Chapter 40
Quality Function Deployment: A Methodology for Testing Agriculture Sickle

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1 Introduction

Agricultural hand tools design as the transformation of a concept into a product to satisfy farmers' needs while ensuring respect for the environment, legislation, and corporate profitability. The initial stage of an agricultural tool design process, therefore, involves identifying and formalizing various expectations of farmers (users) about the product to be designed, among are those relating to ergonomics features either explicitly or implicitly. The sickle is one of the oldest tools used in agriculture. Still widely used, it hasn't changed in design very much since time. Sickle are with two types of cutting edge, i.e., plain and serrated having a narrow serration with a depth of about 1 mm are being used at the farm by the farmers in the country. Of these, the use of plain sickle is more because serrated sickle is mostly preferred for wheat harvesting (Singh 2012). Design features of nine different types of sickles were analyzed and they indicated that blade geometry contributes significantly to human performance (Nag et al. 1988). Improved sickle with serrated edge reduced the drudgery of farm women by about 16.5% as compared to local sickle for harvesting wheat crop (Gite and Agarwal 2000). In India, regarding agriculture hand tools, there is no special design that has been developed for farm women who are doing a tremendous job in agriculture. Women are found to be engaged in agriculture farm activities with traditional old tools like sickle (Karunanithi and Tajuddin 2003). Less work is being reported on sickle design for especially farm women and its effect on women working conditions. There is a need to evaluate sickles and design them accordingly to users (farmers). For designing perspective quality function deployment methodology is the most reliable and used technique in designing agriculture hand tools as per customer needs (Akao 1993). In other words, it is a

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method for introducing quality right from the design stage to satisfy the customer and to transform customer requirements into design objectives and key points that will be required to ensure quality at the production stage**.** QFD methodology was used to design school furniture by defining the most important variables and characteristics of the final product based on the customers' voices. As a result, based on QFD and Ergonomics, the new designs were low maintenance, low cost, ergonomically correct, strong, and durable (Gonzalez et al. 2003). QFD technique reducing all risks of getting ergonomics-related problems and enhances customer-oriented design without ignoring ergonomics principles (Hashim et al. 2012; Powar et al. 2009). In this paper, we demonstrated how a specific design method, the quality function deployment (QFD), can be a vector for integrating ergonomics into the sickle design and, more generally, occupational risk prevention into work equipment design.

2 Methodology

A. *Data collection procedure*

This study used the survey method, which aim was to propose an improvement in the product design of sickle based on farm women's needs. Two resource centers were established in Mangali and Behbalpur villages (one in each) of Hisar District, where improved sickles were kept for use purposes of farm women. Two days training program was organized in each village where a demonstration on the use of sickle was given. After training 60 farm women (30 farm women from each village) were selected as respondents who were found to be working in farm activities on daily basis. The sickle was given to each farm woman for 30 days for use. A register was maintained in which issuing date, return date, and performance level of sickle from each respondent were recorded. A personal interview schedule was done with farm women to collect the data on the use and performance of sickle. Data were analyzed by using QFD methodology to evaluate the sickle performance (Table 1).

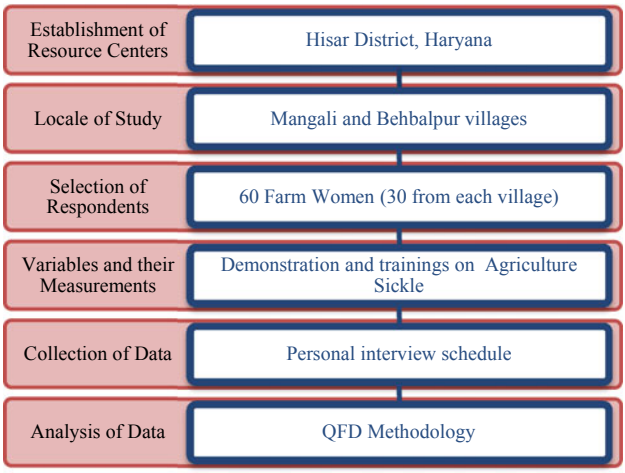
B. *Description of sickle*

The sickle used for research was developed by the Falcon industry. The below table gives a clear picture of the description of the sickle. As the table reflects that total length of the sickle was 40.5 cm with a weight of 230 g. The size of the blade and handle was 22.0 and 18.5 cm, respectively, with a handle diameter of 3.3 cm. The blade was found to serrate up to 0.4 cm with a conclave of the blade being 4.0 cm (Table 2).

C. *Quality function deployments methodology*

For the present study, the sickle was tested based on quality function deployment methodology. Quality Function Deployment (QFD) methodology was developed in 1966 by **Yoji Akao** in Japan. It was a structured methodology to translate the desires

Table 1 Data collection procedure



of the customer into product design. In this study, the researcher focused on 6 steps, to test the sickle. The step-wise description was as below:

Step (1) *Customer needs and their degrees of importance*: Farm women's requirements were gathered from surveys and interviews methods. Then the degree of importance of each need was identified by farm women.

Step (2) *Technical requirements and their interrelationships*: After listing the farm women's needs as customer needs and their degrees of importance, the technical requirements were established. Technical requirements are the translation of these needs into design requirements expressed in measurable attributes. The roof of the House of Quality (HOQ) was used to show the correlation between the technical requirements.

Step (3) *Relationships between customer needs and technical requirements*: This was the center of HOQ. The farm women needs that were listed on the left column were connected to the technical requirements listed across the top, and the correlation of each customer attribute with the technical requirement was analyzed by using the score of 9 (strong correlation), 3 (moderate correlation), 1 (weak correlation) and 0 (no correlation).

Step (4) *Competitive analysis*: Competitive analysis evaluated the sickle with other sickles available in the market. In this step, market sickles were reviewed in satisfying the farm women's needs shown in the rightmost columns. 1 to 5 scales, five being the best, were used in evaluating each competitor's product.

Step (5) *Importance ratings and concept selection*: This section completed the basement of the house where the importance ratings were recorded. The importance ratings were the relative weights of each technical requirement

Table 2 Particulars of studied sickle

Particulars	Dimensions of sickles (cm)
Sickle length	40.5
Maximum handle diameter	3.3
Size of sickle	22.0
Concavity of blade	4.0
Grip space	5.0
Maximum handle length	18.5
Effective handle length	17.0
Length of ferrule	1.8
Blade length	15.0
Serrated blade	0.4
Weight of sickle (g)	230

based on the weight of each item in terms of satisfying the farm women's needs.

Step (6) *Target values for technical requirements and to determine technical difficulties:* The requirements that corresponded to the needs of farm women and for the ones that have a higher degree of importance got more emphasis. Then, the technical difficulties were identified based on how difficult was to achieve the target values selected for each technical requirement. The rankings are done typically using a five-point scale with 1 being the easiest and 5 the most difficult.

3 Results

The present study was conducted on 60 farm women, out of the 40.0% women were found to be the age group of 31–42 years, followed by 38.3% who were from 43 to 54 years of age group and 21.7% farm women were in the ages between 19 and 30 years. Regarding education, nearly about one-third of the farm women (31.7%) were educated up to high school, followed by 18.3% educated up to secondary school and 15.0 and 13.3% were having education of primary and middle school, respectively. Besides this 21.7% of farm women were illiterate. The majority of the respondents/farm women (61.7%) were in a joint family. And more than fifty percent (53.3%) were in a family having 7–9 members. As per the use of sickle, maximum farm women (96.7%) were found to be using sickle on daily basis. Nearly about fifty percent (43.3%) were using sickle 1:00–1:30 h daily, followed by 38.3% using 1:30–2:00 h and 18.3% farm women were found to be using sickle for 0:30 min–1:00 h daily.

Use of Quality Function Deployment methodology for sickle testing

Testing of the sickle was done under 6 phases which were as below:

A. *Customer needs and their degrees of importance*:

The customers' attributes were (C_1) Good quality material, (C_2) proper size of the handle, (C_3) proper size of blade (C_4) grip, (C_5) low cost, (C_6) no maintenance required, (C_7) size of sickle, (C_8) lightweight of sickle, (C_9) no need to a sharp blade, and (C_{10}) not causing pain. Farm women assessed the attributes with the Likert scale method (1–5). The rating was done by women based on the weightage and importance of each attribute in the sickle design. As per finding, farm women gave maximum score (5) to grip, size of sickle and not causing pain when using followed by good quality material, the proper size of handle and blade, and lightweight of sickle got 4 score; and low cost, no maintenance required and no need to sharp blade attributes were having weighted means 3 (Table 3).

B. *Technical requirements and their interrelationships*

Attributes of technical response were taken from ISI sickle and experts in agriculture engineer. Attributes of technical requirements were (T_1) ergonomically designed, (T_2) standard size, (T_3) seriated blade, (T_4) made of cast iron, (T_5) strength, (T_6) standardized weight, (T_7) appropriate shape/size of the handle, (T_8) fixed joint, (T_9) appropriate shape/size of the blade, and (T_{10}) fit users. The next step is to identify the relevant interactions between each of the technical characteristics. In HOQ, the quantity was placed on the roof. By using the roof matrix, it was represented the interrelationship among the technical response. The correlation among technical attributes was studied and the score was given as highly strong (++), strong (+), neutral (). Negative (−), and highly negative (−) (Table 4).

Table 3 Customers need and their importance

Customer requirements	Code used for attribute	Weightage
Good quality material	C_1	4
The proper size of the handle	C_2	4
The proper size of the blade	C_3	4
Grip	C_4	5
Low cost	C_5	3
No maintenance required	C_6	3
Size of sickle	C_7	5
Lightweight of sickle	C_8	4
No need for a sharp blade	C_9	3
Not cause pain	C_{10}	5

Table 4 Technical attributes of sickle

Attributes	Code used for attribute
Ergonomically designed	T_1
Standard size	T_2
Serrated blade	T_3
Made of cast iron	T_4
Strength	T_5
Standardized weight	T_6
Appropriate shape/size of the handle	T_7
Fixed joint	T_8
Appropriate shape/size of the blade	T_9
Fit to users	T_{10}

C. *Relationships between customer needs and technical requirements*:

To determine the relationship matrix of attributes, customer requirements attributes are placed on the vertical edge on the left side, while the technical characteristics are laid out in the horizontal section at the top edge. The relationship between customer requirements and technical requirements was determined based on an appropriate scale of 9–3–1–0 which represented the strong, medium, weak, and no relationship among attributes. The below table shows the relationship of each customer attributes with technical requirements. Each correlation value in the table was multiplied with the weightage of customer importance and then all scores were added to find out the importance weighting of each technical point. Findings in the table revealed that maximum importance weightage ($\overline{x} = 198$) was received by T_7 (appropriate size of handle) and T_9 (appropriate size of the blade), followed by T_1 (ergonomically design)

Table 5 Relationship matrix between customers' need and technical attributes

CR	TR									
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
C1	9	–	3	9	9	3	–	9	–	9
C2	3	9	–	–	–	3	9	–	9	–
C3	3	9	1	9	–	3	9	–	9	–
C4	9	1	–	–	3	3	9	3	9	–
C5	–	–	3	3	–		–	–	–	3
C6	–	–	9	9	9	1	–	9	–	1
C7	9	9	–	–	1	9	9	3	9	–
C8	9	3	–	1	3	9	–	1	–	–
C9	1	–	9	3	3		–	–	–	–
C10	9	3	9	3	3	3	9	9	9	–
IW	189	149	124	136	119	150	198	142	198	48
RIW	7.68	9.75	11.71	10.68	12.2	9.68	7.33	10.23	7.33	30.2

CR: Customer requirement; TR: technical attributes; IW: importance weightage and RIW; relative importance weightage

which got the score of $\overline{x} = 189$ and T6 (standardized weight) and T_2 (standard size) got weighted means of $\overline{x} = 150$ and $\overline{x} = 149$, respectively (Table 5).

D. *Competitive analysis*:

In this step, competitors' sickles available in the market were reviewed because of satisfying the customers' needs shown in the rightmost two columns of the matrix. We used 1 to 5 scales, 5 being the best, were used in evaluating each competitor's product. The improved sickle was compared with other sickles available in the market. Data in the table unveil that improved sickle was found to be more satisfactory on quality of material (C_1), no maintenance required (C_6), and no need to sharp blade (C_9) with highest weighted mean score ($\overline{x} = 5$). Data in line represent that improved sickle was not found to be fit for users regarding size and shape of handle and blade which required immediate improvement (Table 6).

E. *Importance ratings and concept selection*:

Value for the importance was estimated by calculating the total weight for each relationship between product attributes and technical response. Data revealed that maximum interest of farm women was found in ergonomic design of sickle (52) followed by appropriate size of the handle (45) and blade (45). Different concepts were determined and ranks were given based on excellent, best, and worst with a score of 2.0, 1.0, and −1.0, respectively. The concept based on users' anthropometry was found to be excellent in correlation with T_1, T_6, T_7, T_9, and T_{10}. Regarding light in weight, T_7, T_9, and T_{10} were found correlated, and the same result was found for the standardized weight of sickle (Tables 7 and 8).

Table 6 Comparison of studied sickle with other sickles available in market

Our product	Competitor A	Competitor B
5	4	4
3	3	5
3	3	4
4	3	3
4	3	3
5	3	2
4	3	4
4	4	3
5	2	1
2	2	2

Table 7 Level of interest in each technical attribute

Technical requirements	Importance
Ergonomically designed	52
Standard size	34
Serrated blade	34
Made of cast iron	37
Strength	31
Standardized weight	34
Appropriate shape/size of the handle	45
Fixed joint	31
Appropriate shape/size of the blade	45
Fit to users	13

Table 8 Selection of concept based on attributes

Concept selection	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
Based on users' anthropometry	*	–	+	–	–	*	*	–	*	*
Light in weight	–	+	–	–	–	–	*	+	*	*
For both hands	*	–	–	–	–	–	*	–	*	+
Standardized shape	*	=	–	–	–	+	*	–	*	*

F. *Target values for technical requirements and to determine technical difficulties*:

They are determined from the relationship of the technical response. The calculation was performed by translating all weight values of the relationship and dividing the weight of each technical response by the total weight. Furthermore, the level of difficulty (on a scale of 1 to 9) was given based on the range of percentage.

Table 9 Level of difficulties in each technical attribute

Technical requirements	Difficulty
Ergonomically designed	3
Standard size	3
Serrated blade	4
Made of cast iron	3
Strength	4
Standardized weight	3
Appropriate shape/size of the handle	3
Fixed joint	3
Appropriate shape/size of the blade	3
Fit to users	9

(a) 0–5% level of difficulty = 1
(b) 6–11% level of difficulty = 3
(c) 12–17% level of difficulty = 5
(d) 18–23% level of difficulty= 7
(e) >24% level of difficulty= 9

Based on these scores, maximum problems were, fit to users attributes (9), followed by strength (4) and seriated blade (4) which represented that these components should be redesigned as per customers' perception (Table 9).

Overall six target values; 35 cm length of sickle, seriated blade thickness up to 2 ± 0.5 cm, the standard weight of 210 g, size of handle 11 ± 2, size of handle 15 ± 2 and Handle diameter of 3 ± 0.2 cm with grip space 3.5 ± 0.2 cm were decided for improving the design of sickle as per customers' requirements (Table 10).

4 Conclusion

The working and living conditions of female agricultural workers are underprivileged all over India. Heavy physical work, inadequate working methods, working techniques, and tools not only cause unnecessary fatigue and occupational accidents but also leads to low productivity. As per the present study, the product design of sickle was found satisfactory for male farmers, but as per female farmers, no specific design/concept has been corporate by the designer. Women farmers represent more than a quarter of the world's population. Women comprise, on average, 43% of the agricultural workforce in developing countries. Farm women were not found satisfied with the agriculture sickle as it was not as per their requirements. The use of sickle was causing muscle strain, ache in hands, and also reducing their productively on work. They were found to be managing with a sickle for most of the time during agriculture work. This was making them frustrated and less interested in the task. Some of the crucial factors for poor productivity were the use of local artisans made

Table 10 Target value for designing sickle for farm women

Particulars	Dimensions of studied sickles (cm)	Required dimension of sickle
Sickle length	40.5	35.0
Maximum handle diameter	3.3	3 ± 0.2
Size of sickle	22.0	17 ± 2
Concavity of blade	4.0	5 ± 1
Grip space	5.0	3.5 ± 0.5
Maximum handle length	18.5	11 ± 2
Effective handle length	17.0	13 ± 2
Length of ferrule	1.8	1 ± 0.2
Blade length	15.0	15 ± 2
Serrated blade	0.4	0.2 ± 0.5
Weight of sickle (g)	230.0	210 ± 10

tools/equipment; imported tools/ equipment which are not suitable for targeted user's physical capacity; anthropometric data are not taken into considerations for tools/ equipment design (Table 11) (Patel 2017).

The use of proper tools provides promising and encouraging results and hence it becomes utmost necessary to consider the human factors in the design of farm tools to enhance the operating efficiencies, working comforts, and thereby improving the productivity of workers. Ergonomically designed equipment/products enhance the human operating efficiencies and comforts during its operation (Kamate and Kumar 2015). As agriculture work is only considered a male-dominated task while most the of labor-intensive tasks of agriculture are done by women, but there are no specific tools/equipment that has been designed as per women anthropometry dimensions. The era of agriculture has been changing over time, and time demands to incorporate women prospective in agriculture engineering. So, suitable technologies have to be delivered to the farm women for raising farm productivity and empowerment (Patil and Babus 2018).

Table 11 Evaluation of agriculture sickle based on QFD methodology

Customer requirements	Weightage	Technical requirements										Competitor comparison		
		↑ T1	↓ T2	x T3	↑ T4	↑ T5	↓ T6	↓ T7	x T8	↓ T9	↑ T10	Our product	Competitor A	Competitor B
C1		●		○	●	●	○		●		●	5	4	4
C2		○	●				○	●		●		3	3	5
C3		○	●	Δ	●		○	●		●		3	3	4
C4		●	Δ			○	○	●	○	●		4	3	3
C5				○	○						○	4	3	3
C6				●	●	●	Δ		●		Δ	5	3	2
C7		●	●			Δ	●	●	○	●		4	3	4
C8		●	○		Δ	○	●		1			4	4	3
C9		Δ		●	○	○						5	2	1
C10		●	○	●	○	○	○	●	●	●		2	2	2
Importance weighting		189	149	124	136	119	150	198	142	198	48			
Relative Importance weighting		7.6	9.7	11.7	10.6	12.2	9.6	7.3	10.2	7.3	30.2			
Level of difficulty (%)														
Degree of importance (%)														
Concept selection														
Based on users' anthropometry		*	-	+	-	-	*	*	-	*	*			
Light in weight		-	+	-	-	-	-	*	+	*	*			
For both hands		*	-	-	-	-	-	*	-	*	+			
Shape as per users		*	=	-	-	-	+	*	-	*	*			

Improvement direction		
Maximum	↑	1.0
Target	x	0.0
Minimum	↓	-1.0

Concept selection		
Excellent	*	2.0
Best	+	1.0
Worst	-	-

Correlation		
Strong	●	9.0
Moderate	○	3.0
Week	Δ	1.0

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