American Journal of Industrial and Business Management, 2020, 10, 1073-1083
https://www.scirp.org/journal/ajibm
ISSN Online: 2164-5175
ISSN Print: 2164-5167

Joining Methods of Analytic Hierarchy Process (AHP), Kano Model and Quality Function Deployment (QFD) to Improve the Tractor's Seat Design for Tractor Drivers in Bangladesh

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How to cite this paper: Hridoy, R. M., Parvez, Md. S., & Mohsin, N. (2020). Joining Methods of Analytic Hierarchy Process (AHP), Kano Model and Quality Function Deployment (QFD) to Improve the Tractor's Seat Design for Tractor Drivers in Bangladesh. *American Journal of Industrial and Business Management, 10,* 1073-1083.
https://doi.org/10.4236/ajibm.2020.105071

Received: April 14, 2020
Accepted: May 26, 2020
Published: May 29, 2020

Abstract

Nowadays, many product development projects fail as for not meeting customer's expectations up to the mark as product development process is conducted very unsystematically and results in waste of resources. Customer requirement and satisfaction measurement is a major challenge which can be achieved through various methods. This paper presents joining methods of Analytic Hierarchy Process (AHP), Kano Model and Quality Function Deployment to improve the Tractor's Seat design for tractor driver's in Bangladesh in terms of ergonomic and user's needs. A survey was done to 50 Tractor drivers to identify problems of the current seat. By analyzing the data identified the customer requirements and ranked it using AHP. With that Kano questionnaires were developed and answered by 50 tractor drivers. After that, with the integration of Kano model, QFD process was carried out to determine the customer requirement weight and the technical requirement weight to develop a modified design. At the end of the study, it was found out that both methods were able to prioritize the modification elements to be implemented into the new ergonomically designed tractor seat. Still there are some limitations. The analysis was performed based on 50 tractor drivers. For more correct results, more than 50 drivers could be taken into account.

Keywords

Expectations, Unsystematically, Tractor, AHP, Kano, House of Quality

1. Introduction

In the past, many researches were occurred about Kano Model and QFD integration approach for Ergonomic Design Improvement. This present study provides the data of tractor driver requirements and discusses about the AHP ranking procedure of those requirements and Kano Model and QFD integration approach for Ergonomic Design Improvement. A research work discussed the procedure of Kano questionnaire development and Kano questionnaire result using different formulas for calculating customer satisfaction and dissatisfaction to grade the customer requirements and also focused on the house of quality and Kano integration for ergonomic design improvement (Adila & Siti, 2012). Another study found out about customer satisfaction as a function of competitive advantage by discussing customer satisfaction and market share and customer satisfaction and loyalty. Authors discussed the Kano's model of customer satisfaction. By discussing identification of product requirements, analysing customer problems instead of customer desires, construction of the Kano questionnaire, administering customer interviews, evaluation and interpretation, evaluation according to frequencies, customer satisfaction coefficient and quality improvement index they showed the customer satisfaction and dissatisfaction. Further they discussed about the quality function deployment to develop projects more successfully (Kurt & Hans, 1998).

Another analysis focused on the notion of customer satisfaction based on the Kano model and points to the importance of product innovation in exceeding customer satisfaction. It further proposed a combined process model for innovative product development by integrating Kano's model and the quality function deployment (QFD) technique (Shen, Tan, & Xie, 2000). Again a study points out a method for integration of the Kano model in Quality Function Deployment with 289 potential consumers of draft beer mugs. In this study the integration of the Kano model in the QFD allowed innovative requirements to receive the necessary attention in the product's development process. It also showed the development of a new mug of draft beer (Tontini, 2007).

Additional research work combined rough set theory, Kano model and AHP for determining the final importance of the customer requirement. Firstly the research used the relative reduction and relative core in rough set theory to build a system to acquire customer requirement. Then, depending on relative positive field in rough set, the decision system was made plainer and its corresponding new decision system was initiated to determine the fundamental importance ratings of customer requirement. Then by integrating scale method into AHP approach, calculating formulas a new CR was developed. Further for every CR based on anintegration of its rudiment importance rating, the rating of obtaining the improvement ratio of its satisfaction estimation and "its sales point", the final importance rating was calculated (Li et al., 2009). Kano model also plays an important role in quality management in matrix planning and that was shown in various researches (Tan & Shen, 2000).

Some studies analyzed that in case of understanding customer satisfaction Kano model is very essential as the model classifies the requirements in important three kinds of categories. The studies further point out its importance in fulfilling customer defined quality and customer needs by quantitative method (Berger, Blauth, & Boger, 1993; Wang & Ji, 2010). Kano model is also essential in designing multiple product design activities and it is possible by integrating Kano model into quality function development. Combination of fuzzy Kano and fuzzy AHP optimize variety of products for smart cameras. These characteristics were focused on some research works (Yesim, Paul, & Erol, 2007; Chih-Hsuan & Juite, 2014; Chaudha, Jain, & Singh, 2011). Authors worked together to implement Kano. They used various processes to ensure that Kano model actually can delight customers and discussed about how the model does so (Sauerwein et al., 1996).

2. Sample Population

The age of the drivers was between 24 years and 40 years, the mean of their age being 32 years. Only male drivers were taken as sample population as no female driver was found. Sample size was calculated by using Equation (1), (Odunaiya, Owonuwa, and Oguntibeju, 2014). So, n = anticipated sample size, N = population size, and e = accuracy level. In this study, $N = 55$, $e = 5\%$ at 95% confidence level.

$$n = N \big/ \left(1 + Ne^2\right) \tag{1}$$

From the equation, the minimum acceptable sample size was calculated to be 48 or more. The available driver number is 50 having no physical problems and the probability of inappropriate measurements of data or unsuitable data deviation was reduced.

3. Methodology

Figure 1 illustrates the main procedure of the overall research work.

3.1. AHP Procedure

The procedure for using the AHP can be summarized as:

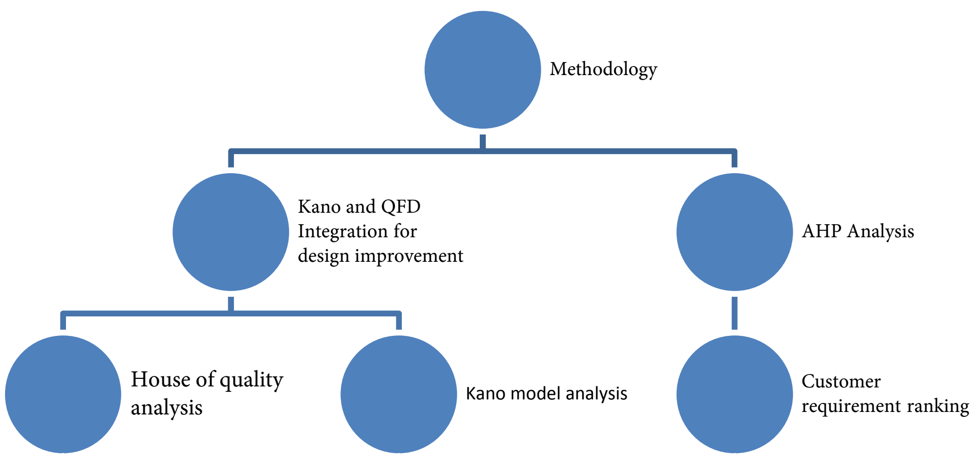


Figure 1. Total methodology flow chart.

1) Model the problem as a hierarchy containing the decision goal, the alternatives for reaching it, and the criteria for evaluating the alternatives.

2) Establish priorities among the elements of the hierarchy by making a series of judgments based on pairwise comparisons of the elements.

3) Synthesize these judgments to yield a set of overall priorities for the hierarchy.

4) Check the consistency of the judgments.

5) Come to a final decision based on the results of this process.

Table 1 shows scale of pairwise comparison where the analytic hierarchy process and how AHP can be used in making a decision was discussed (Saaty, 1990).

3.2. Kano Model Procedure

3.2.1. Kano Questionnaire Development

The Kano questionnaire was developed by direct user contact through interview. A survey consisting of 50 tractor drivers was taken. They gave their opinions regarding the current workstation. All relevant comments and suggestions regarding ergonomic consideration were included in the questionnaire. The language used in the questionnaire was clear and understandable. The questions included in the questionnaire were very much clear and unambiguous. Moreover, unbalanced answering options were avoided and the answers were taken from the survey in such a way so that they could be evaluated directly.

- The effective questionnaires response rate was 97%. Cronbach alpha values for the questionnaire were between 0.70 and 0.85 which means the questionnaire is reliable to be used in this study (Piaw, 2006).

Table 2 shows sample demographic data which was obtained during the survey.

Table 1. Scale of pair wise comparison in AHP.

Intensity of relative importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme/Absolute importance

Table 2. Samples demographic data.

Age	Gender	Frequency
20 - 25	Male	5
25 - 30	Male	15
30 - 40	Male	30

3.2.2. Kano Questionnaire Result

All qualities are measured and classified in six categories; Must-be (M), Attractive (A), One-dimensional (O) and Indifferent (I), Reversible (R), Questinable (Q). Indifferent category is defined as users do not care whether the quality is present or not. This type of quality does not affect user satisfaction at all. A solution was suggested in identifying relative values of meeting user satisfaction or not (Berger, Blauth, & Boger, 1993).

$$\text{Customer satisfaction, CS }(\text{better}) = A + O/(A + O + M + I) \tag{1}$$

$$\text{Customer dissatisfaction, CD }(\text{worse}) = O + M/(A + O + M + I) \tag{2}$$

Based on above equations, it would be easier to identify whether qualities offered will fulfill user satisfaction or lead the user towards dissatisfaction. According to (Wang & Ji, 2010), calculating CS and CD values can reflect the average impacts of each quality provided to customer feeling of satisfaction.

3.3. House of Quality (HOQ)

The House of Quality is a voice of customer analysis tool and a key component of the Quality Functional Deployment technique. It starts with the voice of the customer. It is a tool to translate what the customer wants into products or services that meet the customer wants in terms of engineering design values by way of creating a relationship matrix.

- ❖ Typically the first chart used in Quality Function Deployment.
- ❖ Data intensive and is capable of capturing large amounts of information.
- ❖ Left side: has the customer's needs.
- ❖ Ceiling: has the design features and technical requirements.
- ❖ The Roof: a matrix describing the relationship between the design features.
- ❖ Competitive Section: based primarily on the customer's perspective.
- ❖ Lower level/Foundation: Benchmarking & target values used to rank the "hows".

4. Data Analysis

4.1. AHP Analysis

AHP analysis was done to rank the customer requirements which were obtained from a survey of 50 tractor drivers.

Figure 2 illustrates the pairwise comparison result of customer requirements. To get the result, all the requirements of tractor seat were placed in both row and column by keeping the same sequence number. Then the comparisons were carried out according to the questionnaire result (Saaty, 1990; Saaty, 2008).

Figure 3 was obtained by following the method described by (Saaty, 1990; Saaty, 2008) on how to make pairwise comparison of customer requirements and determine the rank of CR.

Figure 3 clearly depicts that Seat belt with the highest 22.91% weight obtained the 1st rank position. Backrest with 17.41% weight obtained the 2nd rank position. Seat surface with 13.75% weight obtained the 3rd rank position. Adjustable seat

Pairwise Comparision of CR	Leg Space	Seat Surface	Clearness of Sidewall	Ease of Entry & Exit	Head-Rest	Visibility	Backrest	Adjustable Seat	Knee Space	Availability of Footrest	Seat Belt	Less Vibration	Reach to Control Distance
Leg Space	1	1/3	5	3	3	5	1/3	1/3	3	3	1/5	1/3	7
Seat Surface	3	1	7	5	5	7	1/3	3	3	7	1/3	3	9
Clearness of Sidewall	1/5	1/7	1	1/3	1/3	3	1/7	1/7	1/3	1/3	1/9	1/5	3
Ease of Entry & Exit	1/3	1/5	3	1	3	3	1/5	1/3	1/3	3	1/7	1/3	5
Head-Rest	1/3	1/5	3	1/3	1	3	1/7	1/5	1/3	3	1/7	1/3	3
Visibility	1/5	1/7	1/3	1/3	1/3	1	1/9	1/7	1/5	1/3	1/9	1/7	3
Backrest	3	3	7	5	7	9	1	3	5	7	1/3	3	9
Adjustable Seat	3	1/3	7	3	5	7	1/3	1	3	5	1/3	3	7
Knee Space	1/3	1/3	3	3	3	5	1/5	1/3	1	3	1/5	1/3	5
Availability of Footrest	1/3	1/7	3	1/3	1/3	3	1/7	1/5	1/3	1	1/7	1/5	3
Seat Belt	5	3	9	7	7	9	3	3	5	7	1	3	9
Less Vibration	3	1/3	5	3	3	7	1/3	1/3	3	5	1/3	1	7
Reach to Control Distance	1/7	1/9	1/3	1/5	1/3	1/3	1/9	1/7	1/5	1/3	1/9	1/7	1
Total	19.88	9.27	53.67	31.53	38.33	62.33	6.38	12.16	24.73	45.00	3.50	15.02	71.00

Figure 2. Pairwise comparison of customer requirements.

Pairwise Comparision of CR	Leg Space	Seat Surface	Clearness of Sidewall	Ease of Entry & Exit	Head-Rest	Visibility	Backrest	Adjustable Seat	Knee Space	Availability of Footrest	Seat Belt	Less Vibration	Reach to Control Distance	Weight	Weight%	Rank
Leg Space	0.05	0.04	0.09	0.10	0.08	0.08	0.05	0.03	0.12	0.07	0.06	0.02	0.10	0.07	6.76	6
Seat Surface	0.15	0.11	0.13	0.16	0.13	0.11	0.05	0.25	0.12	0.16	0.10	0.20	0.13	0.14	13.75	3
Clearness of Sidewall	0.01	0.02	0.02	0.01	0.01	0.05	0.02	0.01	0.01	0.01	0.03	0.01	0.04	0.02	1.95	11
Ease of Entry & Exit	0.02	0.02	0.06	0.03	0.08	0.05	0.03	0.03	0.01	0.07	0.04	0.02	0.07	0.04	4.04	8
Head-Rest	0.02	0.02	0.06	0.01	0.03	0.05	0.02	0.02	0.01	0.07	0.04	0.02	0.04	0.03	3.10	9
Visibility	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.03	0.01	0.04	0.02	1.50	12
Backrest	0.15	0.32	0.13	0.16	0.18	0.14	0.16	0.25	0.20	0.16	0.10	0.20	0.13	0.17	17.49	2
Adjustable Seat	0.15	0.04	0.13	0.10	0.13	0.11	0.05	0.08	0.12	0.11	0.10	0.20	0.10	0.11	10.89	4
Knee Space	0.02	0.04	0.06	0.10	0.08	0.08	0.03	0.03	0.04	0.07	0.06	0.02	0.07	0.05	5.21	7
Availability of Footrest	0.02	0.02	0.06	0.01	0.01	0.05	0.02	0.02	0.01	0.02	0.04	0.01	0.04	0.03	2.51	10
Seat Belt	0.25	0.32	0.17	0.22	0.18	0.14	0.47	0.25	0.20	0.16	0.29	0.20	0.13	0.23	22.91	1
Less Vibration	0.15	0.04	0.09	0.10	0.08	0.11	0.05	0.03	0.12	0.11	0.10	0.07	0.10	0.09	8.76	5
Reach to Control Distance	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.03	0.01	0.01	0.01	1.12	13
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100	

Figure 3. Showing ranking of customer requirement.

with 10.89% weight obtained the 4th rank position. Less vibration with 8.76% weight obtained the 5th rank position. Leg space with 6.76% weight obtained the 6th rank position. Knee space with 5.21% weight obtained the 7th rank position. Ease of entry and exit with 4.04% weight obtained the 8th rank position. Head rest with 3.1% weight obtained the 9th rank position. Availability of foot rest with 2.51% weight obtained the 10th rank position. Clearance of side wall with 1.95% weight obtained the 11th rank position. Visibility with 1.5% weight obtained the 12th rank position. Reach to control distance with 1.12% weight obtained the 13th rank position.

A research was conducted on how to determine the consistency index (CI), random index (RI) and consistency ratio (CR) after completing a pairwise comparison of factors. The following calculation was done to determine consistency index, Random index and consistency ratio.

The consistency ratio was obtained in Figure 4 by following the procedure used in (Youssef, 2015). Even if AHP has a consistent system, result will depend on decision maker. For this purpose a consistency ratio must be calculated. CR was found in Microsoft excel which was 0.07.

Formula of CR = CI/RI.

Where CI = Consistency index.

And RI = Random index.

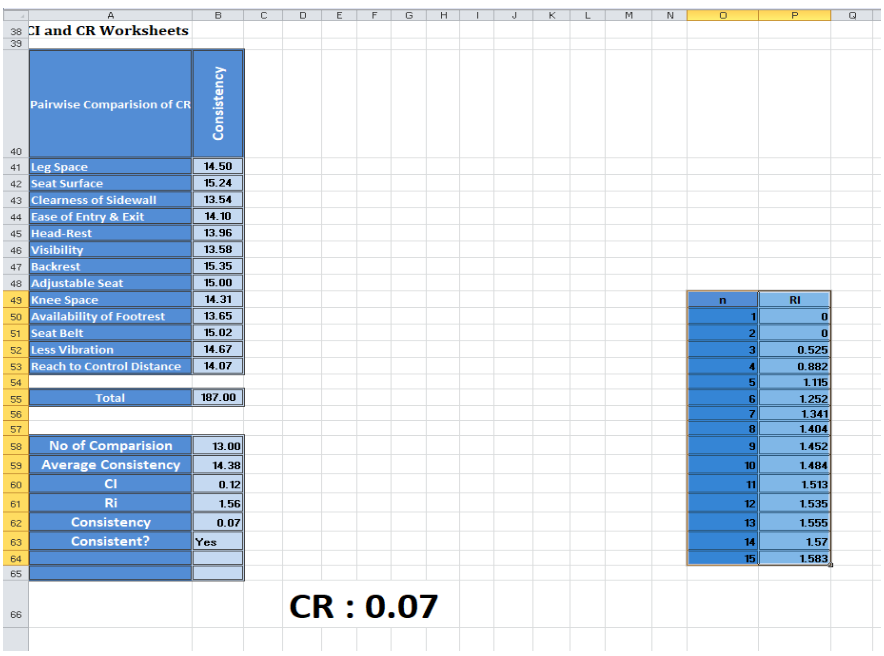
4.2. Kano Model Analysis

Kano analysis was done to determine the customer satisfaction (CS) and dissatisfaction (CD). Every requirement was categorized into five categories. For every requirement, fifty tractor drivers vote were considered.

Figure 5 depicting the analysis of Kano model was obtained through a calculation procedure followed by (Adila & Siti, 2012). Here, the highest customer satisfaction was obtained for seat belt which is 0.90 and highest customer dissatisfaction was obtained for adjustable seat which is 0.86. Here there was no vote found in Q category.

4.3. House of Quality

The QFD matrix can be developed by integrating Kano model. This approach was carried through a research by (Tan & Shen, 2000). By setting all customer



CI and CR Worksheets

Pairwise Comparision of CR	Consistency
Leg Space	14.50
Seat Surface	15.24
Clearness of Sidewall	13.54
Ease of Entry & Exit	14.10
Head-Rest	13.96
Visibility	13.58
Backrest	15.35
Adjustable Seat	15.00
Knee Space	14.31
Availability of Footrest	13.65
Seat Belt	15.02
Less Vibration	14.67
Reach to Control Distance	14.07
Total	187.00

No of Comparision	13.00
Average Consistency	14.38
CI	0.12
Ri	1.56
Consistency	0.07
Consistent?	Yes

n	RI
1	0
2	0
3	0.525
4	0.882
5	1.115
6	1.252
7	1.341
8	1.404
9	1.452
10	1.484
11	1.513
12	1.535
13	1.555
14	1.57
15	1.583

CR : 0.07

Figure 4. Showing consistency ratio.

KANO MODEL

Customer's Requirement	A	M	O	i	R	Q	Total	CS	CD
Leg Space	5	22	17	5	1		50	0.45	0.80
Seat Surface	8	6	28	8			50	0.72	0.68
Clearness of Sidewall	12	4	8	24	2		50	0.42	0.25
Ease of Entry & Exit	14	3	20	13			50	0.68	0.46
Reach to Control Distance	17	9	13	9	2		50	0.63	0.46
Adjustable Seat	4	26	17	3			50	0.42	0.86
Backrest	19	7	23	1			50	0.84	0.60
Visibility	12	6	24	8			50	0.72	0.60
Knee Space	20	6	8	16			50	0.56	0.28
Availability of Footrest	22	5	5	16	2		50	0.56	0.21
Seat Belt	36	3	9	2			50	0.90	0.24
Less Vibration	13	5	25	7			50	0.76	0.60
Head-Rest	12	2	22	14			50	0.68	0.48

Where,
CS= Customer Satisfaction
CD= Customer Dissatisfaction

Figure 5. Kano model analysis.

requirements, absulate weight and absulate importance in the rows, the engineering characteristics as well as kanocategory, k value, user satisfaction, user satisfaction target, adjustment factor, improvement ratio, adjusted improvement ratio and adjustment importance were placed in columns to build the QFD matrix. Table 3 represented ratings for different criterions and Table 4 shows ratings for various relationships (Tan & Shen, 2000).

Figure 6 shows the overall house of quality required for the purpose of the study (Tan & Shen, 2000). For against all the customer requirements, some technical requirements were established and at the very right end customer requirement (adjustment importance) weight were obtained and at the bottom technical requirement (absolute importance) were obtained. Seat belt obtained the highest customer requirement weight and clearance of side wall obtained the lowest weight. On the other hand dimension obtained the highest technical requirement weight and material thickness obtained the lowest. The ratings for various characteristics on different criterions were derived from above mentioned tables.

5. Result and Discussion

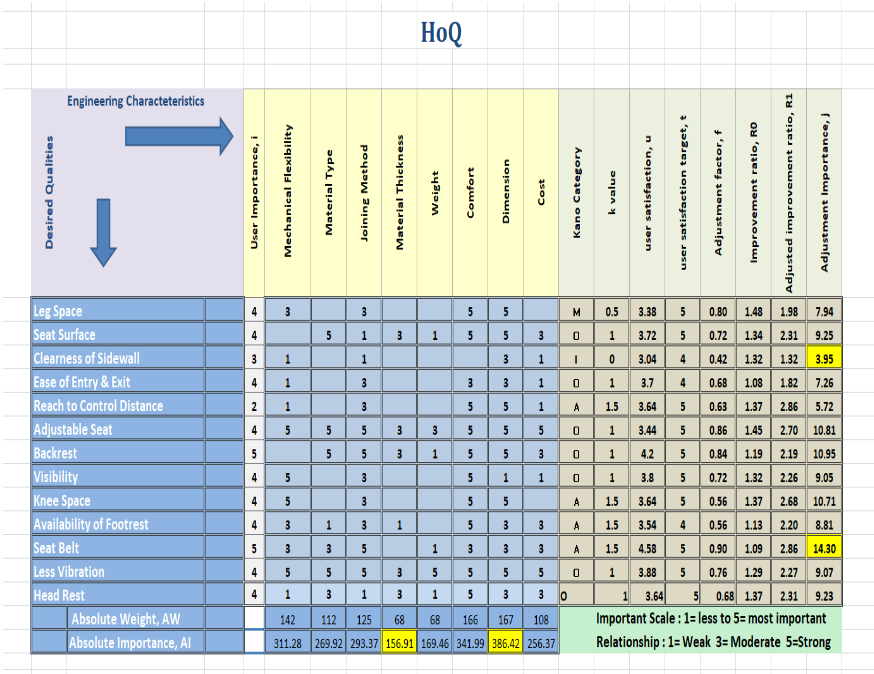
In this paper, all Customer requirements were properly ranked through AHP. All the CS and CD rate were obtained from Kano model analysis. QFD approach uses customer importance ratings and customer satisfaction to establish priorities. The integration of Kano model and QFD clearly identifies the customer requirement weight and the technical requirement weight to develop a modified design. Nowadays, many researchers are conducting their research through the

Table 3. Importance scale.

Criteria	Rating
Very Less Important	1
Less Important	2
Moderately Important	3
Important	4
Most Important	5

Table 4. Relationship scale.

Criteria	Rating
Weak	1
Moderate	3
Strong	5



HoQ

Desired Qualities / Engineering Characteteristics	User Importance, i	Mechanical Flexibility	Material Type	Joining Method	Material Thickness	Weight	Comfort	Dimension	Cost	Kano Category	k value	user satisfaction, u	user satisfaction target, t	Adjustment factor, f	Improvement ratio, R0	Adjusted improvement ratio, R1	Adjustment Importance, j
Leg Space	4	3		3			5	5		M	0.5	3.38	5	0.80	1.48	1.98	7.94
Seat Surface	4		5	1	3	1	5	5	3	O	1	3.72	5	0.72	1.34	2.31	9.25
Clearness of Sidewall	3	1		1				3	1	I	0	3.04	4	0.42	1.32	1.32	3.95
Ease of Entry & Exit	4	1		3			3	3	1	O	1	3.7	4	0.68	1.08	1.82	7.26
Reach to Control Distance	2	1		3			5	5	1	A	1.5	3.64	5	0.63	1.37	2.86	5.72
Adjustable Seat	4	5	5	5	3	3	5	5	5	O	1	3.44	5	0.86	1.45	2.70	10.81
Backrest	5		5	5	3	1	5	5	3	O	1	4.2	5	0.84	1.19	2.19	10.95
Visibility	4	5		3			5	1	1	O	1	3.8	5	0.72	1.32	2.26	9.05
Knee Space	4	5		3			5	5		A	1.5	3.64	5	0.56	1.37	2.68	10.71
Availability of Footrest	4	3	1	3	1		5	3	3	A	1.5	3.54	4	0.56	1.13	2.20	8.81
Seat Belt	5	3	3	5		1	3	3	3	A	1.5	4.58	5	0.90	1.09	2.86	14.30
Less Vibration	4	5	5	5	3	5	5	5	5	O	1	3.88	5	0.76	1.29	2.27	9.07
Head Rest	4	1	3	1	3	1	5	3	3	O	1	3.64	5	0.68	1.37	2.31	9.23
Absolute Weight, AW		142	112	125	68	68	166	167	108	Important Scale : 1= less to 5= most important							
Absolute Importance, AI		311.28	269.92	293.37	156.91	169.46	341.99	386.42	256.37	Relationship : 1= Weak 3= Moderate 5=Strong							

Figure 6. House of quality.

joining methods of Kano model and quality function deployment to improve product or workstation design considering customer requirements (Shen, Tan, & Xie, 2000; Hashim & Dawal, 2012; Tontini, 2007).

It was discovered that ergonomics was the main factor in engineering characteristic in developing a new or modified product nowadays. Most of the tractor drivers feel the necessity of a seat belt while driving tractor. They also feel the importance of less vibration, head rest, adjustable seat, knee space and back rest largely as they think these requirements in a tractor seat will definitely increase their performance. While fulfilling the customer requirements through technical requirements, dimension obtained the highest technical weight as it is closely related to these customer requirements.

Future Scope

The study was conducted by taking a small sample size. In the future, this type of study could be conducted for a large sample size for the betterment of accuracy of the result. Also, the tractor seat could be designed ergonomically by keeping the findings of the study in mind.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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