be delighted to find it that way	I expect it to be that way	I am neutral	I would not like it that way but I can live with it that way	It must not be that way
Has an aesthetic appearance?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have an aesthetic appearance?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is in line with latest trends?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not in line with latest trends?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is easy to carry?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not easy to carry?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Needs less space allocation?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Needs more space allocation?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is damage resistant?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Is not damage resistant?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has crystal clear view?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have crystal clear view?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is comfortable to use?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not comfortable to use?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is compatible with different media types?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not compatible with different media types?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has very fast execution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have very fast execution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has long operation time without charging?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have long operation time without charging?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has low failure rate?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have low failure rate?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is inexpensive?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not inexpensive?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increases my reputation?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Does not increase my reputation?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contributes zero environmental pollution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contributes to environmental pollution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Can be recycled for reuse?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Can not be recycled for reuse?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has safe physical interaction?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have safe physical interaction?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has connectivity to different devices?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have connectivity to different devices?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Can be commendable without touching?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Can not be commendable without touching?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has expandable storage capacity?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have expandable storage capacity?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has solid audio capability?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Does not have solid audio capability?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has powerful graphics solution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have powerful graphics solution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has a flexible (folding) display?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have a flexible (folding) display?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is upgradable?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not upgradable?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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A Survey on Identifying and Categorizing Customer Needs for a New Laptop Product

Assessment of Functional (Positive) and Dysfunctional (Negative) Forms of the Customer Needs for the Past

Remember the last time you have purchased a new laptop or considered buying one. Please mark the appropriate option on the given scale for following items, as if the whole statement reads as "How would you feel if a laptop has an aesthetic appearance?".

How would you feel if a laptop ...

	I would be delighted to find it that way	I expect it to be that way	I am neutral	I would not like it that way but I can live with it that way	It must not be that way
Has an aesthetic appearance?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have an aesthetic appearance?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is in line with latest trends?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not in line with latest trends?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is easy to carry?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not easy to carry?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Needs less space allocation?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Needs more space allocation?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is damage resistant?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Is not damage resistant?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has crystal clear view?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have crystal clear view?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is comfortable to use?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not comfortable to use?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is compatible with different media types?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not compatible with different media types?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has very fast execution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have very fast execution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has long operation time without charging?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have long operation time without charging?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has low failure rate?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have low failure rate?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is inexpensive?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not inexpensive?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increases my reputation?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Does not increase my reputation?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contributes zero environmental pollution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contributes to environmental pollution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Can be recycled for reuse?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Can not be recycled for reuse?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has safe physical interaction?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have safe physical interaction?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has connectivity to different devices?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have connectivity to different devices?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Can be commendable without touching?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Can not be commendable without touching?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has expandable storage capacity?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have expandable storage capacity?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has solid audio capability?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Does not have solid audio capability?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has powerful graphics solution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have powerful graphics solution?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has a flexible (folding) display?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does not have a flexible (folding) display?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is upgradable?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not upgradable?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

BACK

SUBMIT

APPENDIX 2: Results of the Self Stated Questionnaire

CR List	Weight scale -->										WEIGHT
	1	2	3	4	5	6	7	8	9		
Aesthetic appearance	2	2	2	1	1	10	10	10	8		6,587
In line with latest trends	3		1		3	10	7	15	7		6,804
Easy to carry			1	1	2	2	3	11	26		8,087
Smaller space allocation			1	4	4	1	15	8	13		7,196
Damage resistant	1					2	4	17	22		8,152
Cristal Clear View	1			1	1	3	3	13	24		8,022
Comfortable to Use	1		1	1		2	11	13	17		7,696
Compatible with different media types	1	1	1	2	5	2	10	14	10		7,022
Very fast execution					1		7	5	33		8,500
Long operation time without charging			1		2	4	2	3	34		8,283
Low failure rate		1				5	3	9	28		8,196
Inexpensive	1				3	6	9	6	21		7,652
Able to storage large size programs/data		3		4	4	5	7	8	26		7,351
Increases my reputation	4	1	1	3	13	3	6	10	5		5,891
Zero environmental pollution	1	1	4	5	6	7	5	4	13		6,326
Re-cycle for re-use	1	2	5	5	7	5	7	3	11		6,022
Safe physical interaction	1				3	3	9	13	17		7,696
Connectivity to the different devices	1				2	3	10	11	17		7,727
Commandable without touching	5	3	1	3	6	5	11	9	3		5,696
Expandable storage capacity	1	2	1	1	5	1	12	9	10		6,881
Solid audio capability	1				3	3	7	14	18		7,761
Powerful graphics solution	1		1			2	9	9	24		7,978
Flexible (folding) display	5	2	1	5	7	7	5	7	7		5,717
Upgradable	1	1	2	1	2	2	11	11	14		7,244

CR 15	A	O	M	I
A	5	3		1
O		4	2	
M			4	
I	6	2	1	23

CR 16	A	O	M	I
A	7	1	1	
O	2	4		
M			4	
I	6	2		27

CR 17	A	O	M	I
A	5			3
O		14	6	
M		1	4	
I	3	1	2	13

CR 18	A	O	M	I
A	4	1		1
O		8	5	
M		2	4	
I	5	2	2	19

CR 19	A	O	M	I
A	3	2	1	4
O	2	2		
M			1	
I	6		1	31

CR 20	A	O	M	I
A	4	2		1
O	2	4	1	
M		2	1	
I	2	1		29

CR 21	A	O	M	I
A	4	4		6
O	5	6	2	
M			4	
I	3		2	15

CR 22	A	O	M	I
A	4	4		
O	4	14	2	
M			3	
I	5	3		15

CR 23	A	O	M	I
A	7			
O	2	3	1	
M			3	
I	7			34

CR 24	A	O	M	I
A	6			3
O		4	2	
M		3	4	
I	3		1	25

APPENDIX 4: Markov Probability Transitions Matrices and Initial Probabilities for each of CRs 1-24

Initial Probabilities	CR 1	A	O	M	I
0,3273	A	0,556	0,222	0	0,222
0,2182	O	0,667	0,333	0	0
0,0364	M	0	0	1	0
0,4182	I	0,13	0,174	0	0,696

Initial Probabilities	CR 2	A	O	M	I
0,1852	A	0,5	0,3	0	0,2
0,2593	O	0,143	0,5	0,357	0
0,1111	M	0	0	0,833	0,167
0,4444	I	0,125	0,083	0,083	0,708

Initial Probabilities	CR 3	A	O	M	I
0,3019	A	0,875	0,125	0	0
0,1698	O	0	0,667	0,222	0,111
0,1132	M	0	0	0,667	0,333
0,4151	I	0,091	0	0,455	0,455

Initial Probabilities	CR 4	A	O	M	I
0,2167	A	0,846	0	0	0,154
0,1667	O	0,1	0,6	0,3	0
0,0500	M	0	0	1	0
0,5667	I	0,206	0	0,059	0,735

Initial Probabilities	CR 5	A	O	M	I
0,1321	A	0,857	0,143	0	0
0,3585	O	0	0,789	0,211	0
0,1321	M	0	0,143	0,857	0
0,3774	I	0,4	0,1	0	0,5

Initial Probabilities	CR 6	A	O	M	I
0,3014	A	0,455	0,136	0,273	0,136
0,4247	O	0	0,839	0,161	0
0,0959	M	0	0	1	0
0,1781	I	0,231	0,385	0	0,385

Initial Probabilities	CR 7	A	O	M	I
0,2545	A	0,643	0,071	0,071	0,214
0,2000	O	0,273	0,727	0	0
0,0727	M	0	0	1	0
0,4727	I	0,269	0	0,231	0,5

Initial Probabilities	CR 8	A	O	M	I
0,2222	A	0,5	0,25	0,25	0
0,2407	O	0	0,769	0,231	0
0,1481	M	0	0	0,5	0,5
0,3889	I	0,095	0,19	0	0,714

Initial Probabilities	CR 9	A	O	M	I
0,2308	A	0,6	0,267	0,133	0
0,4000	O	0,038	0,846	0,115	0
0,1231	M	0	0,125	0,875	0
0,2462	I	0,313	0,375	0,125	0,188

Initial Probabilities	CR 10	A	O	M	I
0,1296	A	0,714	0,286	0	0
0,2963	O	0	0,75	0,25	0
0,0556	M	0	0	1	0
0,5185	I	0,179	0,286	0,143	0,393

Initial Probabilities	CR 11	A	O	M	I
0,1636	A	0,778	0,111	0	0,111
0,2909	O	0	0,75	0,125	0,125
0,2909	M	0,125	0,125	0,438	0,313
0,2545	I	0,286	0,143	0,143	0,429

Initial Probabilities	CR 12	A	O	M	I
0,4909	A	0,593	0,185	0,074	0,148
0,2364	O	0,692	0,308	0	0
0,0364	M	0	0	1	0
0,2364	I	0,308	0	0	0,692

Initial Probabilities	CR 13	A	O	M	I
0,1731	A	0,556	0,111	0,111	0,222
0,3077	O	0,125	0,5	0,125	0,25
0,0962	M	0	0,2	0,8	0
0,4231	I	0,136	0,273	0,227	0,364

Initial Probabilities	CR 14	A	O	M	I
0,1481	A	0,625	0,125	0	0,25
0,1296	O	0,143	0,429	0,429	0
0,0185	M	0	0	1	0
0,7037	I	0,263	0	0	0,737

Initial Probabilities	CR 15	A	O	M	I
0,1765	A	0,556	0,333	0	0,111
0,1176	O	0	0,667	0,333	0
0,0784	M	0	0	1	0
0,6275	I	0,188	0,063	0,031	0,719

Initial Probabilities	CR 16	A	O	M	I
0,1667	A	0,778	0,111	0,111	0
0,1111	O	0,333	0,667	0	0
0,0741	M	0	0	1	0
0,6481	I	0,171	0,057	0	0,771

Initial Probabilities	CR 17	A	O	M	I
0,1538	A	0,625	0	0	0,375
0,3846	O	0	0,7	0,3	0
0,0962	M	0	0,2	0,8	0
0,3654	I	0,158	0,053	0,105	0,684

Initial Probabilities	CR 18	A	O	M	I
0,1132	A	0,667	0,167	0	0,167
0,2453	O	0	0,615	0,385	0
0,1132	M	0	0,333	0,667	0
0,5283	I	0,179	0,071	0,071	0,679

Initial Probabilities	CR 19	A	O	M	I
0,1887	A	0,3	0,2	0,1	0,4
0,0755	O	0,5	0,5	0	0
0,0189	M	0	0	1	0
0,7170	I	0,158	0	0,026	0,816

Initial Probabilities	CR 20	A	O	M	I
0,1429	A	0,571	0,286	0	0,143
0,1429	O	0,286	0,571	0,143	0
0,0612	M	0	0,667	0,333	0
0,6531	I	0,063	0,031	0	0,906

Initial Probabilities	CR 21	A	O	M	I
0,2745	A	0,286	0,286	0	0,429
0,2549	O	0,385	0,462	0,154	0
0,0784	M	0	0	1	0
0,3922	I	0,15	0	0,1	0,75

Initial Probabilities	CR 22	A	O	M	I
0,1481	A	0,5	0,5	0	0
0,3704	O	0,2	0,7	0,1	0
0,0556	M	0	0	1	0
0,4259	I	0,217	0,13	0	0,652

Initial Probabilities	CR 23	A	O	M	I
0,1228	A	1	0	0	0
0,1053	O	0,333	0,5	0,167	0
0,0526	M	0	0	1	0
0,7193	I	0,171	0	0	0,829

Initial Probabilities	CR 24	A	O	M	I
0,1765	A	0,667	0	0	0,333
0,1176	O	0	0,667	0,333	0
0,1373	M	0	0,429	0,571	0
0,5686	I	0,103	0	0,034	0,862

APPENDIX 5: Markov Chain Results between periods 1-4

CR1	1	2	3	4
A	0,327273	0,3812	0,404492	0,415676
O	0,218182	0,2144	0,216564	0,218075
M	0,036364	0,04	0,04	0,04
I	0,418182	0,3644	0,338944	0,326249
Raw Weight	6,59			

SI	1	2	3	4
	0,55	0,60	0,62	0,63
DI	1	2	3	4
	0,25	0,25	0,26	0,26
max (SI,DI)	0,55	0,60	0,62	0,63
Adj factor	1,55	1,60	1,62	1,63
Predicted weights for CR1	10,18	10,51	10,68	10,76

CR2	1	2	3	4
A	0,185185	0,1886	0,173391	0,15814
O	0,259259	0,2222	0,197208	0,177597
M	0,111111	0,2201	0,292203	0,340499
I	0,444444	0,3691	0,337198	0,323763
Raw Weight	6,80			

SI	1	2	3	4
	0,44	0,41	0,37	0,34
DI	1	2	3	4
	0,37	0,44	0,49	0,52
max (SI,DI)	0,44	0,44	0,49	0,52
Adj factor	1,44	1,44	1,49	1,52
Predicted weights for CR2	9,83	9,81	10,13	10,33

CR3	1	2	3	4
A	0,301887	0,3003	0,284912	0,26985
O	0,169811	0,1514	0,138976	0,128728
M	0,113208	0,3022	0,347758	0,367474
I	0,415094	0,2461	0,228356	0,233949
Raw Weight	8,09			

SI	1	2	3	4
	0,47	0,45	0,42	0,40
DI	1	2	3	4
	0,28	0,45	0,49	0,50
max (SI,DI)	0,47	0,45	0,49	0,50
Adj factor	1,47	1,45	1,49	1,50
Predicted weights for CR3	11,90	11,76	12,02	12,10

CR4	1	2	3	4
A	0,216667	0,3216	0,376338	0,403866
O	0,166667	0,102	0,0612	0,03672
M	0,05	0,1346	0,191708	0,232313
I	0,566667	0,4418	0,370754	0,327101
Raw Weight	7,20			

SI	1	2	3	4
	0,38	0,42	0,44	0,44
DI	1	2	3	4
	0,22	0,24	0,25	0,27
max (SI,DI)	0,38	0,42	0,44	0,44
Adj factor	1,38	1,42	1,44	1,44
Predicted weights for CR4	9,95	10,24	10,34	10,37

CR5	1	2	3	4
A	0,132075	0,2638	0,302868	0,298466
O	0,358491	0,3588	0,36562	0,373853
M	0,132075	0,1874	0,236512	0,280181
I	0,377358	0,19	0,095	0,0475
Raw Weight	8,15			

SI	1	2	3	4
	0,49	0,62	0,67	0,67
DI	1	2	3	4
	0,49	0,55	0,60	0,65
max (SI,DI)	0,49	0,62	0,67	0,67
Adj factor	1,49	1,62	1,67	1,67
Predicted weights for CR5	12,15	13,23	13,60	13,63

CR6	1	2	3	4
A	0,30137	0,1764	0,104979	0,062776
O	0,424658	0,4641	0,45739	0,42491
M	0,09589	0,2482	0,370084	0,471611
I	0,178082	0,1113	0,067547	0,040702
Raw Weight	8,02			

SI	1	2	3	4
	0,73	0,64	0,56	0,49
DI	1	2	3	4
	0,52	0,71	0,83	0,90
max (SI,DI)	0,73	0,71	0,83	0,90
Adj factor	1,73	1,71	1,83	1,90
Predicted weights for CR6	13,85	13,74	14,66	15,21

CR7	1	2	3	4	SI	1	2	3	4
A	0,254545	0,3473	0,3455	0,320124		0,45	0,51	0,49	0,45
O	0,2	0,1642	0,144177	0,129434	DI	1	2	3	4
M	0,072727	0,1963	0,287817	0,363178		0,27	0,36	0,43	0,49
I	0,472727	0,2922	0,222506	0,187263	max (SI,DI)	0,45	0,51	0,49	0,49
					Adj factor	1,45	1,51	1,49	1,49
Raw Weight	7,70				Predicted weights for CR7	11,19	11,63	11,46	11,49

CR8	1	2	3	4	SI	1	2	3	4
A	0,222222	0,149	0,10969	0,08909		0,46	0,46	0,46	0,45
O	0,240741	0,3139	0,345814	0,358765	DI	1	2	3	4
M	0,148148	0,1852	0,202047	0,207983		0,39	0,50	0,55	0,57
I	0,388889	0,3519	0,342449	0,344162	max (SI,DI)	0,46	0,50	0,55	0,57
					Adj factor	1,46	1,50	1,55	1,57
Raw Weight	7,02				Predicted weights for CR8	10,27	10,53	10,87	11,00

CR9	1	2	3	4	SI	1	2	3	4
A	0,230769	0,2315	0,174059	0,128866		0,63	0,74	0,71	0,67
O	0,4	0,51085	0,540809	0,544581	DI	1	2	3	4
M	0,123077	0,21015	0,276107	0,324839		0,52	0,72	0,82	0,87
I	0,246154	0,0475	0,009025	0,001715	max (SI,DI)	0,63	0,74	0,82	0,87
					Adj factor	1,63	1,74	1,82	1,87
Raw Weight	8,50				Predicted weights for CR9	13,86	14,81	15,44	15,89
					Predicted weights for CR9	13,86	14,81	15,44	15,89

CR10	1	2	3	4	SI	1	2	3	4
A	0,12963	0,1859	0,168493	0,133867		0,43	0,60	0,59	0,52
O	0,296296	0,4135	0,422848	0,388936	DI	1	2	3	4
M	0,055556	0,1978	0,329567	0,446352		0,35	0,61	0,75	0,84
I	0,518519	0,2028	0,079092	0,030846	max (SI,DI)	0,43	0,61	0,75	0,84
					Adj factor	1,43	1,61	1,75	1,84
Raw Weight	8,28				Predicted weights for CR10	11,81	13,35	14,51	15,20

CR11	1	2	3	4	SI	1	2	3	4
A	0,163636	0,23645	0,283572	0,310049		0,45	0,54	0,60	0,63
O	0,290909	0,30775	0,31763	0,322812	DI	1	2	3	4
M	0,290909	0,20025	0,162356	0,144242		0,58	0,51	0,48	0,47
I	0,254545	0,25555	0,236442	0,222897	max (SI,DI)	0,58	0,54	0,60	0,63
					Adj factor	1,58	1,54	1,60	1,63
Raw Weight	8,20				Predicted weights for CR11	12,96	12,66	13,12	13,38

CR12	1	2	3	4	SI	1	2	3	4
A	0,490909	0,525	0,496944	0,471997		0,73	0,69	0,65	0,61
O	0,236364	0,1663	0,151303	0,141323	DI	1	2	3	4
M	0,036364	0,075	0,11175	0,146536		0,27	0,24	0,26	0,29
I	0,236364	0,2337	0,240003	0,240144	max (SI,DI)	0,73	0,69	0,65	0,61
					Adj factor	1,73	1,69	1,65	1,61
Raw Weight	7,65				Predicted weights for CR12	13,22	12,94	12,61	12,35

CR13	1	2	3	4	SI	1	2	3	4
A	0,173077	0,19275	0,183582	0,169578		0,48	0,50	0,48	0,46
O	0,307692	0,3071	0,293409	0,286549	DI	1	2	3	4
M	0,096154	0,23405	0,308033	0,352741		0,40	0,54	0,60	0,64
I	0,423077	0,2661	0,214976	0,191132	max (SI,DI)	0,48	0,54	0,60	0,64
					Adj factor	1,48	1,54	1,60	1,64
Raw Weight	7,35				Predicted weights for CR13	10,88	11,33	11,77	12,05

CR14	1	2	3	4	SI	1	2	3	4
A	0,148148	0,29395	0,3386	0,347248		0,28	0,37	0,41	0,42
O	0,12963	0,07465	0,068843	0,071928	DI	1	2	3	4
M	0,018519	0,0759	0,108	0,137602		0,15	0,15	0,18	0,21
I	0,703704	0,5555	0,484558	0,443223	max (SI,DI)	0,28	0,37	0,41	0,42
					Adj factor	1,28	1,37	1,41	1,42
Raw Weight	5,89				Predicted weights for CR14	7,53	8,06	8,29	8,36

CR15	1	2	3	4	SI	1	2	3	4
A	0,176471	0,2149	0,210081	0,186747		0,29	0,39	0,43	0,42
O	0,117647	0,1743	0,216036	0,235893	DI	1	2	3	4
M	0,078431	0,1385	0,210188	0,292391		0,20	0,31	0,43	0,53
I	0,627451	0,4723	0,363695	0,284969	max (SI,DI)	0,29	0,39	0,43	0,53
					Adj factor	1,29	1,39	1,43	1,53
Raw Weight	6,33				Predicted weights for CR15	8,19	8,79	9,02	9,67

CR16	1	2	3	4	SI	1	2	3	4
A	0,166667	0,2794	0,346379	0,384796		0,28	0,41	0,50	0,55
O	0,111111	0,1314	0,148802	0,160922	DI	1	2	3	4
M	0,074074	0,0887	0,119434	0,157536		0,19	0,22	0,27	0,32
I	0,648148	0,5005	0,385385	0,296746	max (SI,DI)	0,28	0,41	0,50	0,55
					Adj factor	1,28	1,41	1,50	1,55
Raw Weight	6,02				Predicted weights for CR16	7,69	8,50	9,00	9,31

CR17	1	2	3	4	SI	1	2	3	4
A	0,153846	0,15295	0,14485	0,133202		0,54	0,46	0,42	0,40
O	0,384615	0,3045	0,275483	0,268767	DI	1	2	3	4
M	0,096154	0,2347	0,312973	0,36236		0,48	0,54	0,59	0,63
I	0,365385	0,30785	0,266694	0,235671	max (SI,DI)	0,54	0,54	0,59	0,63
					Adj factor	1,54	1,54	1,59	1,63
Raw Weight	7,70				Predicted weights for CR17	11,84	11,85	12,22	12,55

CR18	1	2	3	4	SI	1	2	3	4
A	0,113208	0,1691	0,181436	0,172919		0,36	0,42	0,46	0,48
O	0,245283	0,24655	0,275175	0,305682	DI	1	2	3	4
M	0,113208	0,2058	0,258074	0,297448		0,36	0,45	0,53	0,60
I	0,528302	0,37855	0,285315	0,223951	max (SI,DI)	0,36	0,45	0,53	0,60
					Adj factor	1,36	1,45	1,53	1,60
Raw Weight	7,73				Predicted weights for CR18	10,50	11,22	11,85	12,39

CR19	1	2	3	4
A	0,188679	0,2072	0,204132	0,198903
O	0,075472	0,073	0,07794	0,079796
M	0,018868	0,0606	0,101096	0,140014
I	0,716981	0,6592	0,616832	0,581287
Raw Weight	5,70			

SI	1	2	3	4
	0,26	0,28	0,28	0,28
DI	1	2	3	4
	0,09	0,13	0,18	0,22
max (SI,DI)	0,26	0,28	0,28	0,28
Adj factor	1,26	1,28	1,28	1,28
Predicted weights for CR19	7,20	7,29	7,30	7,28

CR20	1	2	3	4
A	0,142857	0,16216	0,182484	0,196021
O	0,142857	0,18344	0,196915	0,208696
M	0,061224	0,04015	0,038931	0,040415
I	0,653061	0,61425	0,58167	0,554867
Raw Weight	6,88			

SI	1	2	3	4
	0,29	0,35	0,38	0,40
DI	1	2	3	4
	0,20	0,22	0,24	0,25
max (SI,DI)	0,29	0,35	0,38	0,40
Adj factor	1,29	1,35	1,38	1,40
Predicted weights for CR20	8,85	9,26	9,49	9,67

CR21	1	2	3	4
A	0,27451	0,2358	0,20511	0,181273
O	0,254902	0,1948	0,156811	0,130589
M	0,078431	0,1565	0,22701	0,291639
I	0,392157	0,4129	0,411069	0,396499
Raw Weight	7,76			

SI	1	2	3	4
	0,53	0,43	0,36	0,31
DI	1	2	3	4
	0,33	0,35	0,38	0,42
max (SI,DI)	0,53	0,43	0,38	0,42
Adj factor	1,53	1,43	1,38	1,42
Predicted weights for CR21	11,87	11,10	10,74	11,04

CR22	1	2	3	4
A	0,148148	0,2436	0,26127	0,256817
O	0,37037	0,3899	0,431065	0,455998
M	0,055556	0,087	0,12599	0,169096
I	0,425926	0,2795	0,181675	0,118089
Raw Weight	7,98			

SI	1	2	3	4
	0,52	0,63	0,69	0,71
DI	1	2	3	4
	0,43	0,48	0,56	0,63
max (SI,DI)	0,52	0,63	0,69	0,71
Adj factor	1,52	1,63	1,69	1,71
Predicted weights for CR22	12,12	13,03	13,50	13,67

CR23	1	2	3	4
A	0,122807	0,2787	0,398442	0,491838
O	0,105263	0,055	0,0275	0,01375
M	0,052632	0,0687	0,07805	0,082725
I	0,719298	0,5976	0,496008	0,411687
Raw Weight	5,72			

SI	1	2	3	4
	0,23	0,33	0,43	0,51
DI	1	2	3	4
	0,16	0,12	0,11	0,10
max (SI,DI)	0,23	0,33	0,43	0,51
Adj factor	1,23	1,33	1,43	1,51
Predicted weights for CR23	7,02	7,63	8,15	8,61

CR24	1	2	3	4
A	0,176471	0,1766	0,172982	0,16928
O	0,117647	0,1406	0,152768	0,162739
M	0,137255	0,1362	0,14043	0,146473
I	0,568627	0,5466	0,53382	0,521508
Raw Weight	7,24			

SI	1	2	3	4
	0,29	0,32	0,33	0,33
DI	1	2	3	4
	0,25	0,28	0,29	0,31
max (SI,DI)	0,29	0,32	0,33	0,33
Adj factor	1,29	1,32	1,33	1,33
Predicted weights for CR24	9,38	9,54	9,60	9,65

APPENDIX 6: Grey Method - GM (1,1) Forecasted Results for the importance weights of CRs 1-24

CR1	GM 1,1
1	10,18
2	10,40
3	10,65
4	10,90

CR2	GM 1,1
1	9,83
2	9,57
3	10,07
4	10,60

CR3	GM 1,1
1	11,90
2	11,62
3	11,95
4	12,29

CR4	GM 1,1
1	9,95
2	10,19
3	10,32
4	10,45

CR5	GM 1,1
1	12,15
2	13,11
3	13,50
4	13,90

CR6	GM 1,1
1	13,85
2	13,08
3	14,44
4	15,93

CR7	GM 1,1
1	11,19
2	11,66
3	11,52
4	11,38

CR8	GM 1,1
1	10,27
2	10,34
3	10,79
4	11,27

CR9	GM 1,1
1	13,86
2	14,34
3	15,37
4	16,46

CR10	GM 1,1
1	11,81
2	12,64
3	14,32
4	16,21

CR11	GM 1,1
1	12,96
2	12,33
3	13,02
4	13,75

CR12	GM 1,1
1	13,22
2	13,23
3	12,62
4	12,04

CR13	GM 1,1
1	10,88
2	11,02
3	11,70
4	12,43

CR14	GM 1,1
1	7,53
2	7,95
3	8,24
4	8,54

CR15	GM 1,1
1	8,19
2	8,31
3	9,13
4	10,04

CR16	GM 1,1
1	7,69
2	8,18
3	8,93
4	9,76

CR17	GM 1,1
1	11,84
2	11,51
3	12,18
4	12,89

CR18	GM 1,1
1	10,50
2	10,70
3	11,78
4	12,98

CR19	GM 1,1
1	7,20
2	7,30
3	7,29
4	7,28

CR20	GM 1,1
1	8,85
2	9,07
3	9,47
4	9,88

CR21	GM 1,1
1	11,87
2	11,02
3	10,96
4	10,90

CR22	GM 1,1
1	12,12
2	12,79
3	13,40
4	14,05

CR23	GM 1,1
1	7,02
2	7,20
3	8,09
4	9,10

CR24	GM 1,1
1	9,38
2	9,49
3	9,60
4	9,71