A QFD Methodology for Product Development

A thesis presented to

the faculty of

the Russ College of Engineering and Technology of Ohio University

In partial fulfillment

of the requirements for the degree

Master of Science

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August 2009

This thesis titled

A QFD Methodology for Product Development

by

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ABSTRACT

CRAIG, RYAN R., M.S., August 2009, Industrial and Systems Engineering

A QFD Methodology for Product Development (89 pp.)

Director ofThesis: David A. Koonce

Quality Function Deployment (QFD) and the house of quality are tools commonly used in product development and quality operations.The current house of quality methodology helps to improve the development process, but is not optimized for time sensitive products. Time sensitive products require precise measurement of the voice of the customer. Customer input is gathered through marketing surveys, market research and previous product feedback. Implementing this research adds to the overall product lead time due to the difficulty of gathering and analyzing the data. By implementing a fractional factorial design when creating the survey, survey analysis time can be decreased. A comparison of data analysis methods including simple K-means, two-step clustering, and conjoint analysis are used to produce a feature set from the survey results. These results are then input into the house of quality in collaboration with a cross-functional team at a consumer electronics company.

Approved: ____

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INTRODUCTION

Quality Function Deployment (QFD) is a tool commonly used in product development and quality operations. QFD is a system engineering technique for improving quality by incorporating the voice of the customer in the development process. The QFD methodology consists of a number of tools to support a house of quality and Kano's model. These tools, specifically the house of quality, combine input from a number of different cross functional teams in the product development organization to improve communication and overall end user satisfaction (Akao, 1990).

Product development is critical to fast paced industries where new products define success due to short product life cycles. Products with short life cycles demand new product introductions and innovations at a faster rate in order to keep up with market pressures and competition. During the current recession, many companies are depending on the success of new innovative consumer products (with the cost of failure of these products being exit from the market). Figure 1 shows the result of a survey of the direct impact of new product development on company performance:

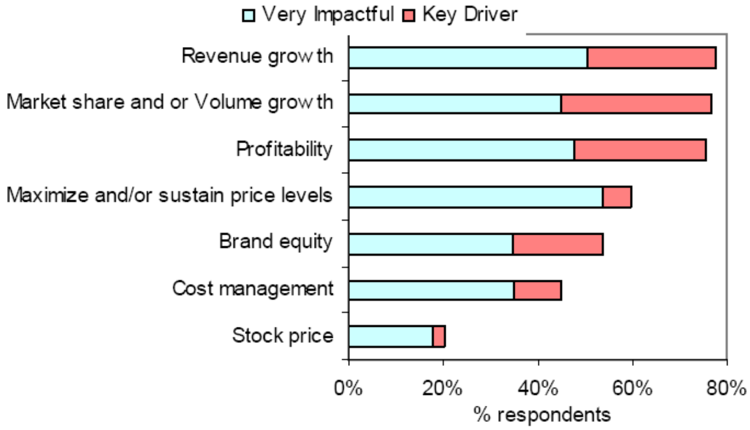

*Figure 1***.**Survey of impact of new product development on company performance.

Source: (Aberdeen Group, 2004)

As can be seen in figure 1, new product development has a critical impact on all measures of company performance, most notably revenue and market share growth. The success of the new product development process depends on factors such as accurate information on customer needs, improved product quality, and decreased bill of material costs (Aberdeen Group, 2004). Figure 2 shows the results of a survey of factors most important to product development firms:

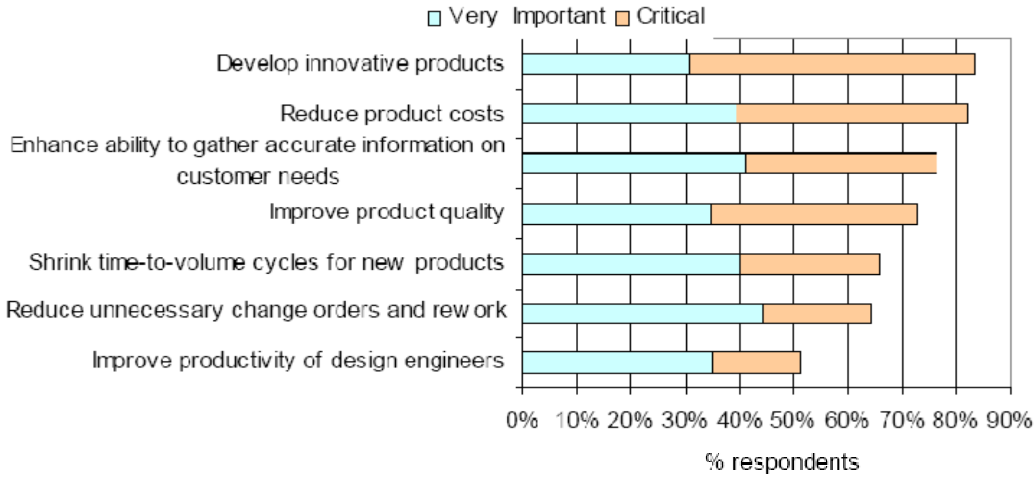

*Figure 2.*Surveyresults of factors most important to product development firms.

Source: (Aberdeen Group, 2004)

As can be seen in figure 2, product innovation (as well as reducing product costs and enhancing customer input) is critical to the success of new product development activities. Current quality function deployment methods are time consuming, and do not efficiently allow for customer input. There is no end to end methodology for bringing a time sensitive product to market (from concept and consumer input to final design). In this paper a methodology using the house of quality is developed to help address the issues and needs of the new product development process for time sensitive and innovative products.

The house of quality builds a matrix of input from all cross functional teams: including engineering, marketing, sales, and management, as well as input from thecustomeror end user (Griffin and Hauser, 1992).Sincethe voice of the customer is necessarily from outside the organization, this input has been typically data from customer surveys and marketing data. This data is often difficult to gather and process. And, due to the inherent noise from these external sources incorporating thisinput into the house of quality can introduce bias and error into the whole QFD process. Despite this shortcoming, there has been little research to improve the customer input, with the goal of improving the house of quality output.

Fast paced industries such as consumer electronics require a short, streamlined development process to release state of the art products at the rate of competitors (Minahan, 2004). The current house of quality methodology helps to improve the development process, but is not optimized for time sensitive products. This leads to the need for an end-to-end tool for developing products with short lead times and life cycles while improving the end quality score.

The goal of this research is to improve existing QFDby developing a methodology to improve the quality of the information incorporated from marketing research. There is no end to end methodology for bringing a time sensitive product to market (from concept and consumer input to final design). The result of this research will be an end-to-end product development process applicable to the consumer electronics product development industry and potentially other product development areas. This process will be compared against current product development methodology for consumer electronics products.

PROBLEM STATEMENT

A constant challenge for any fast paced industry, such as consumer electronics, is the very short technology life span needed to successfully take a product from conception to market while staying competitive with other industry leaders. There are also a wide variety of customers and market segments. Incorporating these factors into a single product design while maintaining a competitive development cycle is both challenging and time consuming.

Customer input is gathered through marketing surveys, market research and previous product feedback. Implementing this research adds to the overall product lead time due to the difficulty of gathering and analyzing the data. This lead time can be reduced by creating a method to process the voice of the customer for direct use in the development cycle.

In the consumer electronics industry (similar to other fast paced industries), there are 3 basic types of customers: "early technology adopter", "general consumer", and "last to market" (Rogers, 1962). Currently corporations target either a single customer type with their product family, or choose to make a range of products to meet, hopefully, the needs of each of these types. In a survey of the literature, there are no documented end-to-end methods for interpreting and applying marketing survey data (that is generalized and not targeted towards a specific group) and producing product/feature sets that reflect the needs of each customer group that can be input directly into the quality function deployment process.

This thesis will present an end-to-end process that can take a product concept, gather and analyze customer marketing data, create a product profile/feature set, and use input from the cross functional teams to maximize the end quality, and customer satisfaction. This tool would be extendable to any "fast paced" industry, such as the consumer electronics industry, and reduce development costs lead time, reduce internal decision time, turn qualitative into quantitative reasoning. The following literature review will show the previous research in areas of product development and quality function deployment related to the goal of this research.

LITERATURE REVIEW

This survey of literature will be divided into 3 sections according to the applicable section of this research. A brief explanation of QFD will be presented first, followed by overview literature, and literature relevant to the proposed methodology. All of this information has contributed to realization for need for further research and development of methodology.

Quality Function Deployment Overview

Quality function deployment is described by quality expert and developer Yoji Akao as a “method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process” (Akao, 1990). QFD consists of a number of tools for developing these functions and relationships for the development process. Specifically the house of quality and Kano’s model will be used in the proposed methodology

The House of Quality

The house of quality (HOQ hereafter) is a matrix of input from all cross functional teams: including engineering, marketing, sales, and management, as well as input from the customer or end user (Griffin and Hauser, 1992). An example completed HOQ matrix for an enterprise product development is shown below in figure 3:

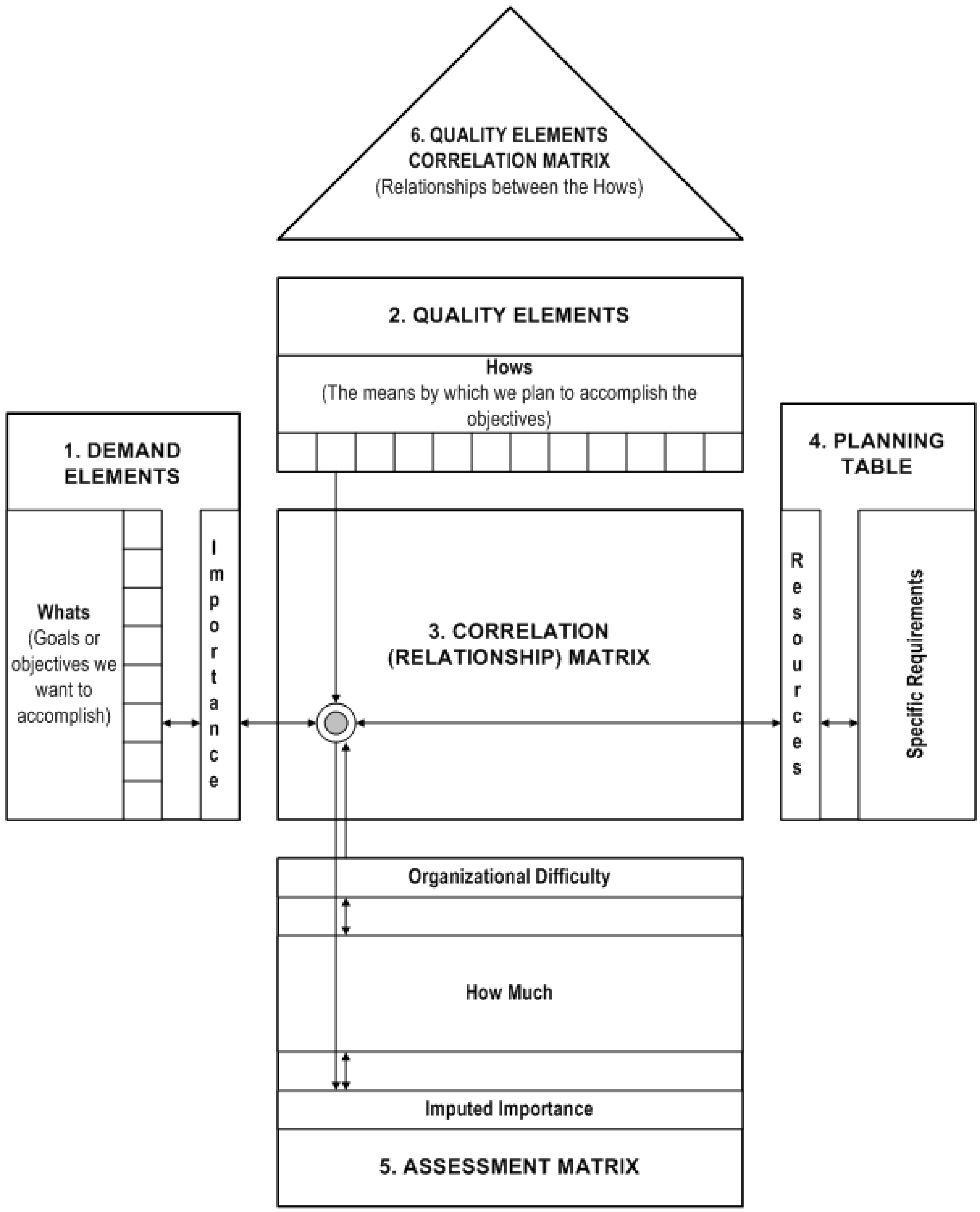

*Figure 3.*Example House of Quality.

Source: (Corporate Orientation and Training Systems, 2005)

As can be seen in figure 3, the house of quality consists of 5 “rooms.” Each of these rooms gathers input from a different part of the cross-functional team. Each input is then compared and contrasted against other team inputs, optimizing the development process and end product. The proposed methodology will optimize the customer input that is used in room 1 of the HOQ to define the voice of the customer, as well as the end quality score that is output to the assessment matrix.

Kano’s Model

Kano’s model is a representation of quality, product features and the voice of the customer. Figure 4 shows Kano’s model:

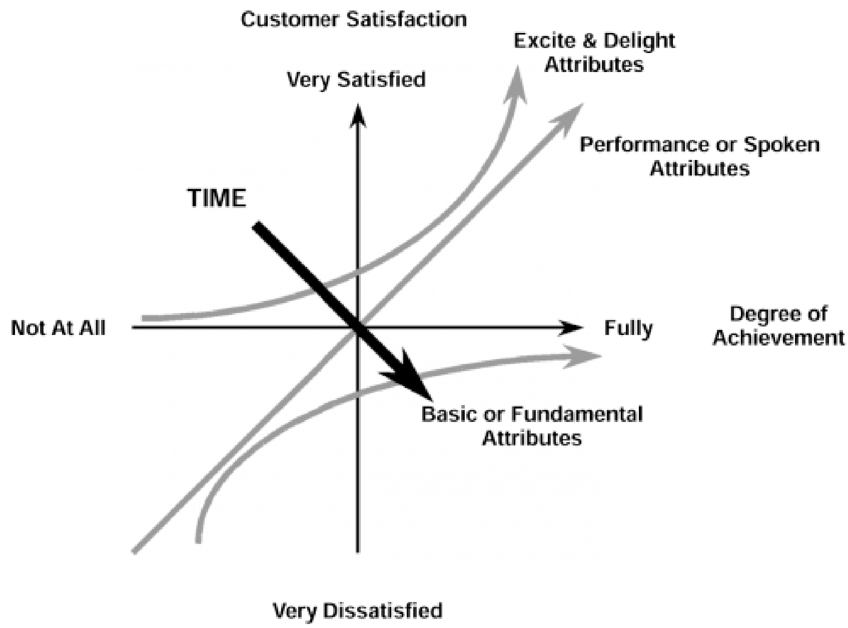

*Figure 4.*Kano's Model.

Source (Kano et al., 1984)

Kano's Model shows 3 types of product features as defined by the voice of the customer: basic features, performance features, and excitement features. Excitement features are unknown to the customer, and may be new to the market. These features often apply directly to the 'early technology adopter' as previously mentioned. To the early adopters, excitement features increase the product quality exponentially as features are added. In the case of a typical alarm clock, an excitement feature would be the ability to listen to internet radio upon waking up. Performance features are features that to the general consumer, increase product quality linearly. They are features known to the general consumer and commonly available in the market. In the case of the alarm clock example, a performance feature would be the ability to listen to standard FM radio upon waking up. A basic feature is defined as ‘must be’ by the consumer. Without this feature, the product is not considered quality, and will not be purchased by the consumer. As these expected features are added, product quality approaches zero. In the case of the alarm clock, a basic feature would be a functioning alarm to wake the customer up in the morning (Kano, 1984). Kano’s model will be used in the proposed methodology to divide customers based on desired features into segments, as well as ensure the product has the correct combination of features for marketability.

QFD Case Studies and Applications

Rafikul, Mohiuddin, and Masliza discuss their use of QFD and the house of quality to improve viewer satisfaction of visitors to a website for a television station in Malayasia (Rafikul et al, 2007). Technical requirements are related to the voice of the customer as gathered by the television station’s website. A house of quality analysis is used to help the organization organize future improvement efforts to the website based on the voice of the customer. The voice of the customer was gathered by using focus groups, online surveys, and website feedback. By using QFD, TV3 Malaysia was able to increase their website traffic and overall customer satisfaction as determined by website feedback and analytics.

Sigal discusses the use of QFD and the house of quality to develop a new consumer electronics DJ product for Numark Industries (Sigal, 2004). Specifically, the relationships that drive the house of quality and QFD were able to be optimized by turning subjective research into objective feedback based on the cross-functional team.

The house of quality is used for all aspects of the product development process. Input is gathered from the cross-functional teams of the organization to be used in the house of quality to determine the optimal product design. Optimization software is used to vary the technical constraints as to best meet the voice of the customer. Special care was taken to ensure that product met market expectations for a product in the DJ segment by adding constraints such as price, margin, and lead times.

Conjoint Analysis Overview

Conjoint analysis is a common marketing research technique in which consumers is asked to rate feature sets and make tradeoffs if they were to purchase the product (Curry, 1996). Conjoint analysis is commonly used for marketing surveys, and is featured in the research by Kazemzadeh et al. Conjoint analysis asks users to rate product profiles consisting of all possible combinations of the product features. By using conjoint analysis, large survey sizes are unnecessary. Sample sizes of 100 to 1,000 are typical for commercial conjoint surveys (Cattin and Wittinck, 1982). This allows for a reduction in cost for firms wishing to capture the voice of the customer by means of a survey as larger sample sizes increase survey costs.

Conjoint designs are typically created by statistical software packages such as SPSS. The combinations of the product attributes are transformed into an orthogonal, fractional factorial design as to reduce the overall survey size (SPSS Conjoint Manual, 2005). These combinations are referred to as product profile cards. Survey respondents are asked to rank these combinations and analyze trade-offs. As the number of product features to be tested increases, the overall survey size increases. This leads to an unmanageable survey size, with respondents having difficulty in accurately ranking product profiles.

After having distributed the survey, and receiving data on customer preferences of each product profile, the ranks are then used to compute the value of each feature in relation to customer satisfaction. Similar to correlation coefficients, each feature has an effect on customer satisfaction. This effect is referred to as part worth utility (Marketing Engineering, 2009). The feature set with the greatest part worth utility also has the greatest level of customer satisfaction. SPSS can natively calculate part worth utility using command line operations. For reference, equation 1 shows how to manually calculate part worth utility as explained by (Marketing Engineering, 2009):

Equation 1. Reference of manual calculation of part-worth utility

$$R_{ij} = \sum_{k-1}^{K} \sum_{m-1}^{M_k} a_{ikm} x a_{jkm} + \varepsilon_{ij}$$

Where

j = individual product design included in survey

R_{ij} = ratings for survey respondent i for product design j

a_{ikm} = part-worth utility for the m^{th} level of the k^{th} product feature/attribute

Mk = number of levels of attribute/product feature *k*

K = number of attributes/product features

xjkm = dummy variables that take on the value 1 if the m^{th} level of the k^{th} attribute is present in product *j* and the value 0 otherwise;

ij = error terms, assumed to be normal distribution with zero mean and variance equal to 2 for all *i* and *j*.

Source: (Marketing Engineering, 2009)

This computation is built into SPSS statistical software, and it's use will be explained further in the research.

Conjoint analysis is a powerful tool for survey design and analysis, allowing for large amounts of data to be gathered when determining the voice of the customer. The process will be a focus for the methodology of this research.

Conjoint Analysis Case Study

Delphi Electronics and Safety division wished to understand the voice of the customer (firm employees), and created a survey to assess process changes in the business and product (Weissa, 2009). The issue within a large global company such as Delphi was that many business processes were redundant, and due to the economy, process streamlining was necessary to cut costs. Master black belts were brought in as consultants to the division, and to analyze the current process for change management approvals. The team studied the current process, and created spreadsheets showing variables explaining each of the processes and distributed them to users. The Six Sigma team created a unique Delphi design of experiment software to create the conjoint analysis survey. The software was designed specially for Delphi and was able to be used to analyze other business processes. The survey was able to output a conjoint design for use in a web survey based on this conjoint design, they used physical profile cards of process changes, and asked users to rank. Respondents created ranks of process, and the team calculated part worth utility to help improve their change management approval process for the corporation. Delphi Corporation won Best Project Contributing to Innovation at the Lean Six Sigma and Process Improvement Summit and Awards.

Overview Literature

Bergquist and Abeysekera discuss the use of Quality Function Deployment for product development, specifically the areas of target values, and scaling scores (Bergquist and Abeysekera, 1996). They use target values for product characteristics and apply QFD methodology to a shoe design ergonomics case study. The case study discusses using safety standards as well as customer requirements as shoe design factors.

Gonzalez et al. discuss marketing intelligence and its incorporation into the overall manufacturing process (Gonzalez, M, Quesada, G, Mueller, R, & Mora-Monge, C, 2004). They propose a methodology to input marketing data into the product development process whilst setting obtainable corporate and quality goals. A competitive advantage can be gained by streamlining the corporate structure in a fast paced industry.

Matzler and Hiterhuber discuss Kano's model and its applicability to the product development process and increasing customer satisfaction (Matzler and Hithuber, 1998). Steps are outlined for using Kano's model in a QFD approach to product development.

Questionnaires and other forms of customer data collection are discussed from a management perspective.

Griffin and Hauser discuss the cross functional teams in product development organizations and their relation to the house of quality and voice of the customer (Griffin and Hauser, 1992). The concept of the house of quality is discussed and how each room of the house of quality allows input from the cross functional teams. This input and it's improvement on team unity and productivity is reviewed. This article is critical to the proposed research due to the need for communication between the cross functional teams in the development process.

Hauser discusses engineering product design from a marketing, management, and engineering standpoint (Hauser, 2003). He explains the need for customer input and feedback in product design, as well as a thorough analysis of the house of quality matrix. Hauser discusses communication between members of the new product development team and its importance to the house of quality and customer needs.

Griffin and Hauser discuss the voice of the customer, its importance to the product development process, and the typical steps taken by a marketing manager to capture customer input (Griffin and Hauser, 1993). The authors discuss the 4 “P”s of marketing: product, promotion, price, and place. The 5 “C”s of marketing are also discussed: company skills, customers, competition, collaborators, and context. Griffin and Hauser also discuss the process of identifying customer needs through segmentation, focus groups, interviews, and most notably, marketing surveys. All of these are critical factors to the customer input and marketing approach of this research.

Yee, Dahan, Hauser, and Orlin discuss the marketing research technique of conjoint analysis and its importance to the new product development and voice of the customer process (Dahan, Hauser, Orlin, and Yee 2007.) They discuss the development of a handheld GPS system using conjoint analysis techniques and web based consumer surveys. An ordinal ranking system is used in a web graphical survey for the customer to determine which feature tradeoffs are necessary to meet their desired price point. An orthogonal design of experiment method is discussed for evaluating feature sets and designing the web based graphical questionnaires. Also presented are software options for conjoint analysis such as Systat, and Sawtooth software.

Methodology Literature

Sigal discusses a product development methodology based on quality function deployment, and business and marketing processes tailored towards the consumer electronics industry (Sigal, 2004). This work is critical to the proposed research, as it provides a partial solution to the need for an end to end product development solution for fast paced industries. Sigal discusses the importance of the cross functional team in the product development process. A case study at an actual consumer electronics company (DJ equipment manufacturer Numark) is presented throughout the research. Kano's model, the house of quality, and quality function deployment are presented as tools for developing a product. This research states the need for future research concerning the customer input section of the house of quality.

Kazemzadeh, et al. discuss a front end methodology for improving the customer input to the house of quality using cluster analysis, benefit segmentation, and marketing survey research (Kazemzadeh, et. al., 2009). Using a conjoint analysis, customer input data is gathered by use of surveys. These customers are then segmented using the marketing research technique of benefit segmentation. A conjoint analysis is then done for each segment. Customers are clustered using a two stage clustering method with Ward's method, and K-means according to their desired product benefits. These benefits are then input as different customers into the house of quality. The house of quality matrix is then analyzed using this improved customer input. A case study of office chairs and ergonomics is analyzed using the customer input and house of quality methodology. This research is also crucial to the proposed methodology following improvements in the clustering methodology based on advancements in data mining techniques.

Arthur and Vassilvitskii propose an improvement to the k-means clustering method known as k-means++ based on improved initial seeding (Arthur and Vassilvitskii, 2007). Simple K-means has decreased accuracy using small sample sizes. The authors were able to overcome this, and other weaknesses by using an improved seeding process for the initial cluster centers. K-means++ uses a seeding methodology to improve accuracy of the k-means clustering algorithm by 10%, and a speed improvement of up to 90%. This accuracy was verified by comparing classification of test data versus using simple k-means. This methodology will be attempted to be implemented in the proposed research, and will be used to improve the accuracy of the product development and house of quality process.

METHODOLOGY

In order to develop the required end-to-end process, a number of existing tools will be combined, as well as improved, to fit the needs of fast paced industries and products. As previously stated, the current methods for input to the house of quality do not allow for direct marketing survey data to be used. Kazemzadeh, Behzadian, Aghdasi, and Albadv's method for taking conjoint analysis based marketing surveys will be used as a front end for preparing the data for input to the house of quality. The marketing survey data will then be analyzed using various clustering processes. For clustering processes, 3 clusters will be used (as to meet the desired 3 customer groups as previously mentioned) as in the research by Kazemzadeh, et al. Their two stage clustering process used simple k-means to then define the features associated with each customer group. Clustering and a conjoint analysis method will be used to better translate the web survey for use in the house of quality. This improvement will help to better capture the voice of the customer, therefore increasing the probability of product sales. After running the clustering algorithm, a product feature set will be ready for input into the house of quality.

After inputting the customer data into the house of quality, Sigal’s methodology of product development will be used. Sigal’s research is tailored to the consumer electronics industry, and fits the goal of a methodology for fast paced industries. With the voice of the customer input data input into the HOQ, the cross functional teams will provide their input (technical, management, and marketing). With the HOQ matrix completed, The product design with the maximum quality score is then chosen and built. This methodology streamlines the product development process, and produces a product that directly represents the voice of the customer as well as the input of the cross functional teams.

Figure 5 shows a process map of the complete methodology:

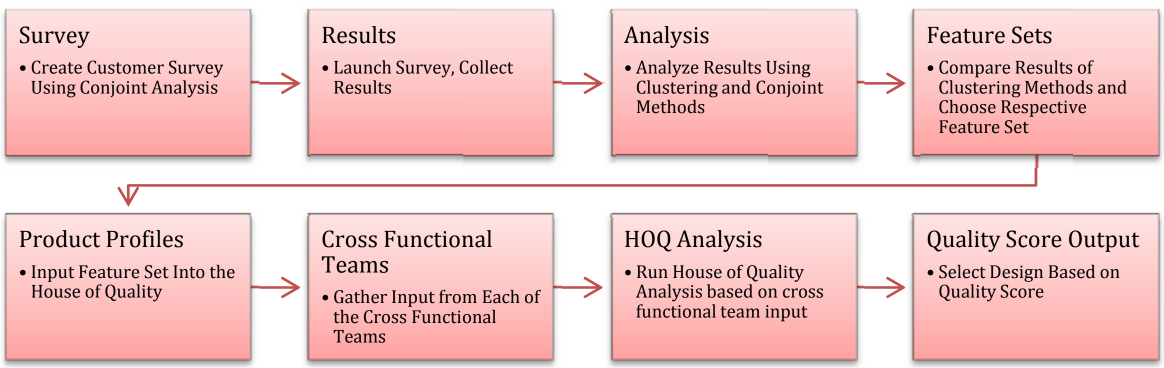

Figure 5. Complete methodology process map.

The detailed description of methodology will be divided hereafter according to the process map shown above.

Methodology Implementation

The methodology detailed below was tested using the development of an actual product. Myine Electronics, developer of home audio consumer electronics, participated in the testing of the methodology with the upcoming 2nd version of the Livio Pandora radio. The Livio radio is the first internet radio with dedicated "thumbs up, thumbs down" controls for the Pandora service. The 1st version of the device was launched in April of 2009 and featured the following technical specifications:

-Wired Ethernet internet connectivity

-Wireless 802.11g internet connectivity

-Access to over 11,000 internet radio stations

-Access to Pandora internet radio

-Included remote control

-Easy setup process

The 2nd version of the device has a number of proposed benefits to the customer. In order to determine what features should be included in the upcoming product concept, a web based survey will be used to capture the voice of the customer.

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Survey

Myine Electronics (and other consumer electronics developers) uses web surveys to help capture the voice of the customer for developing upcoming products. By capturing the voice of the customer, and the desired benefits, technical attributes can be determined to meet those needs. After discussion with the cross functional team (management, marketing, and engineering departments) of Myine Electronics, the following options were defined as desirable functions for the 2nd version Livio product:

-Sets up automatically out of the box when you plug it in

-Connects to internet wirelessly

-Connects to wired Ethernet internet

-Can be moved around the home or office freely

-Includes 11,000 internet radio stations for free including news, sports, and talk radio from around the world

-Has technology to improve the sound of your music

-Connects to your home stereo via S/PDIF and Optical outputs (in addition to the standard RCA (red/white) and boombox aux Input

The product concept according to Myine product management is for a internet radio remote similar to a Logitech Harmony multifunction, programmable media remote with the addition of internet radio connectivity in line with version 1 of the Livio radio. Myine product management and marketing developed the above list of potential benefits to the customer in according with industry trends and expert knowledge.

Using the aforementioned potential benefits to the customer, a web survey was created by using the method for integrating conjoint analysis survey design into the house of quality as researched by Kazemzadeh, et. al.. Each benefit was input into SPSS statistical software in order to create the conjoints. Refer to Appendix A for documentation on using SPSS statistical software to create an orthogonal design and consequently, a fractional factorial design.

Using a fractional factorial design allows comparison of multiple benefit attributes, while keeping the actual experimental design smaller. In the Livio V2 example, 8 attributes were tested, leading to a fractional factorial design (as created by SPSS software) of size 8.

Each survey question is based on a profile card, a combination of the attributes in the factorial design. SPSS creates an orthogonal design of size 7 (based on 8 attributes in the Livio V2 example), and designates each attribute by a binary number in the matrix. This binary number denotes if the particular attribute is to be included (and tested) in that profile card/question. Table 1 shows the orthogonal design as created by SPSS:

Table 1

Orthogonal design as created by SPSS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Card 1	2	1	2	2	2	1	1
Card 2	1	2	1	2	2	2	1
Card 3	2	2	1	1	2	1	2
Card 4	1	1	2	1	2	2	2
Card 5	2	2	2	1	1	2	1
Card 6	2	1	1	2	1	2	2
Card 7	1	2	2	2	1	1	2
Card 8	1	1	1	1	1	1	1

SPSS designates that the attribute is included on the profile card by a “1”. A “2” designates that the attribute is not included for that profile card.

Using the profile cards created by SPSS, a total of 8 survey questions are created. Each question consists of each of the attributes as indicated by the conjoint matrix. An example of the question created by profile card 2 is shown below:

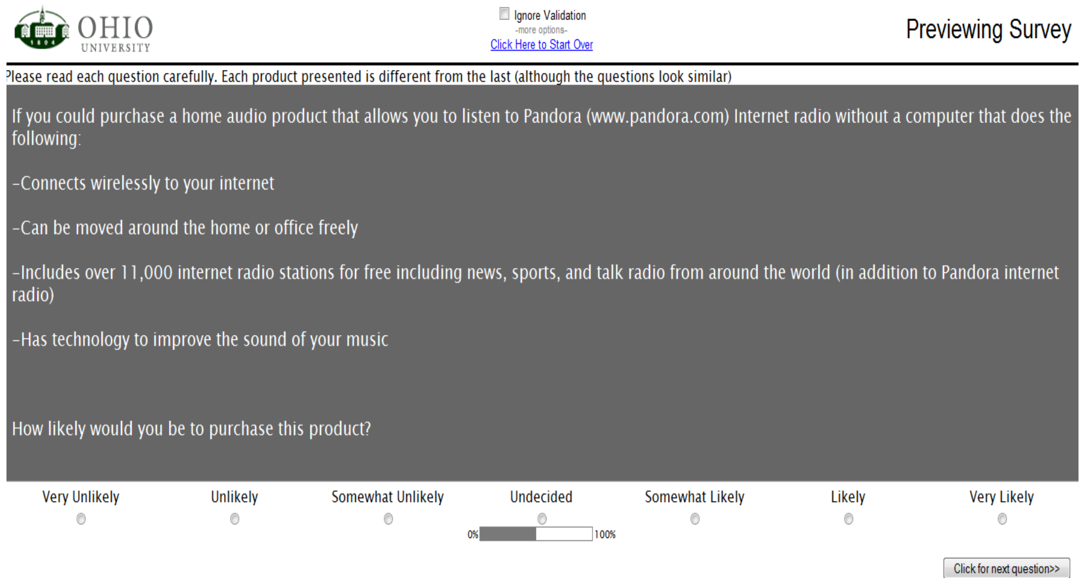

Figure 6. Question example.

The survey respondent is presented with all of the survey questions created by the profile cards via a web based survey. For the Livio example, Qualtrics web survey design services were used due to educational availability. Qualtrics has a number of features designed to increase the accuracy of the survey results as to better capture the voice of the customer. One of these features is the ability to randomize the order of particular questions as presented to the respondent. In order to increase the accuracy of the survey, all questions (profile cards) were randomized with the exception of profile card 8. Profile card 8 presents the product concept to the user without adding or changing any of the attributes. Presenting this question first helps capture the respondent's initial opinion of the product concept.

Respondents are asked to rate each product concept (profile card) on a scale of 1-7, 7 being most likely to purchase, 1 being very unlikely to purchase. Using a scale of odd numbered ordinal values helps the respondent to discretely evaluate the question due to the central value acting as a neutral response.

Survey Results

The survey was advertised by means of Facebook, Twitter, and viral social media. An estimated 10,000 people viewed ads to take the survey, with only 119 actually following through to the Qualtrics survey portal. The view count was estimated by following means: 5,000 people were invited to the Facebook survey group, 3,000 were reached by means of Twitter, and 2,000 were is the average for all means of blogging combined. 119 respondents participated in the survey over a period of 3 weeks. 19 of these respondents did not finish the survey, and the respective data was not included in the analysis. 100 surveys total were completed. Based on the estimated number of views and actual completed surveys, a response rate of 1% was calculated. For the general population, the average survey response rate is 1-20% (Ray, 2006).

For the data obtained by the survey, the mean response value for each question was computed. Table 2 shows the mean results of each question:

Table 2

Mean results of survey

Question #/ Card #	Mean Response
1	4.84
2	5.32
3	5.19
4	5.13
5	4.95
6	5.09
7	4.96
8	4.25

The survey responses were also analyzed using the mode, but proved to provide no useful data.Using these calculated averages and results, the data can be analyzed in preparation for input into the house of quality.

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ANALYSIS

Overview

3 methods were used to analyze the data from the marketing survey. Multiple tools were available for use in the SPSS statistical software. With the goal of creating a time efficient product development tool in mind, multiple data analysis methods were used to find the optimal feature set for input into the house of quality. Research by Kazemzadeh et al. (2009) uses a two-stage clustering process for survey data. This clustering process consists of Ward’s Method, followed by simple k-means algorithm. The data gathered by the authors has a large number of types and includes demographic information. Typical surveys for the consumer electronics industry have pre-defined demographic targets. Product development firms have a target demographic for their brands and product families, and specify this target when marketing the survey to respondents. Myine electronics specifically targets the baby boomer demographic (44-63) based on NPD research and expert knowledge. Firms such as Myine require a more streamlined process for interpreting survey results when compared to the research by Kazemzadeh et al. Various algorithms for analyzing conjoint survey data will be explored in order to best meet the needs of firms such as Myine electronics.

Algorithms

The research by Kazemzadeh et al. was modified and simplified for the consumer electronics and other demographic centric industries. Research was done to determine various methods for determining the optimal feature set based on the conjoint design based survey. Methods used include simple k-means, two-step clustering algorithm, and conjoint part worth utility. The use of K-means++, which is a variation of simple k-means and uses improved seeding for an increase in accuracy up to 10% was proposed. The accuracy of the three analysis methods will be compared to feature sets proposed by the cross functional team.

Simple K-means

SPSS statistics software features a number of built-in clustering algorithms for analyzing survey data. Simple K-means was used as part of a two stage clustering algorithm in the research by Kazemzadeh et al., and will be used first for the simplified survey analysis.

The survey results for each question were input into the SPSS software, and k-means was selected to be performed on the data (found under the analyze and classify menus). Screenshots of the analysis process using SPSS can be found in Appendix B Data for all questions was analyzed using the k-means algorithm with a pre-defined number of clusters. Three clusters were selected based on the 3 customer groups in Kano's model. The complete output from SPSS is shown in Appendix C. Table 3 shows the distribution of each of the 3 clusters:

Table 3

Number of cases in each cluster

Cluster	1	50.000
	2	35.000
	3	15.000
Valid		100.000
Missing		.000

As can be seen in table 3, using k-means clustering assigns 50% of the cases to the first cluster. After multiple iterations, the final cluster centers are shown below in table 4:

Table 4

Final cluster centers using K-means

	Cluster		
	1	2	3
Q1	6	4.49	2.24
Q2	6.48	4.91	2.82
Q3	6.34	4.97	2.35
Q4	6.22	4.94	2.41
Q5	6.08	4.57	2.47
Q6	6.25	4.8	2.35
Q7	6.12	4.69	2.12
Q8	5.64	3.31	2.18

Focusing on cluster 1 due to previously discussed instance distribution, the top 3 feature sets can be determined. The questions (profile cards) with the top 3 largest cluster centers are chosen for input into the house of quality, and for analysis by the cross functional team. These feature sets are as follows (in order of decreasing cluster center): profile 2, profile 3, and profile 6. Referring to the original conjoint design, these profiles are translated to voice of the customer specifications as follows:

Profile 2:

-Connects wirelessly to your internet

-Can be moved around the home or office freely

-Includes over 11,000 internet radio stations for free including news, sports, and talk radio from around the world (in addition to Pandora internet radio)

-Has technology to improve the sound of your music

Profile 3:

-Sets up out of the box automatically when you plug it in

-Connects wirelessly to your internet

-Includes over 11,000 internet radio stations for free including news, sports, and talk radio from around the world (in addition to Pandora internet radio)

-Connects to your home stereo via S/PDIF and Optical outputs (in addition to the standard RCA (red/white) and boombox Aux Input)

Profile 6:

-Sets up out of the box automatically when you plug it in

-Can be moved around the home or office freely

-Has technology to improve the sound of your music

-Connects to your home stereo via S/PDIF and Optical outputs (in addition to the standard RCA (red/white) and boombox Aux Input)

These profiles are able to be input into the house of quality, but do not show the value of each feature in relation to customer satisfaction. A second clustering method will be compared to the k-means algorithm to determine the appropriate method for analyzing the survey data.

Two-Step Cluster Analysis

Two- step cluster analysis was used as a comparison clustering method to k-means. Two-step clustering is built into the SPSS software package (under the analyze and clustering menus). It is designed for very large data sets, and will be used to analyze the Livio data set despite the number of survey respondents. Two-step clustering differs from Kazemzadeh et al.'s two-stage clustering analysis in that it uses a hierarchical method of clustering as opposed to two clustering algorithms in tandem (SPSS, 2009). Two-step divides the data into clusters, and proceeds to divide the larger clusters into sub clusters to classify the data. Complete documentation for using two-step cluster analysis is located in Appendix D

When using two-step cluster analysis in SPSS, the number of clusters is set to 3 (as mentioned in the k-means analysis to match the Kano customer groups). In this research, the clustering criterion was selected to be Schwarz'sBayesian Criterion. Bayesian Criterion was better suited for profile data analyses over Akaike's Information Criterion as Akaike's is designed to compare various models as opposed to analysis of gathered data (SPSS, 2009).

Upon running two-step cluster analysis, the following case distribution is shown in Table 5:

Table 5

Cluster distribution using two-step clustering

		N	% of Combined	% of Total
Cluster	1	43	43.0%	43.0%
	2	33	33.0%	33.0%
	3	24	24.0%	24.0%
Total		100		100.0%

As can be seen in Table 5, cluster 1 has the highest percentage of results. Using this cluster, SPSS creates tables of results for each question including the number of responses for each numerical value between 1-7. A truncated results table for question 1 is show below, complete results are available in Appendix E. This table shows only values for survey responses of 5, 6, and 7 (which would indicate a purchase or preference by the survey respondent).

Table 6

Truncated response frequencies, divided by cluster for question 1

		5.00		6.00		7.00	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Cluster	1	3	12.5%	8	29.6%	15	93.8%
	2	19	79.2%	19	70.4%	1	6.3%
	3	2	8.3%	0	.0%	0	.0%
	Combined	24	100.0%	27	100.0%	16	100.0%

Only frequencies from cluster 1 are considered as defined in the cluster distribution shown above. The frequencies for values 5, 6, and 7 are summed together in order to create a ranking value for each profile card. For question 1 as shown in table 6, the value would be 26. This is done to create a uniform system for evaluating each sub cluster (preference value) within the larger cluster indicated by the distribution of values. Based on this method, approximately 5 questions result in a ranking value of 28. This lack of differentiation leads to no useful information for a house of quality analysis, and no possibility for inclusion in the conjoint data analysis methodology.

Conjoint Analysis by Part-Worth Utilities

By using part-worth utility as featured by SPSS, a definite feature set can be found. The part-worth utility is based on linear regression as mentioned in the review of literature. In order to adapt the algorithm based in SPSS for standard numerical rated surveys, the survey must be pre-processed. Normal conjoint analysis requires users to rank profiles cards. Research by Kazemzadeh et al. required survey respondents to rank approximately 27 product profiles. Survey respondents have trouble differentiating a product profile ranked 15 and one ranked 16. By eliminating this ranking system and implementing standard numerical value systems, users will be able to better differentiate product profiles should the survey size become larger in another study.

Pre-processing the data simply requires taking the average value for each question, then using those averages as a single record for conjoint analysis. Data was averaged, and a data file was created with a single line of data, and columns with the averages. This preference file, as well as the original orthogonal design as was created to design the survey are input into the SPSS software.

Using SPSS software's conjoint analysis command syntax, these two files are analyzed to determine the part worth utility. Table 7 shows the part-worth utilities for each question:

Table 7

Part-worth utilities using conjoint analysis and SPSS

		Utility Estimate
Q1	Unimportant to me	.250
	Important to me	-.250
Q2	Unimportant to me	-1.000
	Important to me	1.000
Q3	Unimportant	1.000
	Important to me	-1.000
Q4	Not Important	.250
	Important to me	-.250
Q5	Not important to me	-1.000
	Important to me	1.000
Q6	Not important to me	-1.250
	Important to me	1.250
Q7	Not Important to me	-.750
	Important to me	.750
(Constant)		4.500

Question 6 has the highest part-worth utility (1.250), followed by Questions 2,3 and 5 respectively. This parallels the results of the k-means clustering. Profile card 6 is the top choice for implementation according to both part-worth utility and k-means clustering.

Comparison of Data Analysis Methods

Three methods were used to analyze the results of the conjoint survey: simple k-means, two-stage clustering, and conjoint part-worth utility. A fourth method, k-means++ was proposed and attempted. This algorithm was not used due to lack of documentation and a robust software implementation from the authors. Further research using k-means++ could potentially yield more accurate results.

Both k-means, and part-worth utility show that the voice of the customer requests profile 6 for implementation. K-means is simple and quick to implement, but requires more advanced knowledge of clustering processes. Being a machine learning algorithm, it also has the potential to produce different results each time it is ran. K-means also has a more complicated output in terms of understanding. Although it may produce the same output, k-means will be more difficult to use by the entire cross functional team.

Part-worth utility provides a distinct, clear result to which feature sets should be input into the house of quality. The software implementation is simple, and requires no background knowledge of linear regression. A software tool could specifically be created to easily output the results of part-worth utility so that the entire cross-functional team could use the data. Part-worth utility also produces the exact result each time the analysis is ran. Consistency is key for implementation across the cross functional team.

Based on the results from all 3 algorithms, part-worth utility is recommended for in preparation for survey data for use in the house of quality.

House of Quality Analysis

The cross-functional product development team at Myine electronics met to determine the final feature set for the Livio Pandora radio product. Each member of the team was asked to provide input for their respective departments (marketing, engineering, product management, sales). This input helped to fill out the various sections of the House of Quality. An HOQ Excel template was used to aid the analysis (www.QFDonline.com).

The HOQ analysis will cover each of the following sections:

1. Customer Input (Demanded Quality)
2. Technical Quality Characteristics
3. Demanded Quality Vs. Cross-functional Team Matrix
4. Technical Attribute Relationship Matrix
5. Results

Customer Input

The results of the conjoint analysis as previously discussed were input into the house of quality. This feature set was as follows:

-Sets up out of the box automatically when you plug it in

-Can be moved around the home or office freely

-Has technology to improve the sound of your music

-Connects to your home stereo via S/PDIF and Optical outputs (in addition to the standard RCA (red/white) and boombox Aux Input)

These features were placed into the customer input (also known as demanded quality) section of the house of quality. The features indicated by the conjoint analysis were assigned a maximum importance weight of 100. Other features that were proposed in the initial marketing survey, but were not part of the resulting product profile from the conjoint analysis were assigned a weight of 50. This value was determined by the cross-functional team due to features outside of profile 6 being neither chosen, nor indicated that it should not be included in the product. The following features were assigned a weight of 50:

-Connects to internet wirelessly

-Includes 11,000 internet radio stations for free

-Connects to your home stereo via SPIF and Optical Output

-Connects to wired internet

After all of these features (as well as their respective weights) were input to the demanded quality section, the next step was to discuss with the engineering and product management teams to determine the technical quality characteristics.

Technical Quality Characteristics

The cross functional team discussed the customer demands, and determined the following engineering technical attributes to meet those and the demands of typical consumer electronics products:

-Screen size

-Has a Wi-Fi chip

-Has an RJ32 jack

-Remote control

-Works on 110/220 volts

-RCA cables included

-RCA to 1/8th inch adapter included

-Remote firmware upgrade ability

-Remote assistance

-Alarm clock functionality

-Ability to input alphanumeric characters

-Quality of user guide

-Level of technical support

-Headphone jack

-Digital audio output

These characteristics were determined by expert knowledge in engineering and consumer electronics product development. The customer input/demanded quality matrix was then evaluated.

Demanded Quality vs. Cross-functional Team Matrix

With the completed demanded quality and technical quality characteristics sections, the central relationship matrix could be completed. Attributes were compared and the relationship between each was calculated. These relationships were measured as “Strong”, “Moderate”, or “Weak”. The quality score multiplier for each of these measurements was 9, 3, and 1 respectively. These were hard coded into the Excel template, and can vary between cross-functional teams and analyses.

Each of the relationships were compared by the cross functional team, and the quality score for each value was tallied in the results section at the bottom of the house of quality. The relationship between each technical attribute was then compared using the “roof” of the house of quality.

Technical Characteristic Attribute Matrix

The “roof” of the house of qualityis used to compare the relationship between the technical attributes required by the engineering and product management teams. Relationships were rated by the team as having strong positive correlation, positive correlation, negative correlation, or strong negative correlation. These relationships were also tallied in the results section at the bottom of the house of quality based on the Excel template. As with the demanded quality and technical quality characteristics section, the values added to the quality score vary with each cross-functional team. At this point, the quality scores had been calculated, and a final feature set could be determined.

Results

Based on the results of the house of quality analysis, the max relationship values for each technical attribute, their weight and importance and relative weights were found by automatic calculation using the Excel template.

There is a direct correlation between the max relationship values and weight/importance and relative weights. The max relationship value demonstrates the value between each technical attribute and all of the customer demanded qualities. The weight for each technical attribute is assigned by a combination of the cross-functional team and the relationships between each of the technical attributes (the “roof” of the house of quality).

Technical attributes for inclusion in the product and focus by the cross-functional team (in terms of devoting man-power, funding, and development time) were chosen based on a combination of the largest max relationship values and the largest relative weights. Any attribute with a max value relationship less than or equal to 3 would not be focused on by the team.

As previously mentioned, the entire house of quality as completed by the Myine Electronics cross-functional team can be found in appendix H. The following technical attributes were determined by the HOQ analysis: 1 2 3 6 7 9

-Screen size

-Has a Wi-Fi chip

-Has an RJ32 jack

-RCA cables included

-RCA to 1/8th inch adapter included

-Digital audio output

These specifications are in line with speculations the cross-functional team had in prior discussions. The house of quality analysis confirms these speculations and helps the cross-functional team to begin designing hardware to incorporate these technical attributes.

CONCLUSIONS AND OPPORTUNITIES FOR FURTHER RESEARCH

The conjoint analysis methodology proved to be a simple, efficient way for translating the voice of the customer into hard requirements for use in the house of quality. The orthogonal design helped to reduce the overall survey size, increasing the number of customers that will take it to completion. The part-worth utility method of analyzing the orthogonal design and survey results also proved to be efficientand simple for preparing the data for use in the house of quality.

Although a number of data analysis methods were used to interpret the results of the consumer survey, others exist that could improve accuracy. K-means++ was explored for use, but lacked proper documentation and a robust software implementation. Other methods for designing experiments also exist, and upon exploration could improve the accuracy and decrease the size of the web survey.

Future research could explore larger sample sizes for the initial survey, use of software other than SPSS for analyzing data and creating the orthogonal design, and the use of other data mining algorithms.

Overall, the use of conjoint analysis and the house of quality proved to be a powerful, useful tool for product development. It helps to decrease lead time, better capture the voice of the customer, and decrease costs. Firms wishing to implement this methodology can look to increases in customer satisfaction and product development efficiency. Consumers can benefit from this methodology when firms are able to produce a better product based on the consumer's requirements.

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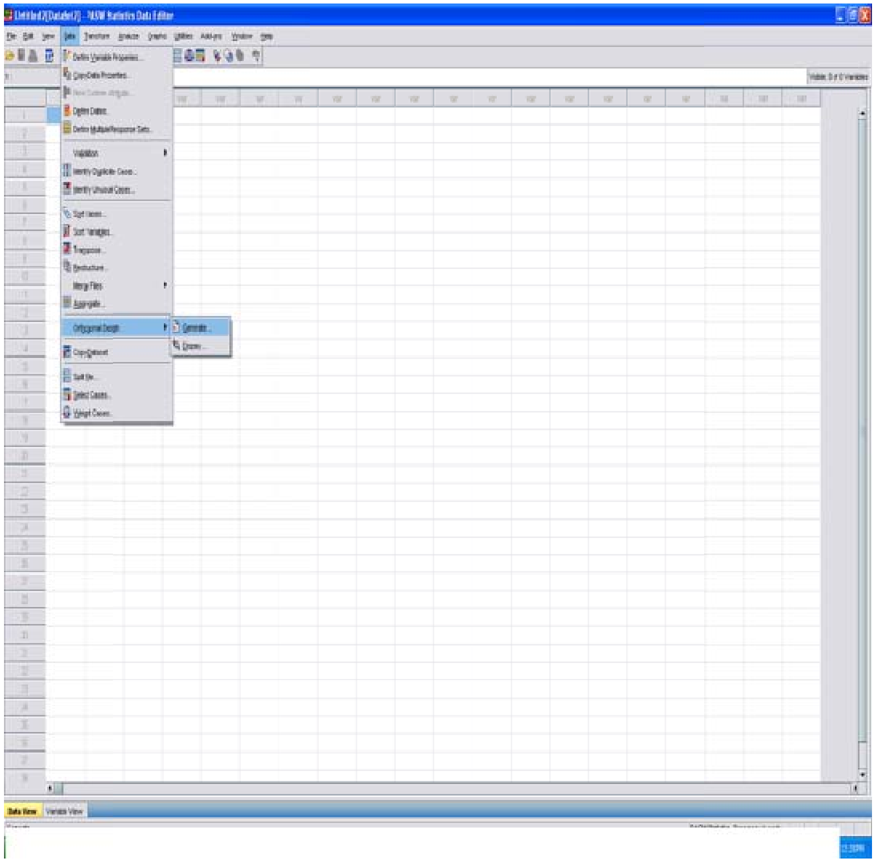
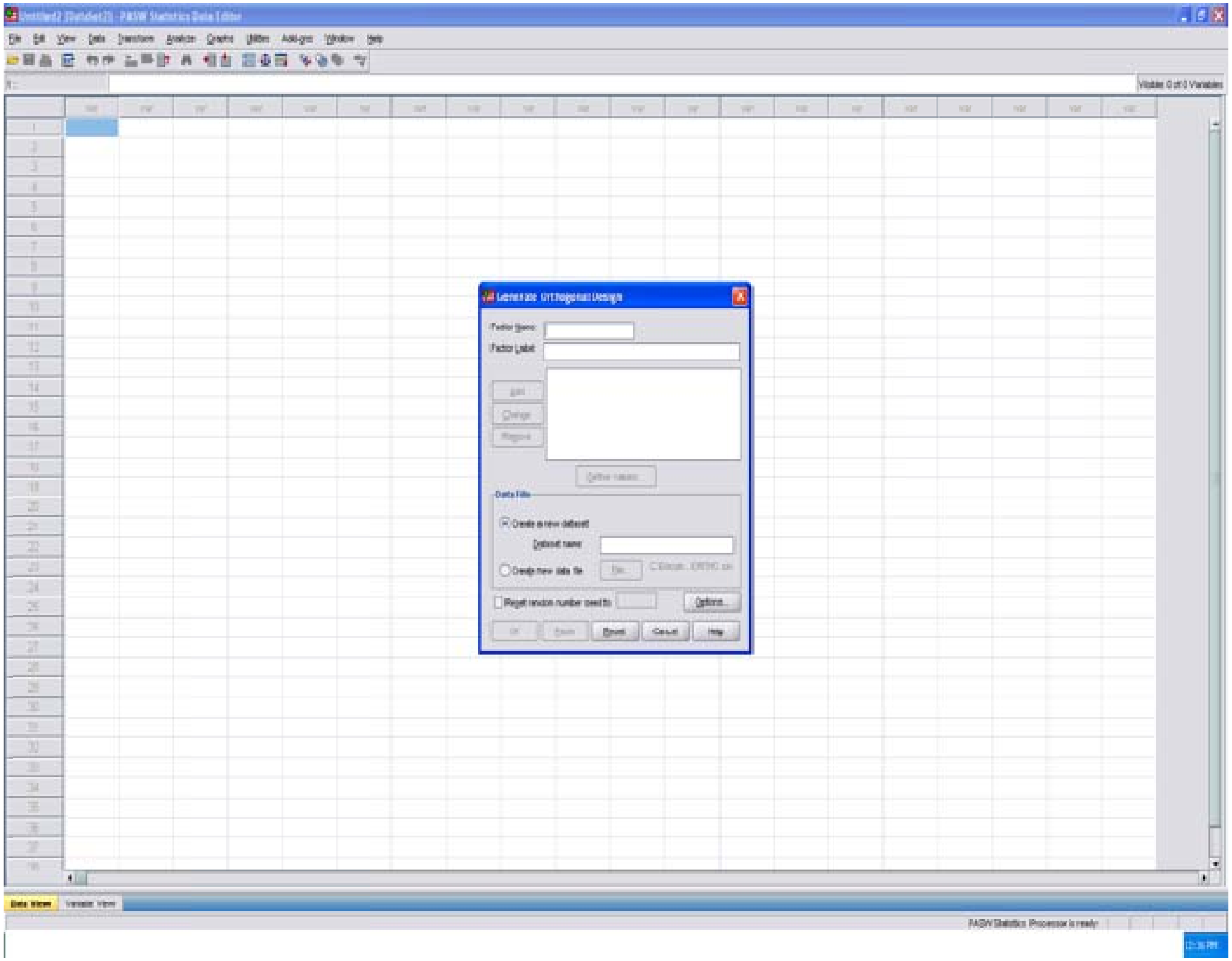
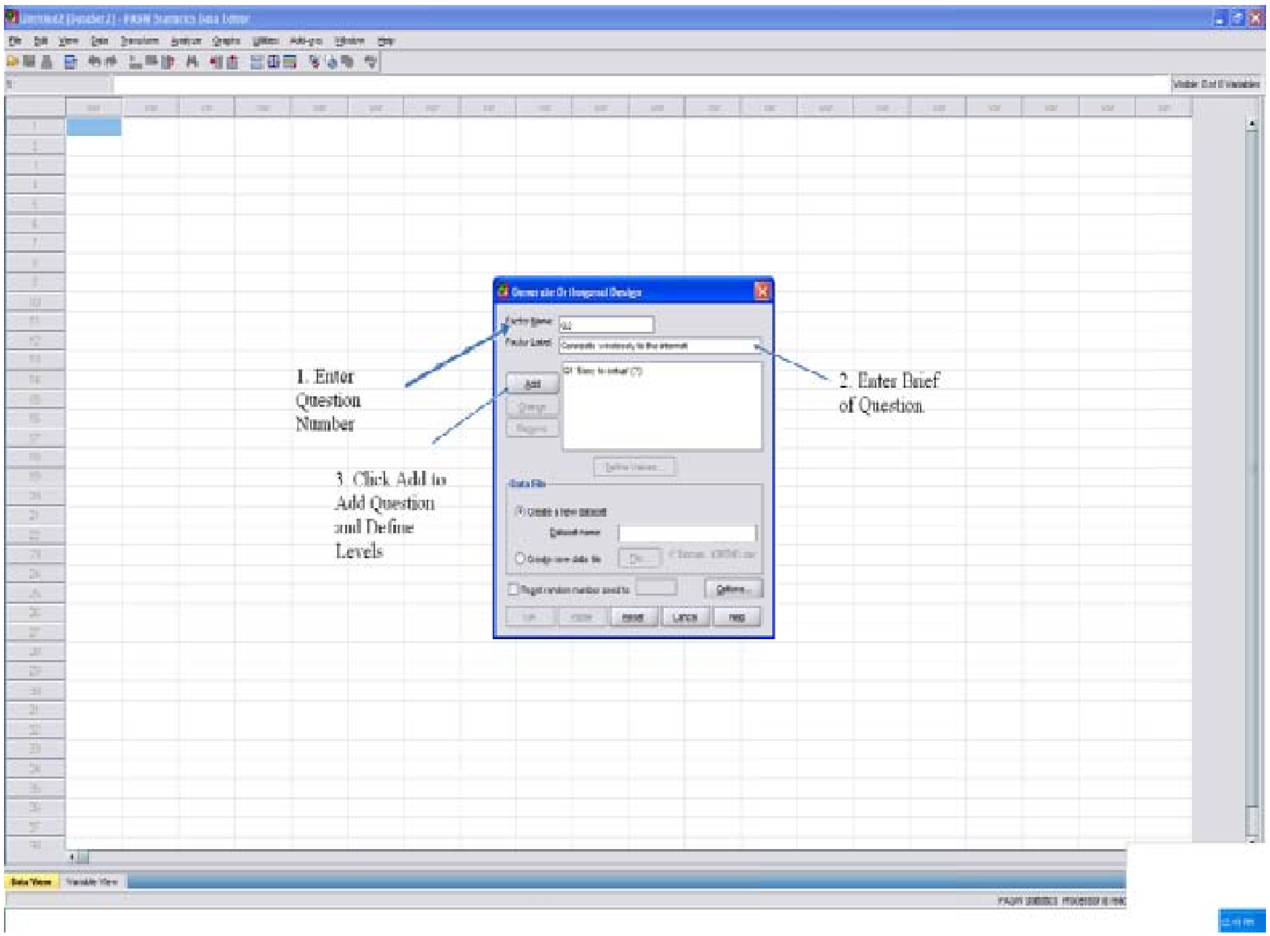
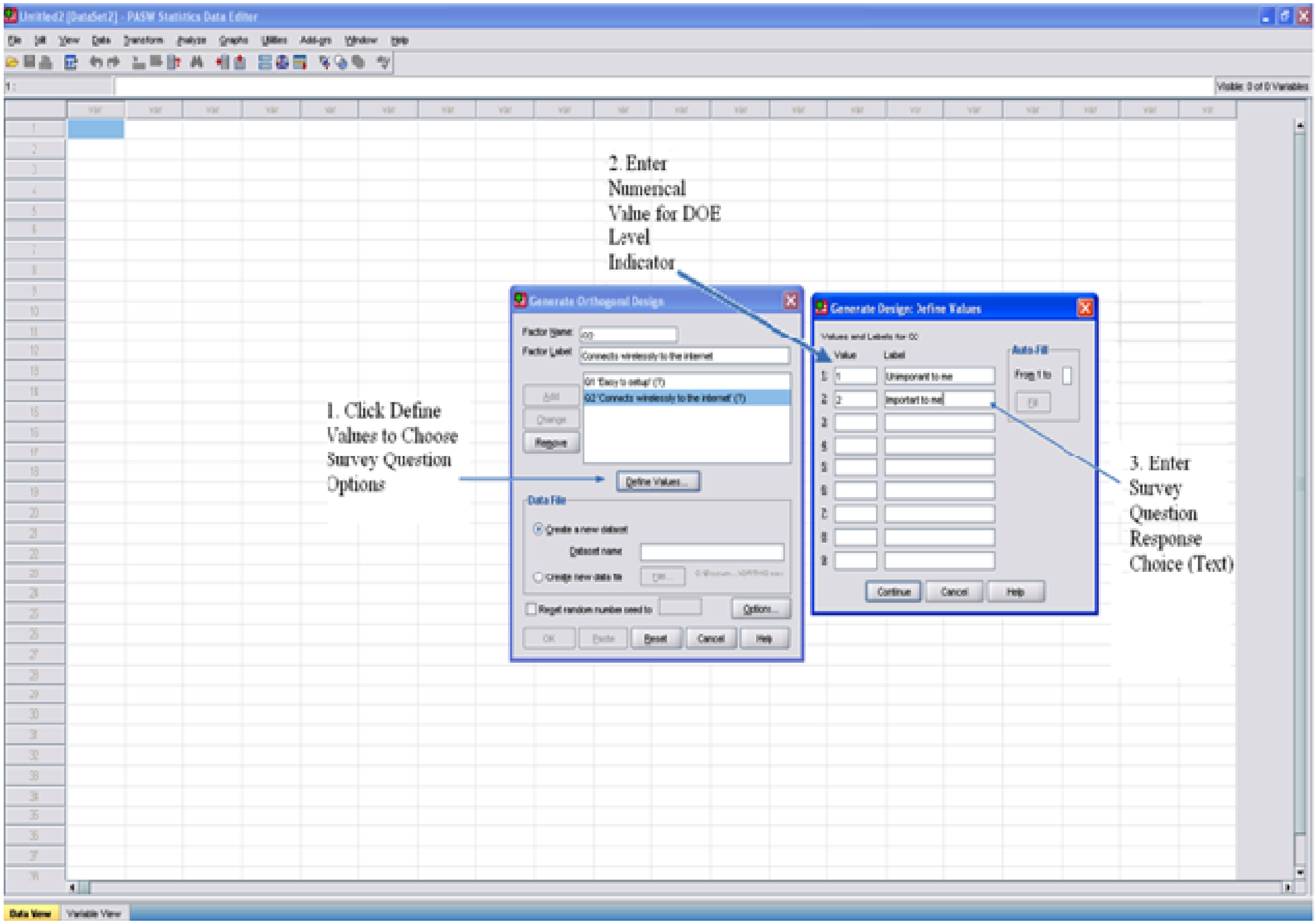
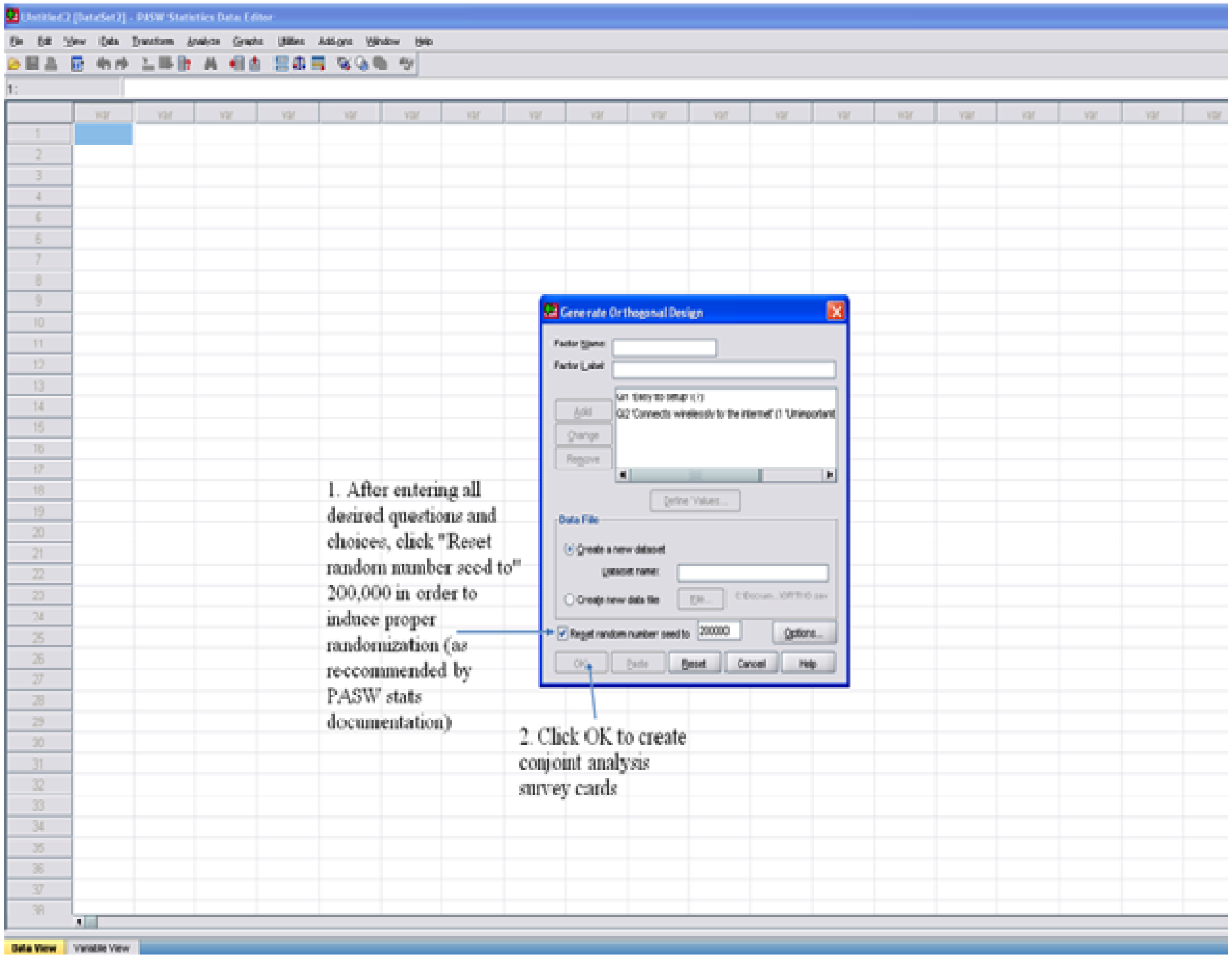
APPENDIX A: CREATING THE ORTHOGONAL DESIGN SURVEY USING SPSS

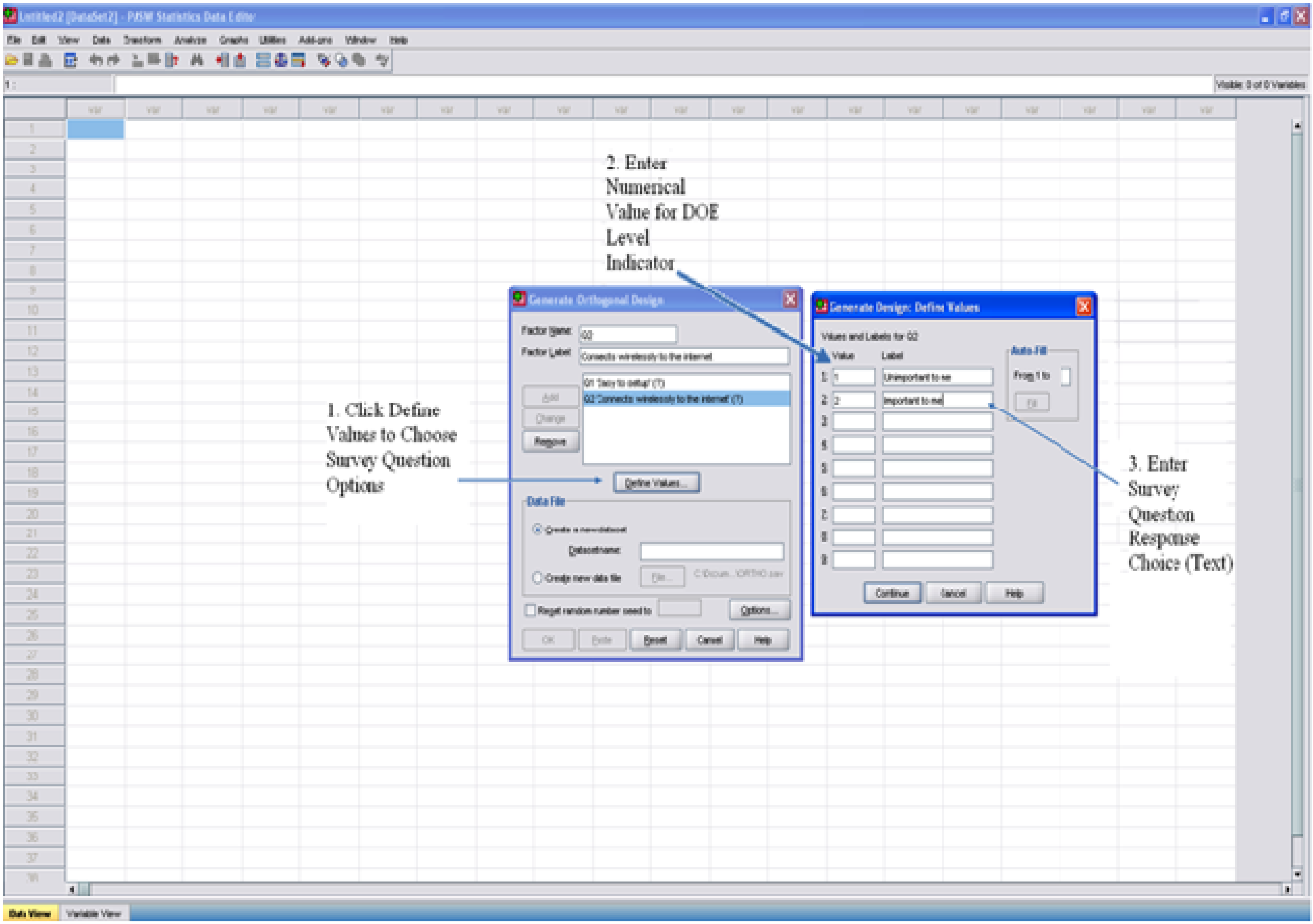


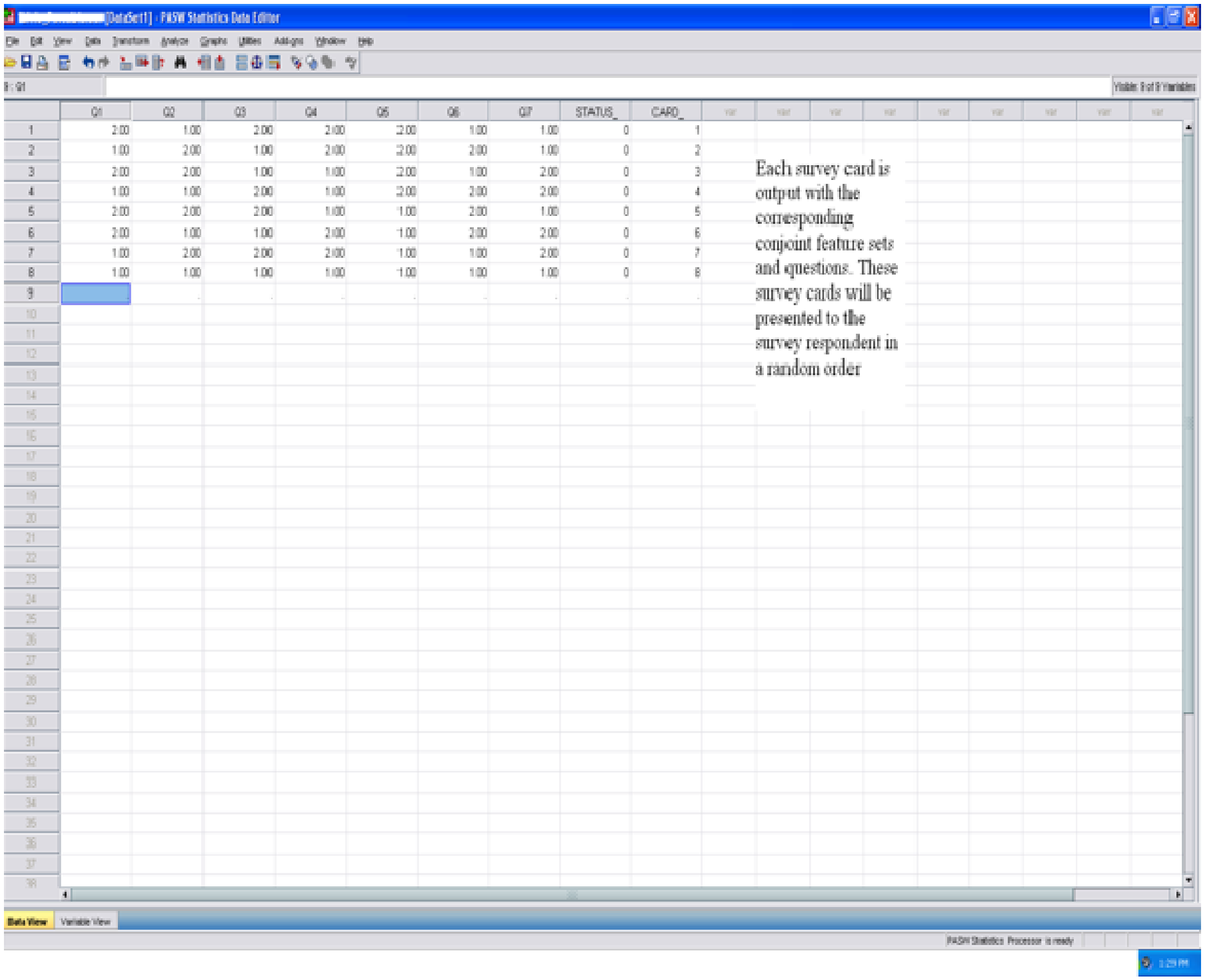



1. Enter
Question
Number
2. Enter Brief
of Question
3. Click Add to
Add Question
and Define
Levels

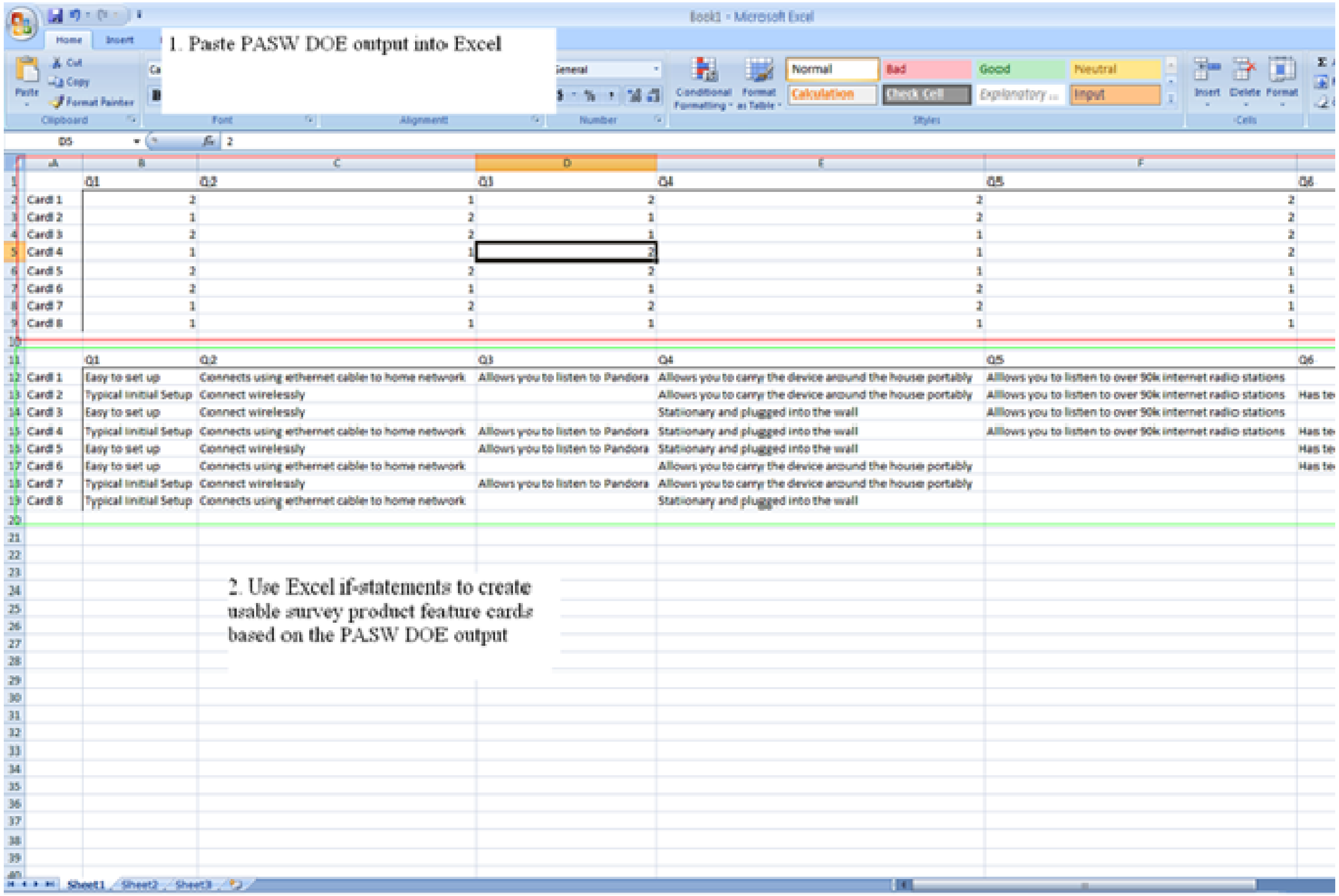

Untitled2 [DataSet2] - PASW Statistics Data Editor
Generate Orthogonal Design
Generate Design: Define Values
1. Click Define Values to Choose Survey Question Options
2. Enter Numerical Value for DOE Level Indicator
3. Enter Survey Question Response Choice (Text)


Generate Orthogonal Design
1. After entering all desired questions and choices, click "Reset random number seed to" 200,000 in order to induce proper randomization (as reccommended by PASW stats documentation)
2. Click OK to create conjoint analysis survey cards


2. Enter Numerical Value for DOE Level Indicator
1. Click Define Values to Choose Survey Question Options
3. Enter Survey Question Response Choice (Text)
Generate Orthogonal Design
Generate Design: Define Values



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	STATUS_	CARD_
1	2.00	1.00	2.00	2.00	2.00	1.00	1.00	0	1
2	1.00	2.00	1.00	2.00	2.00	2.00	1.00	0	2
3	2.00	2.00	1.00	1.00	2.00	1.00	2.00	0	3
4	1.00	1.00	2.00	1.00	2.00	2.00	2.00	0	4
5	2.00	2.00	2.00	1.00	1.00	2.00	1.00	0	5
6	2.00	1.00	1.00	2.00	1.00	2.00	2.00	0	6
7	1.00	2.00	2.00	2.00	1.00	1.00	2.00	0	7
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0	8


1. Paste PASW DOE output into Excel
Q1 Q2 Q3 Q4 Q5 Q6
Card 1 2 1 2 2 2
Card 2 1 2 1 2 2
Card 3 2 2 1 1 2
Card 4 1 1 2 1 2
Card 5 2 2 2 1 1
Card 6 2 1 1 2 1
Card 7 1 2 2 2 1
Card 8 1 1 1 1 1
Card 1 Easy to set up Connects using ethernet cable to home network Allows you to listen to Pandora Allows you to carry the device around the house portably Allows you to listen to over 90k internet radio stations
Card 2 Typical Initial Setup Connect wirelessly Allows you to carry the device around the house portably Allows you to listen to over 90k internet radio stations
Card 3 Easy to set up Connect wirelessly Stationary and plugged into the wall Allows you to listen to over 90k internet radio stations
Card 4 Typical Initial Setup Connects using ethernet cable to home network Allows you to listen to Pandora Stationary and plugged into the wall Allows you to listen to over 90k internet radio stations
Card 5 Easy to set up Connect wirelessly Allows you to listen to Pandora Stationary and plugged into the wall
Card 6 Easy to set up Connects using ethernet cable to home network Allows you to carry the device around the house portably
Card 7 Typical Initial Setup Connect wirelessly Allows you to listen to Pandora Allows you to carry the device around the house portably
Card 8 Typical Initial Setup Connects using ethernet cable to home network Stationary and plugged into the wall
2. Use Excel if-statements to create usable survey product feature cards based on the PASW DOE output

APPENDIX B: COMPLETE SURVEY AND RESULTS

1. If you could purchase a home audio product that allows you to listen to Pandora (www.pandora.com) Internet radio without a computer that does the following:-Sets up out of the box automatically when you plug it in-Connects to wired (Ethernet) Internet-Can be moved around the home or office freely-Includes over 11,000 Internet radio stations for free including news, sports, and talk radio from around the world (in addition to Pandora Internet radio)How likely would you be to purchase this product?

1	Very Unlikely	3	3%
2	Unlikely	11	10%
3	Somewhat Unlikely	13	12%
4	Undecided	10	9%
5	Somewhat Likely	24	23%
6	Likely	27	25%
7	Very Likely	18	17%
	Total	106	100%

Mean	4.83
Variance	2.90
Standard Deviation	1.70
Total Responses	106

2. If you could purchase a home audio product that allows you to listen to Pandora (www.pandora.com) Internet radio without a computer that does the following:-Connects wirelessly to your internet-Can be moved around the home or office freely-Includes over 11,000 internet radio stations for free including news, sports, and talk radio from around the world (in addition to Pandora internet radio)-Has technology to improve the sound of your music How likely would you be to purchase this product?

1	Very Unlikely	3	3%
2	Unlikely	7	6%
3	Somewhat Unlikely	9	8%
4	Undecided	3	3%
5	Somewhat Likely	28	26%
6	Likely	28	26%
7	Very Likely	31	28%
	Total	109	100%

Mean	5.33
Variance	2.69
Standard Deviation	1.64
Total Responses	109

3. If you could purchase a home audio product that allows you to listen to Pandora (www.pandora.com) internet radio without a computer that does the following:-Sets up out of the box automatically when you plug it in-Connects wirelessly to your internet-Includes over 11,000 internet radio stations for free including news, sports, and talk radio from around the world (in addition to Pandora internet radio)-Connects to your home stereo via S/PDIF and Optical outputs (in addition to the standard RCA (red/white) and boombox Aux Input)How likely would you be to purchase this product?

1	Very Unlikely	3	3%
2	Unlikely	12	11%
3	Somewhat Unlikely	5	5%
4	Undecided	4	4%
5	Somewhat Likely	26	25%
6	Likely	28	27%
7	Very Likely	27	26%
	Total	105	100%

Mean	5.19
Variance	3.00
Standard Deviation	1.73
Total Responses	105

4. If you could purchase a home audio product that allows you to listen to Pandora (www.pandora.com) internet radio without a computer that does the following:-Connects to your wired (Ethernet) internet connection-Includes over 11,000 internet radio stations for free including news, sports, and talk radio from around the world (in addition to Pandora internet radio)-Has technology to improve the sound of your music-Connects to your home stereo via S/PDIF and Optical outputs (in addition to the standard RCA (red/white) and boombox Aux Input)How likely would you be to purchase this product?

1	Very Unlikely	1	1%
2	Unlikely	11	11%
3	Somewhat Unlikely	10	10%
4	Undecided	1	1%
5	Somewhat Likely	26	25%
6	Likely	30	29%
7	Very Likely	24	23%
	Total	103	100%

Mean	5.19
Variance	2.73
Standard Deviation	1.65
Total Responses	103

5. If you could purchase a home audio product that allows you to listen to Pandora (www.pandora.com) internet radio without a computer that does the following:-Sets up out of the box automatically when you plug it in-Connects wirelessly to your internet-Connects to your wired (Ethernet) internet connection -Has technology to improve the sound of your music. How likely would you be to purchase this product?

1	Very Unlikely	3	3%
2	Unlikely	9	9%
3	Somewhat Unlikely	8	8%
4	Undecided	10	10%
5	Somewhat Likely	25	24%
6	Likely	31	30%
7	Very Likely	18	17%
	Total	104	100%

Mean	5.02
Variance	2.66
Standard Deviation	1.63
Total Responses	104

6. If you could purchase a home audio product that allows you to listen to Pandora (www.pandora.com) internet radio without a computer that does the following:-Sets up out of the box automatically when you plug it in-Can be moved around the home or office freely-Has technology to improve the sound of your music-Connects to your home stereo via S/PDIF and Optical outputs (in addition to the standard RCA (red/white) and boombox Aux Input)How likely would you be to purchase this product?

1	Very Unlikely	2	2%
2	Unlikely	11	10%
3	Somewhat Unlikely	8	7%
4	Undecided	8	7%
5	Somewhat Likely	25	23%
6	Likely	32	30%
7	Very Likely	21	20%
	Total	107	100%

Mean	5.08
Variance	2.70
Standard Deviation	1.64
Total Responses	107

7. If you could purchase a home audio product that allows you to listen to Pandora (www.pandora.com) internet radio without a computer that does the following:- Connects wirelessly to your internet-Connects to your wired (Ethernet) internet connection-Can be moved around the home or office freely-Connects to your home stereo via S/PDIF and Optical outputs (in addition to the standard RCA (red/white) and boombox Aux Input)How likely would you be to purchase this product?

1	Very Unlikely	5	5%
2	Unlikely	12	11%
3	Somewhat Unlikely	11	10%
4	Undecided	4	4%
5	Somewhat Likely	27	25%
6	Likely	27	25%
7	Very Likely	23	21%
	Total	109	100%

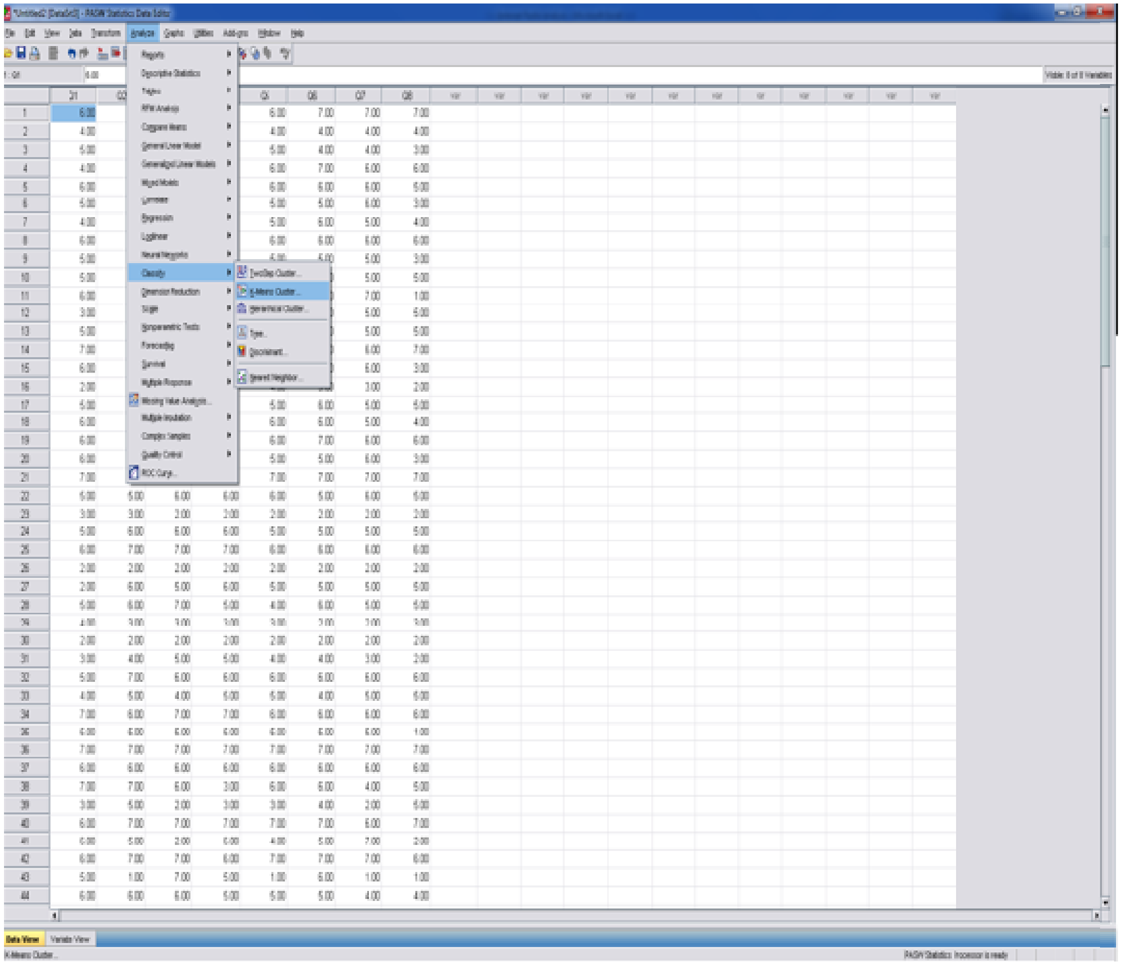
Mean	4.92
Variance	3.28
Standard Deviation	1.81
Total Responses	109

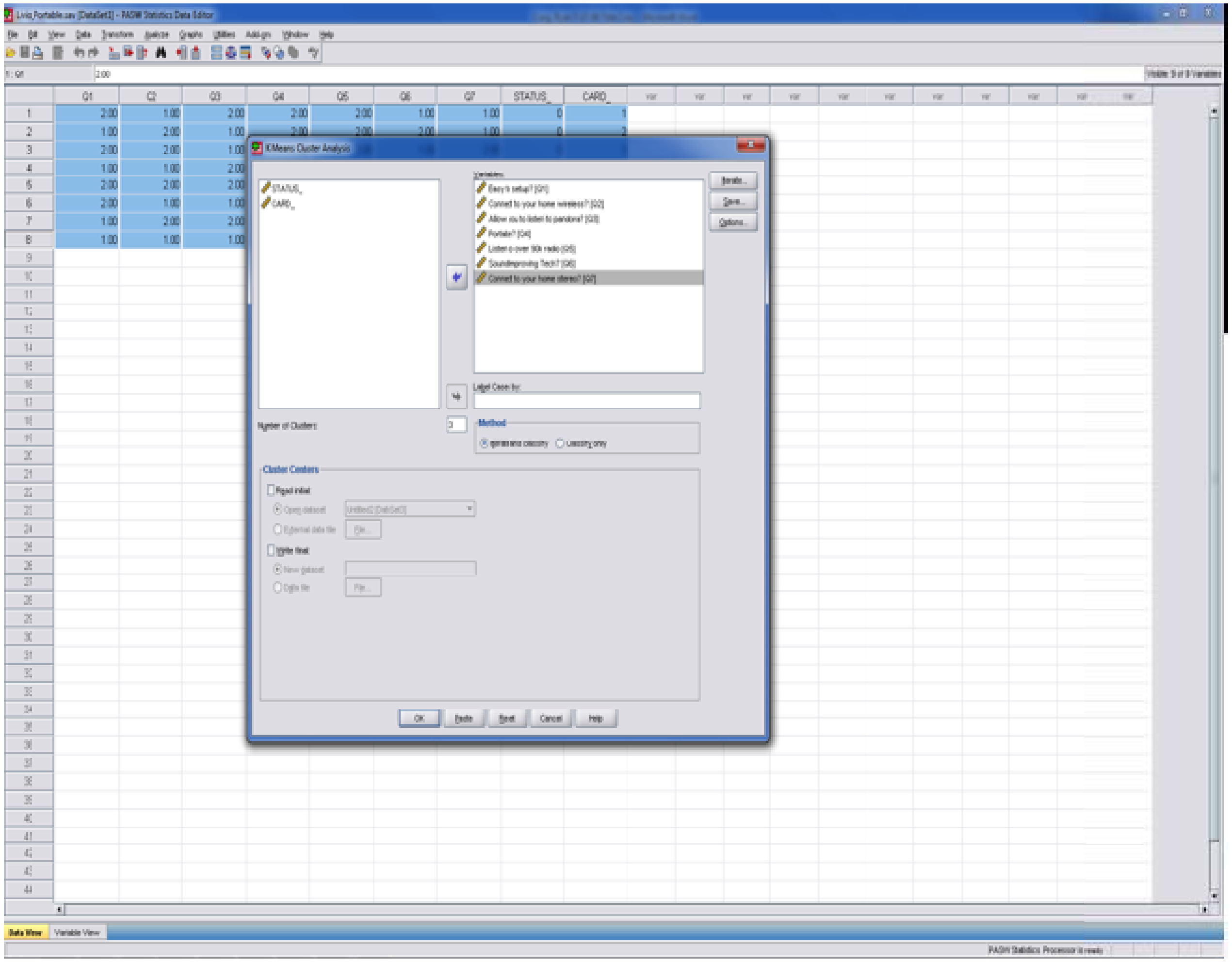
8. If you could purchase a home audio product that allows you to listen to Pandora (www.pandora.com) internet radio without a computer. How likely would you be to purchase this product?

1	Very Unlikely	10	8%
2	Unlikely	18	15%
3	Somewhat Unlikely	16	13%
4	Undecided	8	7%
5	Somewhat Likely	28	24%
6	Likely	26	22%
7	Very Likely	13	11%
	Total	119	100%

Mean	4.31
Variance	3.52
Standard Deviation	1.88
Total Responses	119

APPENDIX C: SIMPLE K-MEANS ANALYSIS USING SPSS




K-Means Cluster Analysis
Number of Clusters:
Method
Cluster Centers
OK
Cancel
Help
Data View
Variable View

APPENDIX D: SIMPLE K-MEANS SPSS OUTPUT

```
QUICK CLUSTER Q1 Q2 Q3 Q4 Q5 Q6 Q7
  /MISSING=LISTWISE
  /CRITERIA=CLUSTER(3) MXITER(10) CONVERGE(0)
  /METHOD=KMEANS(NOUPDATE)
  /PRINT INITIAL.
```

Quick Cluster

Notes

Output Created		21-Jul-2009 16:14:04
Comments		
Input	Data	C:\Users\Ryan\Desktop\Thesis\Livio_Portable.sav
	Active Dataset	DataSet1
	File Label	Orthoplan output
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	8
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any clustering variable used.
Syntax		QUICK CLUSTER Q1 Q2 Q3 Q4 Q5 Q6 Q7 /MISSING=LISTWISE /CRITERIA=CLUSTER(3) MXITER(10) CONVERGE(0) /METHOD=KMEANS(NOUPDATE) /PRINT INITIAL.
Resources	Processor Time	0:00:00.047
	Elapsed Time	0:00:00.086
	Workspace Required	1352 bytes

[DataSet1] C:\Users\Ryan\Desktop\Thesis\Livio_Portable.sav

Initial Cluster Centers

	Cluster		
	1	2	3
Easy to setup?	2.00	1.00	2.00
Connect to your home wireless?	1.00	2.00	2.00
Allow you to listen to pandora?	2.00	1.00	1.00
Portable?	2.00	2.00	1.00
Listen to over 90k radio	2.00	2.00	2.00
Sound Improving Tech?	1.00	2.00	1.00
Connect to your home stereo?	1.00	1.00	2.00

Iteration History[a]

	Change in Cluster Centers		
Iteration	1	2	3
1	1.291	.000	.000
2	.000	.000	.000

a. Convergence achieved due to no or small change in cluster centers. The maximum absolute coordinate change for any center is .000. The current iteration is 2. The minimum distance between initial centers is 2.000.

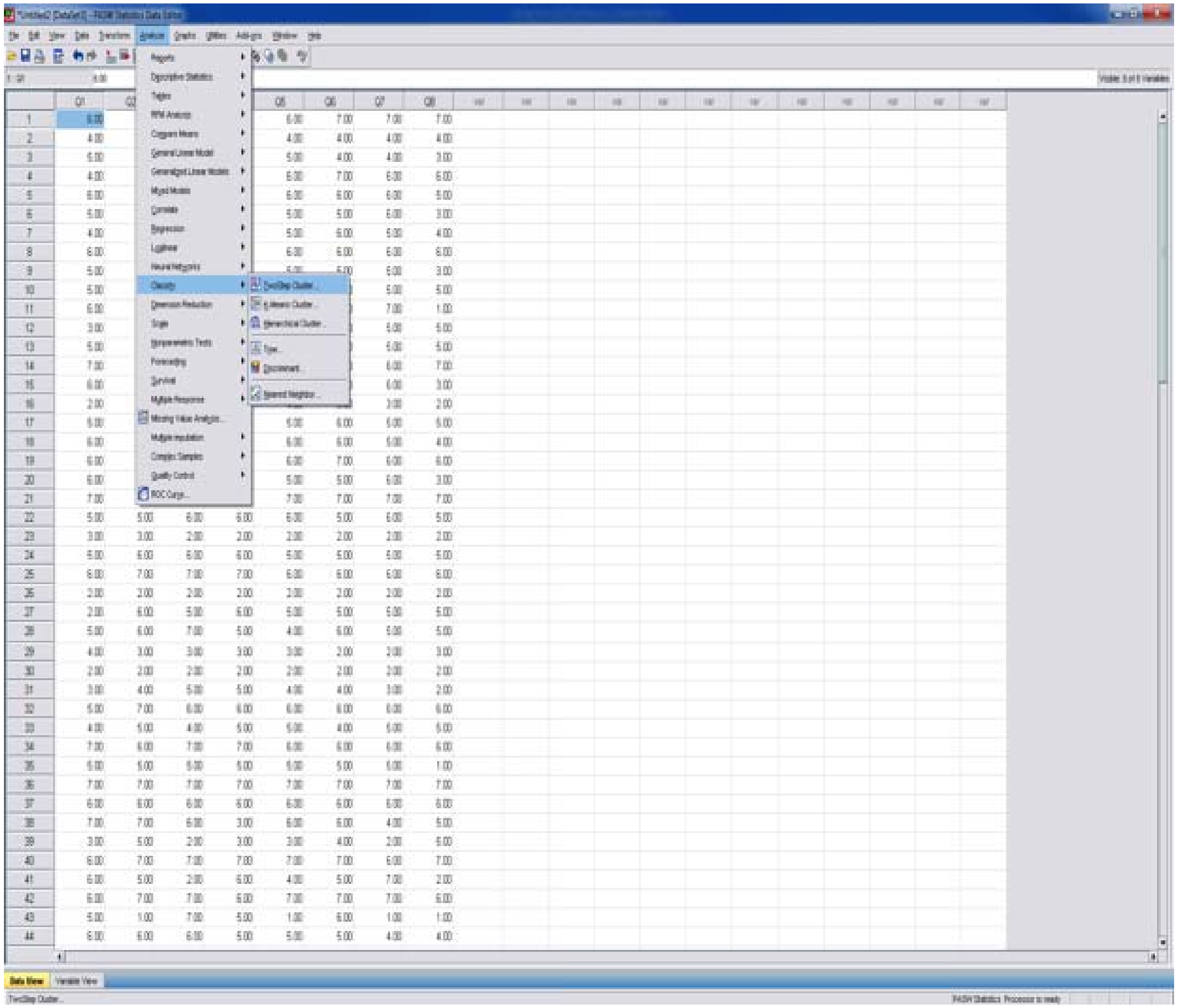
Final Cluster Centers

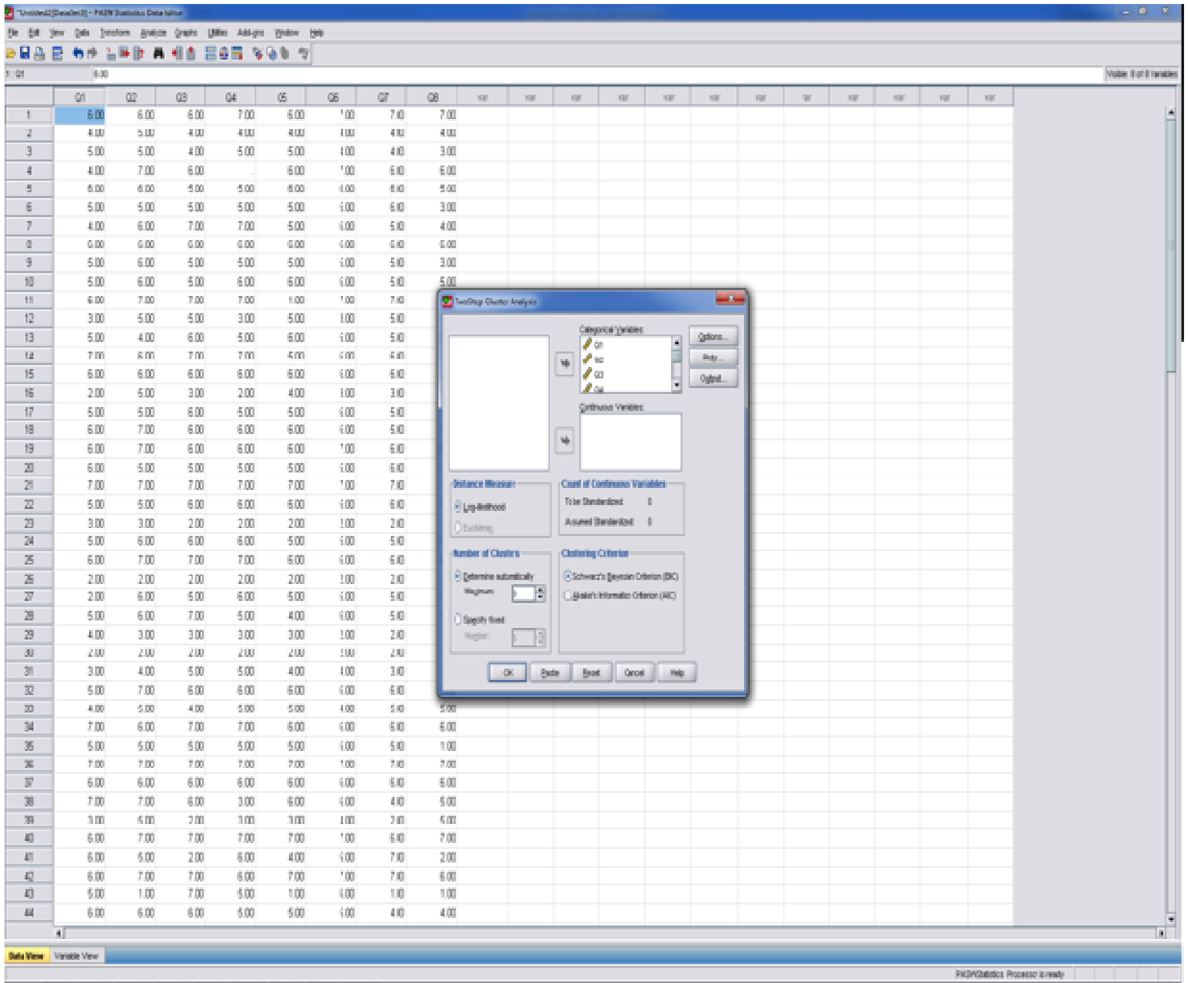
	Cluster		
	1	2	3
Easy to setup?	1.50	1.00	2.00
Connect to your home wireless?	1.33	2.00	2.00
Allow you to listen to pandora?	1.67	1.00	1.00
Portable?	1.50	2.00	1.00
Listen to over 90k radio	1.33	2.00	2.00
Sound Improving Tech?	1.50	2.00	1.00
Connect to your home stereo?	1.50	1.00	2.00

Number of Cases in each Cluster

Cluster	1	6.000
	2	1.000
	3	1.000
Valid		8.000
Missing		.000

APPENDIX E: TWO-STEP CLUSTER ANALYSIS USING SPSS




TwoStep Cluster Analysis
Categorical Variables:
Continuous Variables:
Options...
Distance Measure
Log-likelihood
Euclidean
Count of Continuous Variables
Number of Clusters
Determine automatically
Specify fixed
Clustering Criterion
Schwarz's Bayesian Criterion (BIC)
Akaike's Information Criterion (AIC)
OK
Paste
Reset
Cancel
Help
Data View
Variable View

APPENDIX F: TWO-STEP CLUSTER ANALYSIS SPSS OUTPUT

TwoStep Cluster

Notes

Output Created		21-Jul-2009 16:22:35
Comments		
Input	Active Dataset	DataSet3
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	100
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the analysis.
Syntax		TWOSTEP CLUSTER /CATEGORICAL VARIABLES=Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 /DISTANCE LIKELIHOOD /NUMCLUSTERS AUTO 3 BIC /HANDLENOISE 0 /MEMALLOCATE 64 /CRITERIA INITHRESHOLD(0) MXBRANCH(8) MXLEVEL(3) /PRINT COUNT SUMMARY.
Resources	Processor Time	0:00:00.031
	Elapsed Time	0:00:00.059

[DataSet3]

Cluster Distribution

		N	% of Combined	% of Total
Cluster	1	43	43.4%	43.0%
	2	56	56.6%	56.0%
	Combined	99	100.0%	99.0%
Excluded Cases		1		1.0%
Total		100		100.0%

Cluster Profiles

Frequencies

Q1

		1		2		3		4		5		6		7	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Cluster	1	0	0.00%	0	0.00%	0	0.00%	2	25.00%	6	25.00%	19	73.10%	16	100.00%
	2	2	100.00%	11	100.00%	12	100.00%	6	75.00%	18	75.00%	7	26.90%	0	0.00%
	Combined	2	100.00%	11	100.00%	12	100.00%	8	100.00%	24	100.00%	26	100.00%	16	100.00%

Q2

		1		2		3		4		5		6		7	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Cluster	1	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	3.80%	16	59.30%	26	100.00%
	2	2	100.00%	7	100.00%	9	100.00%	2	100.00%	25	96.20%	11	40.70%	0	0.00%
	Combined	2	100.00%	7	100.00%	9	100.00%	2	100.00%	26	100.00%	27	100.00%	26	100.00%

Q3

		1		2		3		4		5		6		7	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Cluster	1	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	7.70%	19	73.10%	22	91.70%
	2	2	100.00%	11	100.00%	6	100.00%	4	100.00%	24	92.30%	7	26.90%	2	8.30%
	Combined	2	100.00%	11	100.00%	6	100.00%	4	100.00%	26	100.00%	26	100.00%	24	100.00%

Q4

		1		2		3		4		5		6		7	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Cluster	1	0	0.00%	0	0.00%	2	20.00%	0	0.00%	1	4.20%	18	62.10%	22	100.00%
	2	1	100.00%	11	100.00%	8	80.00%	2	100.00%	23	95.80%	11	37.90%	0	0.00%
	Combined	1	100.00%	11	100.00%	10	100.00%	2	100.00%	24	100.00%	29	100.00%	22	100.00%

Q5

		1		2		3		4		5		6		7	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Cluster	1	1	33.30%	0	0.00%	0	0.00%	1	10.00%	4	16.00%	22	75.90%	15	100.00%
	2	2	66.70%	9	100.00%	8	100.00%	9	90.00%	21	84.00%	7	24.10%	0	0.00%
	Combined	3	100.00%	9	100.00%	8	100.00%	10	100.00%	25	100.00%	29	100.00%	15	100.00%

Q6

		1		2		3		4		5		6		7	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Cluster	1	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	13.00%	22	71.00%	18	100.00%
	2	1	100.00%	11	100.00%	8	100.00%	7	100.00%	20	87.00%	9	29.00%	0	0.00%
	Combined	1	100.00%	11	100.00%	8	100.00%	7	100.00%	23	100.00%	31	100.00%	18	100.00%

Q7

		1		2		3		4		5		6		7	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Cluster	1	0	0.00%	0	0.00%	0	0.00%	1	25.00%	3	11.10%	20	83.30%	19	95.00%
	2	3	100.00%	11	100.00%	10	100.00%	3	75.00%	24	88.90%	4	16.70%	1	5.00%
	Combined	3	100.00%	11	100.00%	10	100.00%	4	100.00%	27	100.00%	24	100.00%	20	100.00%

Q8

		1		2		3		4		5		6		7	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Cluster	1	1	12.50%	1	6.70%	2	13.30%	3	37.50%	7	30.40%	20	95.20%	9	100.00%
	2	7	87.50%	14	93.30%	13	86.70%	5	62.50%	16	69.60%	1	4.80%	0	0.00%
	Combined	8	100.00%	15	100.00%	15	100.00%	8	100.00%	23	100.00%	21	100.00%	9	100.00%

APPENDIX G: CONJOINT ANALYSIS USING SPSS- CODE

```
CONJOINT PLAN=*
/DATA='e:\Livio_Prefs.sav'
/SEQUENCE=PREF1 TO PREF8
/SUBJECT=ID
/PRINT=SUMMARYONLY.
```

APPENDIX H: CONJOINT ANALYSIS SPSS OUTPUT

```
CONJOINT PLAN=*
/DATA='Livio_Prefs.sav'
/SEQUENCE=PREF1 TO PREF8
/SUBJECT=ID
/PRINT=SUMMARYONLY.
```

Conjoint Analysis

Notes

Output Created		22-Jun-2009 17:13:35
Comments		
Input	Data	E:\Livio_Portable.sav
	Active Dataset	DataSet1
	File Label	Orthoplan output
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	8
	Plan File	working data file
	Data File	e:\Livio_Prefs.sav
Missing Value Handling	Definition of Missing	User-defined missing values in any preference data (ranks, scores, or profile numbers) are treated as missing..
	Cases Used	Statistics are based on all cases with all valid preference data (ranks, scores, or profile numbers).
Syntax		CONJOINT PLAN=* /DATA='e:\Livio_Prefs.sav' /SEQUENCE=PREF1 TO PREF8 /SUBJECT=ID /PRINT=SUMMARYONLY.
Resources	Processor Time	0:00:00.016
	Elapsed Time	0:00:00.066

```
[DataSet1] E:\Livio_Portable.sav
```

Warnings

There are not enough degrees of freedom to compute the standard errors.
No reversals occurred.

Model Description

	N of Levels	Relation to Ranks or Scores
Q1	2	Discrete
Q2	2	Discrete
Q3	2	Discrete
Q4	2	Discrete
Q5	2	Discrete
Q6	2	Discrete
Q7	2	Discrete

All factors are orthogonal.

Overall Statistics

Utilities

		Utility Estimate	Std. Error
Q1	Unimportant to me	.250	.
	Important to me	-.250	.
Q2	Unimportant to me	-1.000	.
	Important to me	1.000	.
Q3	Unimportant	1.000	.
	Important to me	-1.000	.
Q4	Not Important	.250	.
	A battery and speaker are important	-.250	.
Q5	Not important to me	-1.000	.
	Important to me	1.000	.
Q6	Not important to me	-1.250	.
	Important to me	1.250	.
Q7	Not Important to me	-.750	.
	Important to me	.750	.
(Constant)		4.500	.

Importance Values

Q1	4.545
Q2	18.182
Q3	18.182
Q4	4.545
Q5	18.182
Q6	22.727
Q7	13.636

Averaged Importance Score

Correlations[a]

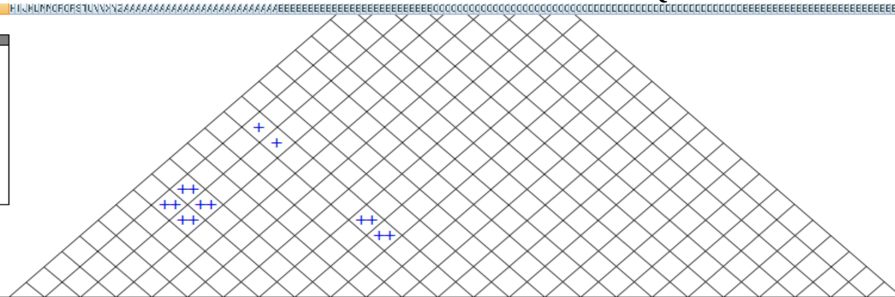
	Value	Sig.
Pearson's R	1.000	.
Kendall's tau	1.000	.000

a. Correlations between observed and estimated preferences

APPENDIX I: COMPLETED HOUSE OF QUALITY

A	B	C	D	E	F	G	HIJKLMNOPQRSTUVWXYZ…	FB	FC	FD	FE	FF	FG	FH	FI	FJ	FK	FL	FM	FN

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
—	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	X	X	X	X	X	X	X	X	X	X	X	▲	X	X										
				Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Screen Size	Has wifi chip	Has an RJ32 Jack	Remote Control	Works on 110/220V	RCA Cables Included	RCA to 1/8th Inch Included	Remote Firmware Upgrade	Remote Asistance	Alarm Clock	Ability to input alphanumeric characters	Quality of User Guide	Level of Technical Support	Headphone Jack	Digital Audio Output										
1	9	16.7	100.0	Sets up out of the box automatically	O	O	O	O	O	O	O	▲	Θ	O	O	▲	▲	O	O										
2	9	16.7	100.0	Can be moved around the home or office freely	Θ	Θ	Θ	O	O	O	O	O	O	O	O	O	O	O	O										
3	9	16.7	100.0	Has technology to improve the sound of your music	O	O	O	O	O	O	O	O	O	O	O	O	O	O	Θ										
4	9	16.7	100.0	Connects to your home stereo	O	O	O	O	O	Θ	Θ	O	O	O	O	O	O	O	Θ										
5	9	8.3	50.0	Connects to internet wirelessly	O	Θ	O	O	O	O	O	O	O	O	O	O	O	O	O										
6	3	8.3	50.0	Includes 11,000 internet radio stations for free	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O										
7	9	8.3	50.0	Connects to your home stereo via SPIF and Optical Output	O	O	O	O	O	O	O	O	O	O	O	O	O	O	Θ										
8	9	8.3	50.0	Connects to wired internet	O	O	Θ	O	O	O	O	O	O	O	O	O	O	O	O										
9																													
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				Target or Limit Value																									
				Difficulty (0-Easy to Accomplish, 10-Extremely Difficult)	8	0	0	0	0	0	0	2	3	1	2	1	0	0	7										
				Max Relationship Value in Column	9	9	9	3	3	9	9	3	9	3	3	3	3	3	9										
				Weight / Importance	400.0	450.0	450.0	300.0	300.0	400.0	400.0	266.7	400.0	300.0	300.0	266.7	266.7	300.0	550.0										
				Relative Weight	7.5	8.4	8.4	5.6	5.6	7.5	7.5	5.0	7.5	5.6	5.6	5.0	5.0	5.6	10.3										

Competitive Analysis (0-Worst, 5-Best)						
Our Company	Competitor 1	Competitor 2	Competitor 3	Competitor 4	Competitor 5	Our Company; Competitor 1; Competitor 2; Competitor 3; Competitor 4; Competitor 5 — 0 1 2 3 4 5

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