MultiCraft

International Journal of Engineering, Science and Technology
Vol. 2, No. 9, 2010, pp. 1-12

INTERNATIONAL JOURNAL OF ENGINEERING, SCIENCE AND TECHNOLOGY
www.ijest-ng.com

A proposed computer system on Kano model for new product development and innovation aspect: A case study is conducted by an attractive attribute of automobile

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Abstract

Voice of Customer is important for new product development. New product development is a complex task in which a great deal of human physical resources, methods, and tools are involved. One of the well- appreciated models is Kano model for customer needs study for product development. Customer requirements are an important component of new product development. The customer expectations to the technical requirements of products are also necessary for new product development. The success of a new product development process for a desired customer satisfaction is sensitive to the customer needs assessment process. In most cases, customer needs of a product or product family are incorporated by setting the customer requirements and their relative importance in the first house of quality of QFD. This procedure is practically informal and does not present an obvious link between customer satisfaction and product attribute. In this view, Kano Model is a superior choice. Kano model has two dimensional questionnaires regarding customer satisfaction, i.e. functional and dysfunctional. Both functional and dysfunctional answer is determined Kano evaluation (product attribute). A computer system has been developed using the Monte-Carlo Simulation technique to simulate functional and dysfunctional answers independently and subsequently the Kano evaluation. Using this system one can determine the minimal number of respondents make a reliable conclusion for a definite product attribute. A case study is conducted for system verification by an attractive attribute regarding Kano model about an automobile.

Keywords: Kano Model, Attributes of Product, New Product Development and Innovation, Monte-Carlo Simulation

1. Introduction

Customer needs are changing due to technology, and their age, income, profession, education. The assessment of customer needs is now continuous process. In the case of new product development and innovation is now considered the customer satisfaction, affordability, production rate, technical ability, value chain and competition for successfully launch and sustaining the product in the market, which are shown in Fig.1 (Browing, 2006 and 2003). New product development is a complex engineering task in which a great deal of human-physical resources, methods, and tools are involved for greater customer satisfaction (Fujita and Matsuo, 2006) which are shown in Fig.2. Product development team of QFD could consider the customer requirements (CR) as an arbitrary basis in the first house of quality of QFD (Kobayashi, 2006; Poel, 2007 and Hari et al., 2007). For removing this arbitrary value of CR, a fuzzy QFD approach could be used to find appropriate CR from customer feedback (Bottani and Rizzi, 2006). In this perspective, Kano model (Kano et al., 1984) is also a better tool for determination CR for new product development and innovation. Presently, Kano model has been applied for multiple new product design and innovation for compliance customer need with respect to customer satisfaction (Sireli et al., 2007, Chen and Chuang, 2008, Chen at al., 2010, Lee and Huang, 2009, Xu et al., 2009).

Section 2 describes the elements of Kano model for how to customer satisfaction, i.e. both functional and dysfunctional answer leads to a mapping Kano evaluation/customer needs regarding product attribute. The usual practice is to use questionnaires and obtain the opinion of customers. Yet, it is difficult to obtain answers of respondents on time. Ullah and Tamaki (2009, 2010) have shown how to simulate missing or unknown answer. Ullah and Tamaki's study has been used for finding limited frequency of unknown respondents. The present study is also directed Kano model based computer system for generic respondents.

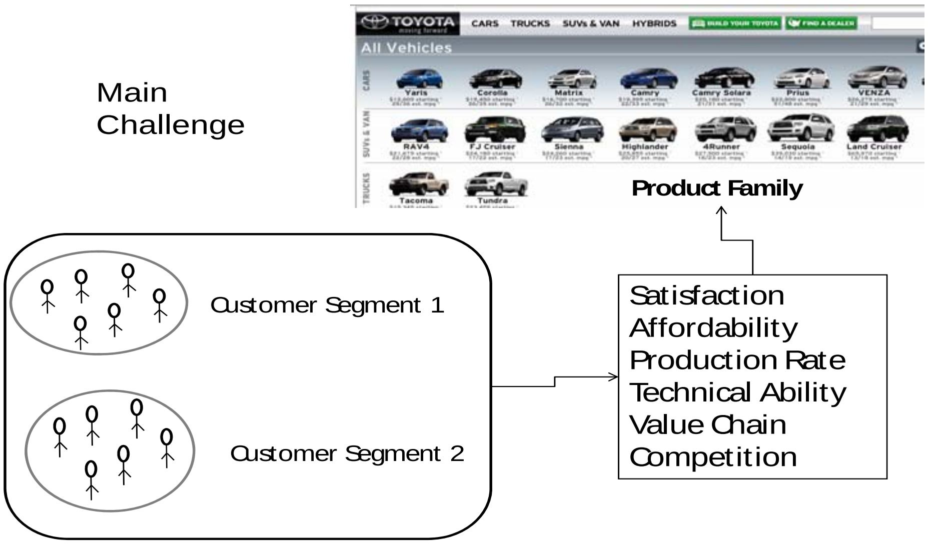

Figure 1. Main challenge of new product development and innovation

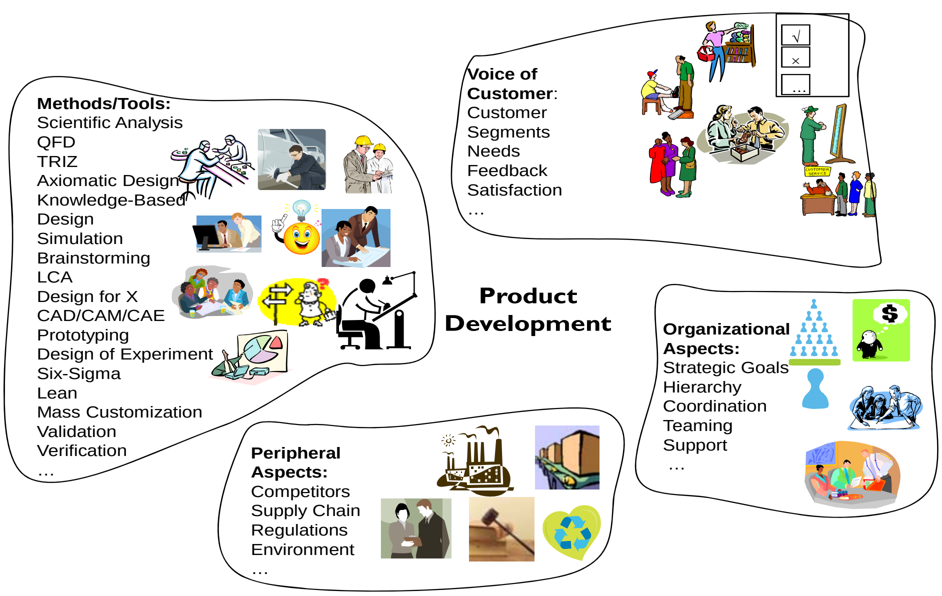

Figure 2. Elements of new product development (Ullah and Tamaki, 2010)

In this circumstance, we deal to customer needs assessment a generic computer system procedure shown in section 3 on Kano model aspect for new product development to know the needs of the customers for a given product (or a set of products). It is noted that recently the authors, the proposed computer system's verification and applications on Kano model aspect is presented (Rashid et al., 2010). Moreover, this raises a fundamental question that is how many customers should be asked to make a reliable conclusion for an attractive attribute. This question is answered as a case study discussion in section 4. It is also used for system verification. In this situation, a Kano model based computer system is shown a screen print in Appendix A and conclusion in section 5.

2. A Study the Frame of Kano Model

Kano model of customer satisfaction defines the relationship between product attribute regarding classifications of customer needs and customer satisfaction and provides five types of product attributes: 1) *Must-be (M)*, 2) *One-dimensional (O)*, 3) *Attractive (A)*, 4) *Indifferent (I)*, and 5) *Reverse (R)*, as schematically illustrated Fig.3. In Fig.3, the upward vertical axis represents satisfaction and downward vertical axis represents dissatisfaction. The leftward horizontal axis represents absence of performance that is called dysfunctional side. The rightward horizontal axis represents presence of performance that is called functional side.

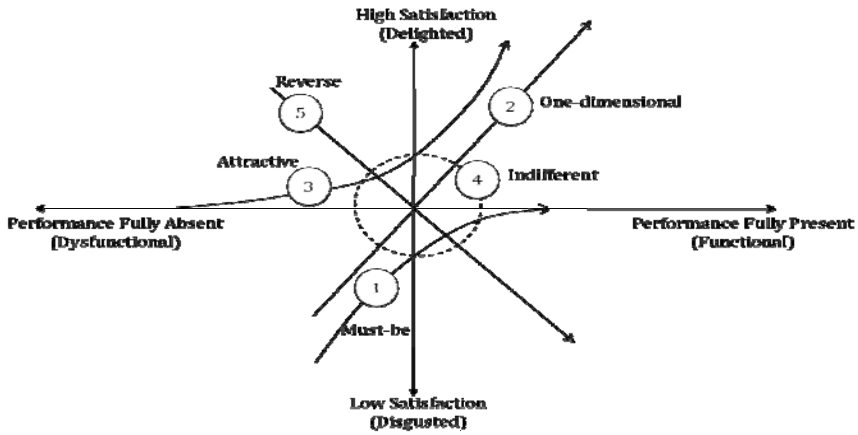

Figure 3. Relationship between products attribute regarding customer needs and customer satisfaction (Ullah and Tamaki,2010)

Table 1 describes the meaning of Must-be (M), One-dimensional (O), Attractive (A), Indifferent (I), and Reverse (R) attribute.

Table 1. Five categories of product attributes for customer satisfaction adapted from Ullah and Tamaki (2010)

Product attributes	Definition	Recommendations
Attractive	An Attractive attribute leads to a better satisfaction, whereas it is not expected to be in the product.	Include a good number of Attractive attributes
One-dimensional	A One-dimensional attribute fulfillment helps enhance the satisfaction and vice versa.	Include a good number of One-dimensional
Must-be	A Must-be attribute absence produces absolute dissatisfaction and its presence does not increase satisfaction	Continue Must-be attributes
Indifferent	An Indifferent attribute, that result neither in satisfaction nor dissatisfaction, whether fulfilled or not.	Avoid Indifferent attributes as many as possible
Reverse	A Reverse attribute presence causes dissatisfaction and its absence causes satisfaction.	Avoid Reverse attributes

The combination of *functional* and *dysfunctional* answers is then used to identify the status of the attribute in term of: 1) *Must-be*, 2) *One-dimensional*, 3) *Attractive*, 4) *Indifferent*, or 5) *Reverse*. All possible combinations of customer answers and the corresponding type of product attribute are summarized in following Table 2.

Table 2. Kano evaluation (**KE**) adapted from Berger et al. (1993)

Functional (**FA**) (↓) Dysfunctional (**DFA**) (→)	Like (L)	Must-be (M)	Neutral (N)	Live-with (Lw)	Dislike (D)
Like (L)	Q	A	A	A	O
Must-be (M)	R	I	I	I	M
Neutral (N)	R	I	I	I	M
Live-with (Lw)	R	I	I	I	M
Dislike (D)	R	R	R	R	Q
KE : A=Attractive, I=Indifferent, M=Must-be, O=One-dimensional, Q=Questionable, and R=Reverse					

As seen from Table 2, besides the above mentioned five types of attribute in Table 1, there is one more type of attribute called *Questionable*. This occurs when one selects Like or Dislike from both *functional* and *dysfunctional* sides (i.e., when an answer does not make any sense). As mentioned earlier, Kano model is accommodating for integrating the VOC into the succeeding processes of product development. Thus, for the meaningful integration of VOC into the succeeding processes of product development, it is important to follow of recommendation of Table 1. The straight forward relationship is shown in Table 3 among functional answer (FA), dysfunctional answer (DFA) and Kano evaluation (KE). This table is also exposes a frame among functional answer (FA), dysfunctional answer (DFA) and Kano evaluation (KE).

Table 3. Correlations among FA, DFA and KE

Sl	FA	DFA	Combination of FA and DFA	KE
1	Like	Like	Like Like	Questionable (Q)
2	Like	Must-be	Like Must-be	Attractive (A)
3	Like	Neutral	Like Neutral	Attractive (A)
4	Like	Live-with	Like Live-with	Attractive (A)
5	Like	Dislike	Like Dislike	One-dimensional (O)
6	Must-be	Like	Must-be Like	Reverse (R)
7	Must-be	Must-be	Must-be Must-be	Indifferent (I)
8	Must-be	Neutral	Must-be Neutral	Indifferent (I)
9	Must-be	Live-with	Must-be Live-with	Indifferent (I)
10	Must-be	Dislike	Must-be Dislike	Must-be (M)
11	Neutral	Like	Neutral Like	Reverse (R)
12	Neutral	Must-be	Neutral Must-be	Indifferent (I)
13	Neutral	Neutral	Neutral Neutral	Indifferent (I)
14	Neutral	Live-with	Neutral Live-with	Indifferent (I)
15	Neutral	Dislike	Neutral Dislike	Must-be (M)
16	Live-with	Like	Live-with Like	Reverse (R)
17	Live-with	Must-be	Live-with Must-be	Indifferent (I)
18	Live-with	Neutral	Live-with Neutral	Indifferent (I)
19	Live-with	Live-with	Live-with Live-with	Indifferent (I)
20	Live-with	Dislike	Live-with Dislike	Must-be (M)
21	Dislike	Like	Dislike Like	Reverse (R)
22	Dislike	Must-be	Dislike Must-be	Reverse (R)
23	Dislike	Neutral	Dislike Neutral	Reverse (R)
24	Dislike	Live-with	Dislike Live-with	Reverse (R)
25	Dislike	Dislike	Dislike Dislike	Questionable (Q)

3. A Proposed Computer System

For the design of computer system, a generic method of simulation using the concept of Monte Carlo is discussed in subsection 3.1. A proposed computer system for consumer needs analysis regarding kano model by simulate functional and dysfunctional answer independently and then calculate the probability of kano evaluation is discussed in subsection 3.2. While a proposed computer system for consumer needs analysis regarding Kano model by simulates the functional and dysfunctional answers for a given Kano evaluation is discussed in subsection 3.3.

3.1 A generic Method of Simulation using the concept of Monte Carlo

The simulation of customer answer needs a method. This method is formulated in the following way by using Monte Carlo simulation principle. For this reason, an event is a set of outcomes to which a probability is assigned. An event vector $\mathbf{E} = (E_{1\ldots} E_n)$, whose components are scalar-valued random variables on the same probability space (Ω, F, P). Every such random event vector gives rise to a probability measure. An event vector with non-negative entries is that which adds up to one. The event vector components must sum to one $\sum_{i=1}^{n} P_i = 1$. The requirement of each individual component must have a probability between zero and one; $0 \leq P_i < 1$; for all i. The probability of an event is a non-negative real number: $0 \leq P(E) \leq 1$; $\forall E \in F$; Where, probability P of some event E is denoted P(E), F is the event space and E is any event in F. Any countable sequence of pair wise disjoint events $E_1, E_2, \ldots, E_n$ satisfies $P(E_1 \cup E_2 \cup, \ldots, E_n) = \sum_{i=1}^{n} P(E_i)$. This simulation process is also considered discrete-event simulation. The operation of a system of discrete event simulation is represented as a chronological sequence of events. Each event occurs at an instant in time and marks a change of state in the system. In discrete-event simulations, events are generated instantaneously. This simulation is also followed at least one list of simulation events. The simulation process has been needed random number in the interval [0, 1]. It is normally generated by using RAND () formula. Theoretically a discrete–event simulation could run forever. Thus, this simulation is done after processing 'n' number of events. The theoretical explain of present simulation process is constituted among start, do loop and end phase. Start Phase is initialized ending condition to FALSE, system state variables, clock (usually starts at simulation time zero and schedule an initial event (i.e. put some initial event in to the Events list). When ending condition is FALSE then do loop or while loop phase is acted to set clock to next event time, to do next event and remove from the event list and to update statistics. End Phase is generated the statistical report. The simulation process is following:

Inputs:
V $= (E_1,\ldots, En)$ //Event Vector
P $= (Pr\ (E_1),\ldots, Pr\ (E_n))$ //Event Probability Vector
N //Number of Trials
Calculate:
$CPr\ (E_i) = Pr\ (E_1) + \ldots + Pr\ (E_i),\ i=1,\ldots, n$ //Cumulative Probability of Events
For $j=1,\ldots, N$
Do $r_j \in [0, 1]$ //r_j is a random number in the interval [0, 1]
If $r_j \leq CPr\ (E_1)$ *Then* $S_j = E_1$
Otherwise
For $i=2,\ldots, n$
If $CPr\ (E_{i-1}) < r_j \leq CPr\ (E_i)$ *Then* $S_j = E_i$ (1)

This formulation also guarantees that the summation of all C*Pr (Si)* is equal to 1 (i.e., the axiom of Normality as required by the concept of classical probability). Therefore, simulating *Si*, the probability of *Si* should be maintained around C*Pr (Si)*.However, for the sake of simulation, first the cumulative probability should be considered, as follows:

CPr =Pr (S1)+,...,+Pr(Si), where , i=1,…,n

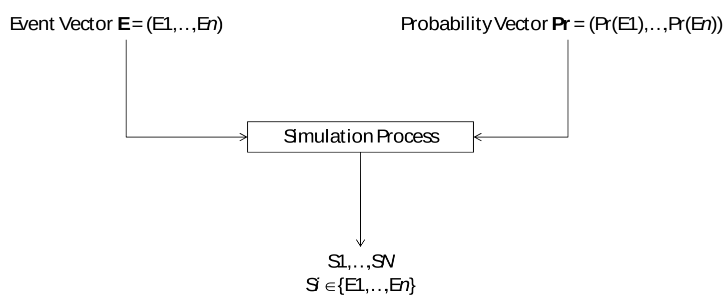

Figure 4. A generic method of simulation

It is important that the cumulative probability of the last event *Sn* is 1, *i.e.* C*Pr (Sn) =1*. The cumulative probability, C*Pr (Si)* can be applied along with a random number r_j in the scale [0, 1] to simulate the states *Ss* $\in\{S1,\ldots, Sn\}$.r_j is between the cumulative probabilities of the two consecutive event *Sj* and *Si, (j=i-1),* then *Ss = Si*.

3.2 A proposed computer system for consumer needs analysis regarding Kano Model by simulate functional and dysfunctional answer independently and then calculate the probability of Kano Evaluation.

Figure 5 shows a customer need analysis model for the proposed simulation process. Six steps are involved in this process, as described below:

Step 1: Choices of FA and DFA of unknown customer,
FA, or DFA $\in$ *{Like (L), Must-be (M), Neutral (N), Live-with (LW), Dislike (D)}*
Step 2: Generate a set of random inputs
Step 3. Simulation of dysfunctional answer of customer independently
Step 4. Simulation of functional answer of customer independently
Step 5. Simulation of customer evaluation by using combination of FA and DFA
Step 6. Analysis for consistency of developed model.

A unique probability distribution may be hard to identify, when information is scarce, vague, or conflicting (Coolen et. al., 2010) for product design information. In that case probability represents the real knowledge, and provides tools to modeling and work weaker states of information. As a result, the unknown customers' FA and DFA is generally uncertain, *i.e.,* scarce, vague etc. It is facilitated to consider equal probability of choices. This formulation also guarantees that the summation of all choices probabilities is equal to 1 (*i.e.,* the axiom of Normality as required by the concept of classical probability). In this simulation process probability has been applied. (Walley, 1991; Cooman and Hermans, 2008). Generic individuals are considered and it is expected that these individuals opinion are enough Choices *FA, or DFA* $\in$ *{L, M, N, Lw, D}* is considered uniform cumulative vector probability of individuals. According to step 2, a set of random inputs has been generated by using the formula=RAND () in a cell of Microsoft office Excel.

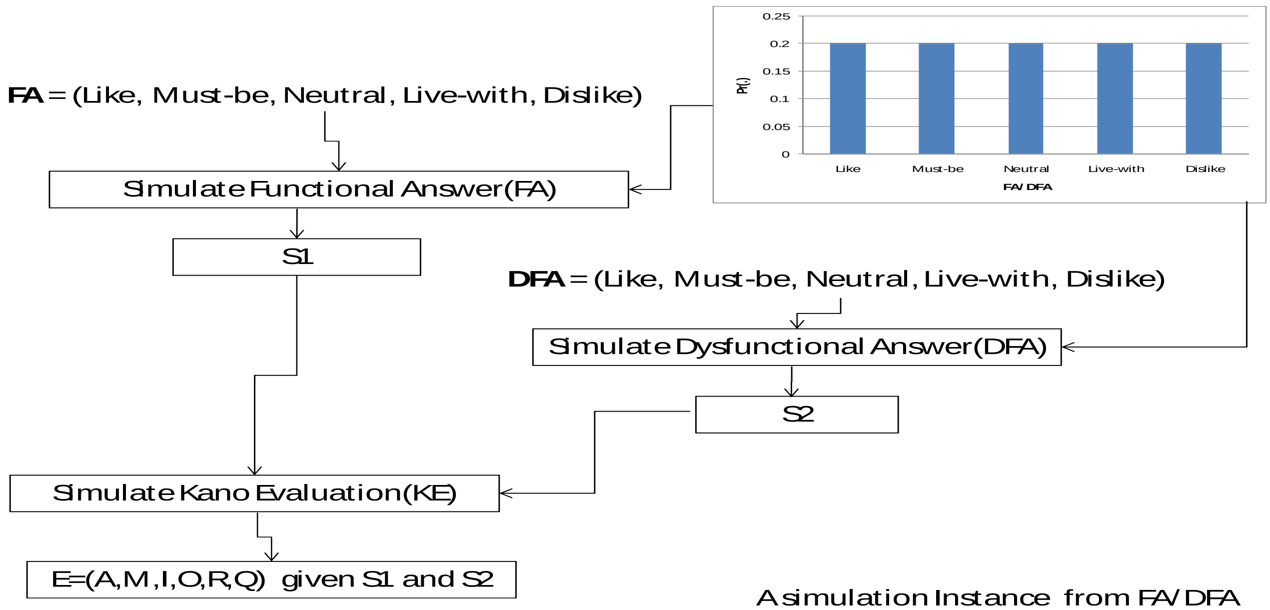

Figure 5. Analysis of scenario

In Table 3, shows the rules of combination of functional and dysfunctional answer for customer Evaluation from Kano model. This rule was applied for simulated the unknown customer answer, where combination of answers for functional and dysfunctional parts of Kano questionnaire for choosing evaluation *KE* $\in$ *{A, O, M, I, R, Q}*. Therefore, a system is developed to implement the simulation in accordance with Eq.1, (i e., in accordance with steps 1-6).

3.3 *A proposed computer system for consumer needs analysis regarding Kano Model by simulates the functional and dysfunctional answers for a given Kano evaluation.*

Figure 6 shows illustrate the proposed simulation process for consumer needs analysis regarding Kano Model by simulates the functional and dysfunctional answers for a given Kano evaluation (KE) (Must-be, Attractive, One-dimensional, Indifferent, or Reverse and Questionable). Six steps are also involved in this process, as described below:

Step 1: Choices of Kano evaluations of customer, KE $\in$ {A, I, M, O, Q, R,} is considered uniform probability.

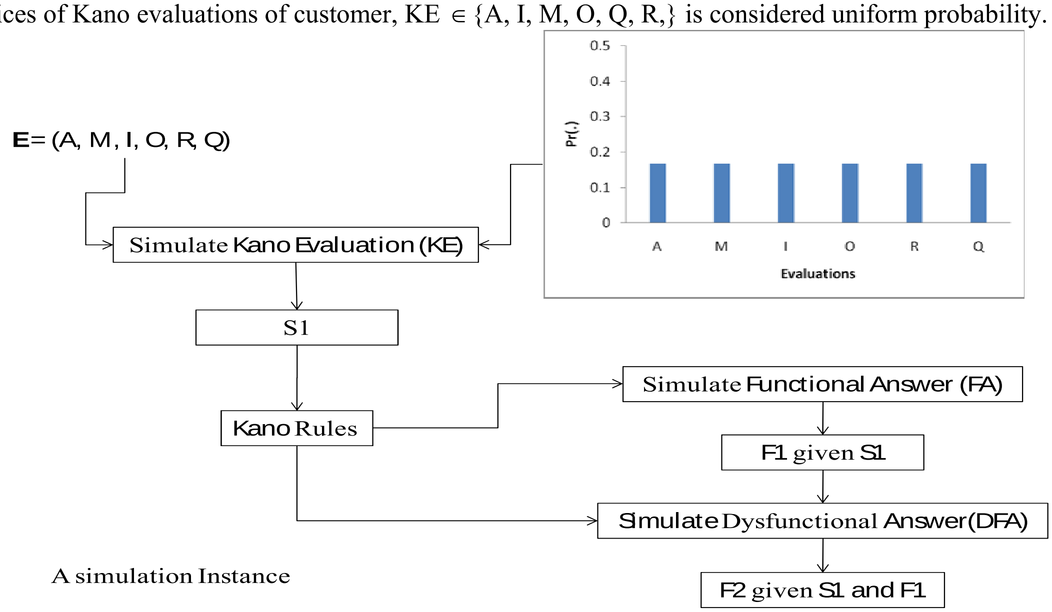

Figure 6. Proposed Simulation Process

Step 2: Generate a set of random inputs
Step 3. Simulate the Kano evaluation
Step 4. Simulation of functional answer (FA) from simulated KE by using Kano Rules
Step 5. Simulation of dysfunctional answer (DFA) from KE by using Kano Rules
Step 6. Analysis for consistency of developed model.

4. A Case Study for Model Verifications and Discussions

A case is considered in Fig. 7 for model verification and application of the system. According to Fig.7, there is a questionnaire regarding a product (automobile) attribute (radio antenna automatically retracts when the radio is turned off). It is well-known that radio antenna of an automobile is "Attractive" attribute. Therefore, the ideal answer of a respondent would be "Like" from functional side (i.e., the automobile should have radio antenna automatically retracts) and "Neutral" from dysfunctional side (i.e., if the radio antenna does not automatically retract when the radio is turned off, I am neutral in this regard). This combination of answer (Like, Neutral) yields an "Attractive" attribute according to Kano Evaluation (see Table 2). In reality, respondents exhibit a rather fuzzy behavior and sometimes answer different than the ideal one. For example, see the frequency of the answers of 23 (Berger et al., 1993) respondents shown in Fig.7. As a result, some respondents answer makes the attribute "Attractive" some others make it "Indifferent" and so on. This raises a fundamental question that is how many respondents should be requested to know for certain that the specified attribute is an Attractive attribute or not.

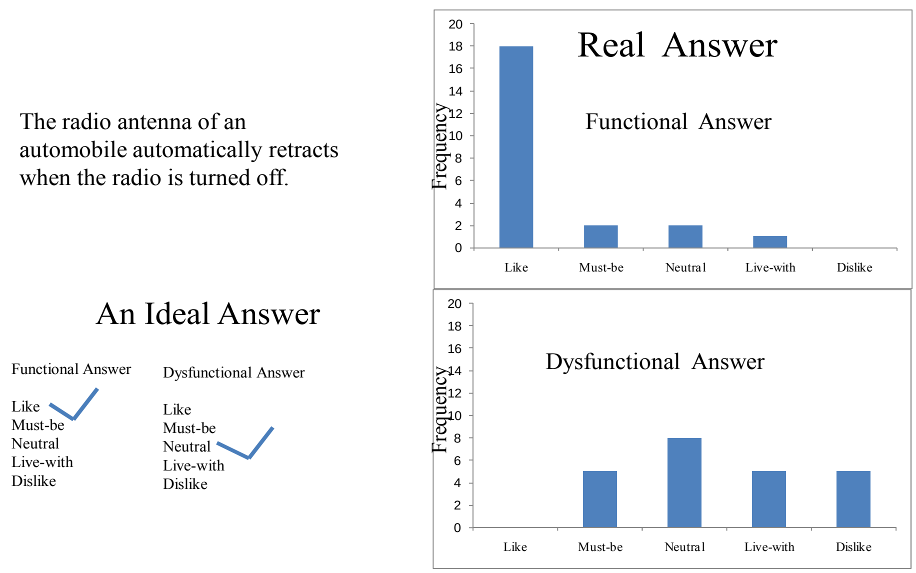

Figure 7. Ambiguity in respondents answer

This question can be answered using the system shown in the previous section. To use the system shown in the previous sub section in 3.2, the first step is to input the probability vectors of functional answers and dysfunctional answers. To determine the probability vectors of functional/ dysfunctional answers the following procedure can be used.

As it is seen from the case shown in Fig.8, from functional side, the respondents are "most-likely" to choose "Like", "less-likely" to choose "Must-be, Neutral, Live-with and Dislike". On the other hand, from the dysfunctional side, the respondents are "quite-likely" to choose Neutral , "some-likely" to choose "Must-be, Live-with and Dislike" and less likely "Like".

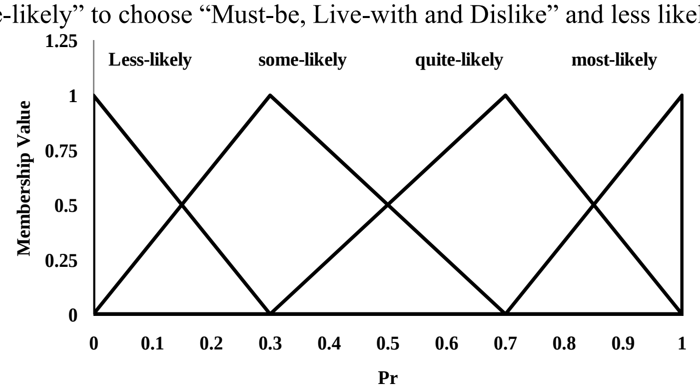

Figure 8. Defining linguistic likelihoods by fuzzy numbers (Ullah and Tamaki, 2010)

These linguistic likelihoods ("most-likely", "some-likely", "less-likely", and so on) can be transformed into numerical probability using fuzzy logic. Ullah and Tamaki, 2010 have afforded a fuzzy logic method, which is used here. Figure 8 illustrates the fuzzy numbers defining the linguistic likelihoods "most-likely", "quite-likely", "some-likely", and "less-likely."

From the linguistic likelihoods shown in Fig.8, the average value and lower and upper limits of are determined using centroid method (Ullah and Harib, 2006) and α-cuts at α=0.5, respectively. The results are shown in Table 4.

Table 4. Numerical probability of linguistic likelihoods

Linguistic likelihoods	Pr		
	Lower limit	Upper limit	Average
most-likely	0.85	1	0.9
quite-likely	0.5	0.85	2/3
some-likely	0.15	0.5	1/3
less-likely	0	0.15	0.1

Table 5 shows the probabilities of functional answers for average and worst-case scenarios. For average scenario the average probabilities of linguistic likelihoods (shown in Table 4) are used. These probabilities are normalized to calculate crisp probabilities shown in 4-th column in Table 5. For worst-case scenario, the lower limit of most-likely is used and upper limits of quite –likely, some-likely and less-likely are used. These limits are normalized to calculate the crisp probabilities for worst-case scenarios, as shown in last column in Table 5.

Table 5. Probabilities of functional answers for average and worst-case scenarios.

		average scenario		worst-case scenario	
Functional Answers	Linguistic likelihoods	average Pr	Crisp Pr	upper/lower limits of Pr	Crisp Pr
Like	Most-likely	0.9	0.69230769	0.85	0.5862069
Must-be	some-likely	0.1	0.07692308	0.15	0.10344828
Neutral	some-likely	0.1	0.07692308	0.15	0.10344828
Live-with	Less-likely	0.1	0.07692308	0.15	0.10344828
Dislike	Less-likely	0.1	0.07692308	0.15	0.10344828

Similarly the probabilities of dysfunctional answers for average and worst-case scenarios are determined and listed in Table 6.

Table 6. Probabilities of dysfunctional answers for average and worst-case scenarios.

		average scenario		worst-case scenario	
Dysfunctional Answers	Linguistic likelihoods	average Pr	Crisp Pr	upper/lower limits of Pr	Crisp Pr
Like	less-likely	0.1	0.05665722	0.15	0.06
Must-be	some-likely	0.333	0.18866856	0.5	0.2
Neutral	quite-likely	0.666	0.37733711	0.85	0.34
Live-with	some-likely	0.333	0.18866856	0.5	0.2
Dislike	some-likely	0.333	0.18866856	0.5	0.2

The results shown in Tables 5-6 provides two sets probabilities of functional/dysfunctional answers. These probabilities are illustrated in Fig. 9. Using these probabilities a study has been carried out to determine the minimum number of respondents to conclude whether or not an attribute is Attractive. Figure 10 shows results for average scenario. As observed from Fig. 10, for 25 respondents there is overlap among the probabilities of Attractive and Indifferent. This means that using the results of 25 respondents it is not reliable to conclude that the attribute is a Reverse attribute. For the case of 50 respondents, there is no overlap between the probabilities of Attractive and Indifferent, this trend remains more or less the same for more respondents (e.g., compares the results of 50 respondents,100 respondents and 200 respondents shown in Fig.10).

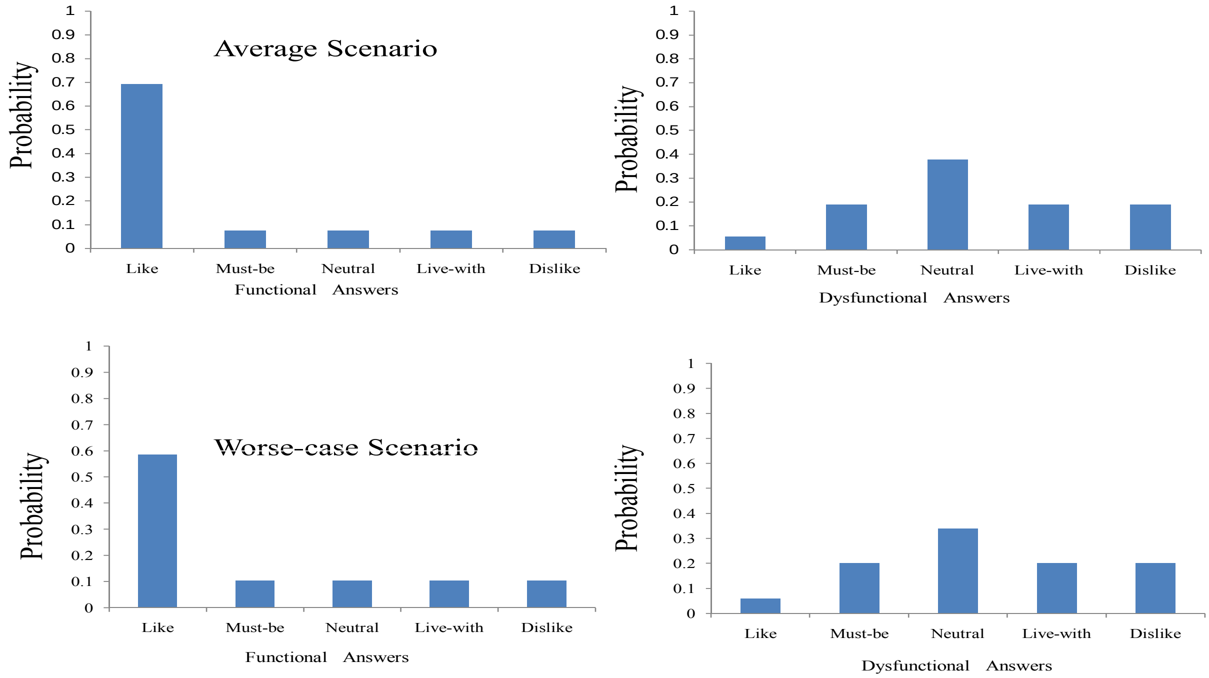

Figure 9. Probabilities of functional/dysfunctional answers for two scenarios

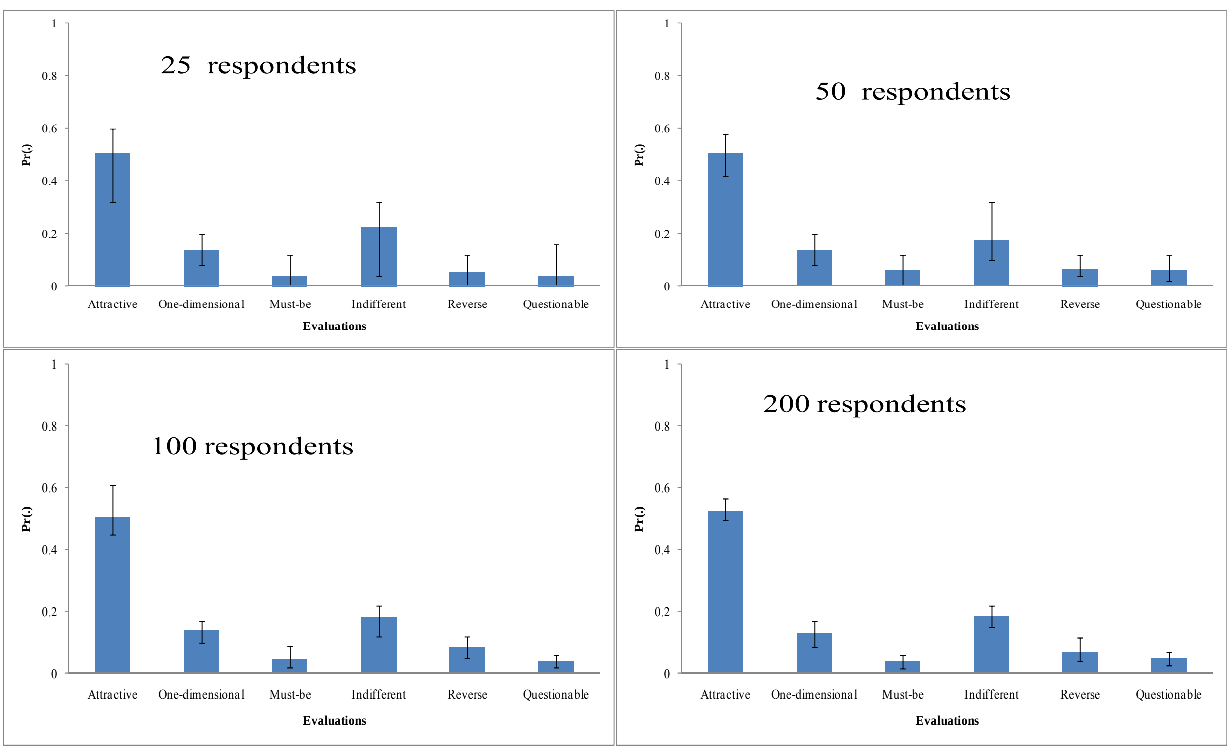

Figure 10. Number of respondents versus Kano Evaluation for average scenario

Therefore, at least answer from 50 respondents should be collected to determine that an attribute is an Attractive attribute. What if the other set of probabilities (probabilities for worst-case scenario) is used? Figure 11 shows the results for the case. In that case 25 respondents it is not reliable to conclude that the attribute is an Attractive attribute. For the case of 50 respondents, there is no an overlap between the probabilities of Attractive and Indifferent, this trend remains more or less the same for more respondents (e.g., compares the results of 50 respondents,100 respondents and 200 respondents shown in Fig.11).

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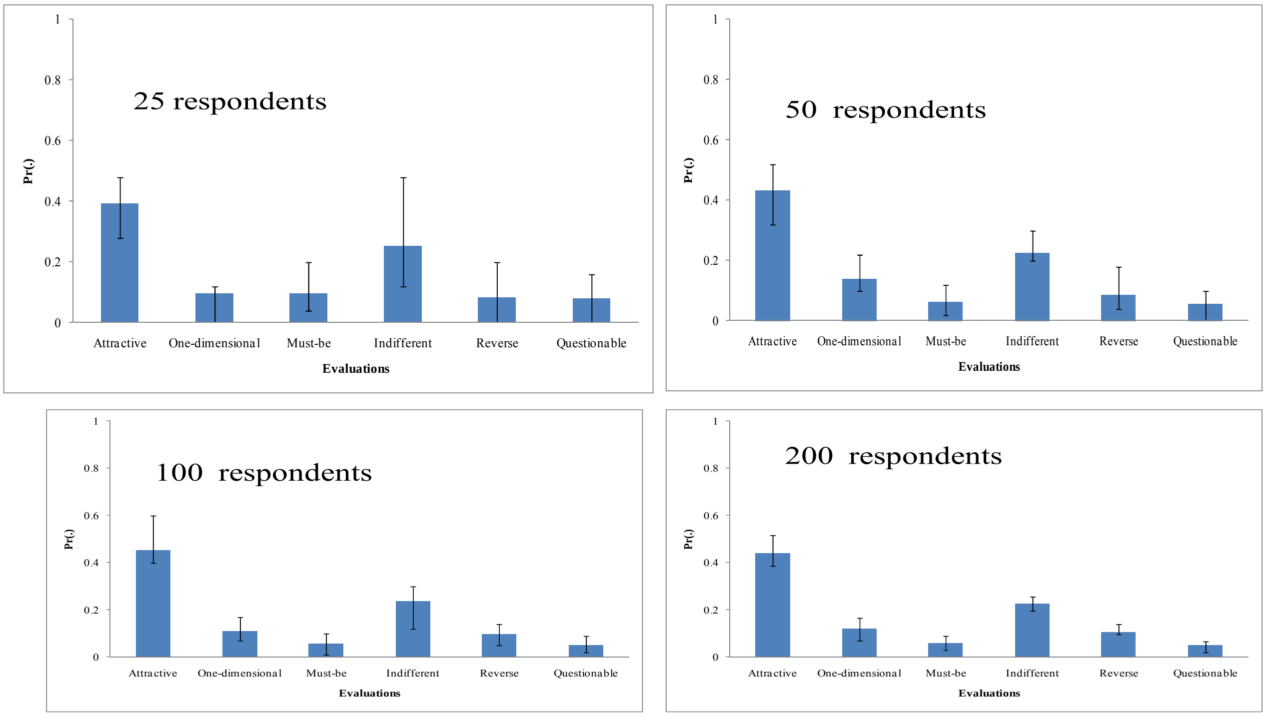


Figure 11. Number of respondents Versus Kano Evaluations for worst case scenario

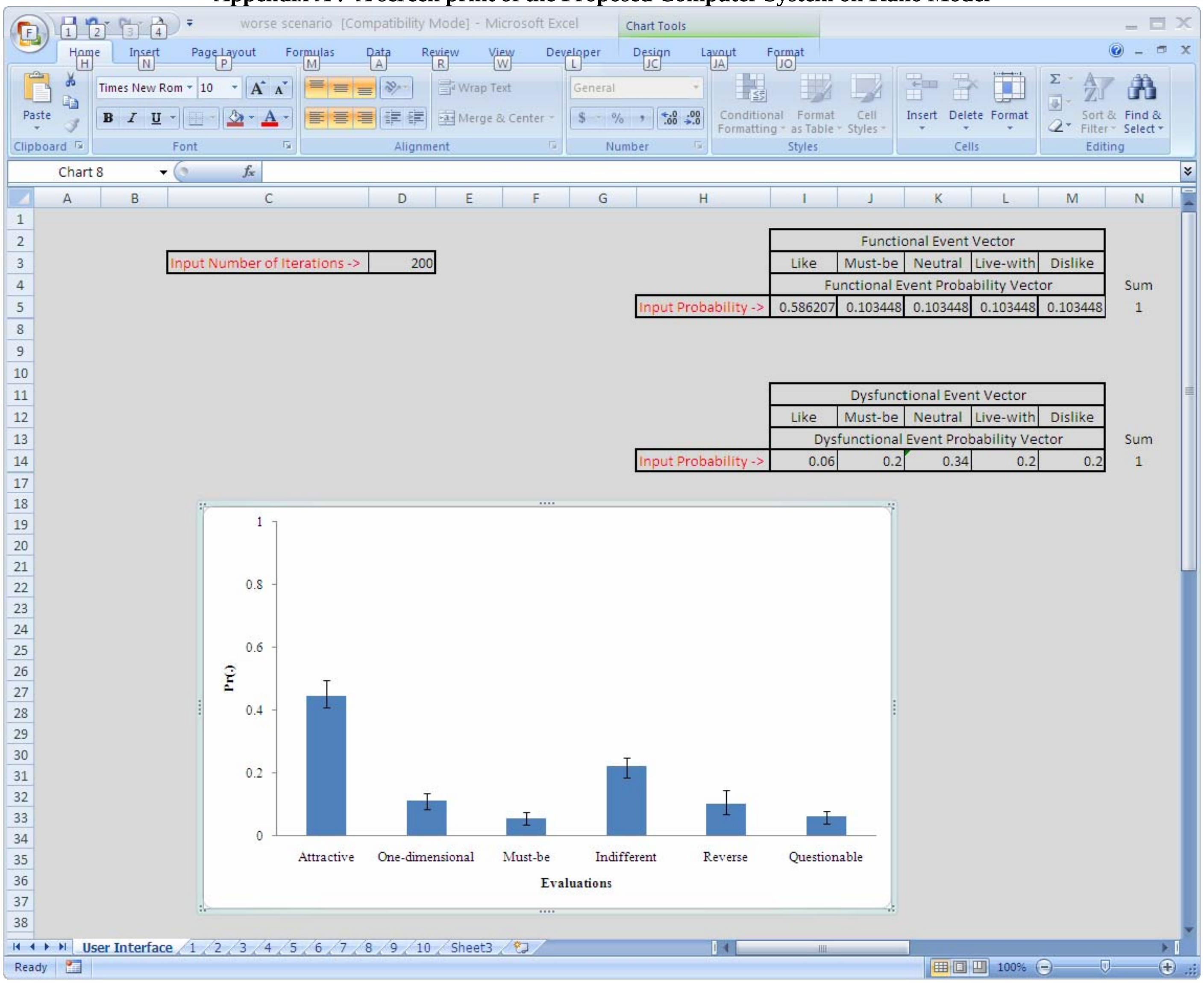
According to the above results it can be completed that if the answers of at least 50 respondents should be considered an Attractive attribute. This working standard can be used as a guideline while distinctive an Attractive attribute from others in all kinds of products. A proposed computer system on Kano model aspect can support a product development team by providing an answer to the question: minimal how many respondents should be asked to determine whether or not an attribute is Must-be, One-dimensional or Indifferent in accordance with Kano Model. Exactly it is found that at least 50 respondents should be requested to verify whether or not an attribute is an Attractive attribute.

Monte Carlo simulation applies random number and simulates states of a variable using a predefined probability mass or density function. In for more details are illustrated in chapter 20 for how to generate and use random number and error occurs because of the limitation of computer–generated random number for Monte-Carlo simulation. This error will be reduces exponentially with the increase in number of iterations N (Hiller and Lieberman, 2005). In this case study, when increased numbers of iterations (number of respondents) then the errors are decreased in Figs. 10 and 11. Therefore, this case study is shown for both verification and application of the system.

5. Conclusions

A computer system can be developed to simulate functional (FA) and dysfunctional answers (DFA) independently and then calculate the probability of Kano evaluation (KE). A system can also be developed to simulate the functional and dysfunctional answers for a given Kano evaluation (KE). This system can comply regarding Kano Model based for product attribute regarding customer needs with customer satisfaction.

Appendix A : A screen print of the Proposed Computer System on Kano Model



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Received August 2010
Accepted October 2010
Final acceptance in revised form October 2010