Design and selection of agricultural machinery using a quality function deployment technique

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Abstract: The demand of agricultural machinery has been increasing day by day due to lack of availability of human power and increasing the cost of cultivation. The agricultural machinery development is hundreds of time what they were several years ago. The growth of agro industry depends on the farmers; so the production of farm products must be based on farmer's requirement. Even though they are producing required products still there is a gap between farmers and designers. The most agricultural machinery operator having suffered injuries on shoulder, wrist and elbow, most researchers have concentrated their attention on propelling efficiency or biomechanics issues, not operation interface based on operator s' requirements. Though some innovative changes have been introduced in the engineering aspect, they are not as popular as expected in rural and urban areas because of the lack of knowledge from farmers. Hence a study was proposed to compile the farmer's requirements and designers possibilities by using a simple technique of Quality function deployment (QFD). A survey was conducted to identify the farmers, dealers problems and requirements by a group of technical people and the opinions were compared and finally the majority opinions were sorted out and fitted in QFD approach to identify the major needs and problems of farmers for designing and development of machinery based on their opinions' at the production level of agro industry.

Keywords: QFD, agricultural machinery, house of quality, selection technique

Citation: Ashok Kumar, A., V. K. Tewari , J.Maiti, and B. Nare. 2015. Design and selection of agricultural machinery using a quality function deployment technique. Agric Eng Int: CIGR Journal, 17(4):91-99.

1 Introduction

Agriculture demands more power and energy to produce food to feed the ever increasing world population. Inefficient tractor implement operations increase the cost of production. The need to maintain agriculture profitability is, however, very much dependent upon both the land and machinery productivity. Management decisions related to agricultural machinery can affect plantation profits in many ways. Operational efficiency of tractor can be improved by maximizing work output or minimizing the fuel consumption.

As competition becomes more intense, agricultural machinery producing companies are adopting quality as a source of advantage. To survive, they have to achieve higher customer satisfaction. Currently the Agricultural Industry is in the midst of change. The agricultural machinery development is hundreds of time what they were several years ago. Even though there are different technologies were available to optimize the customer's requirements and designers considerations a Quality function deployment (QFD) was selected due to its accuracy. QFD is a design-oriented nature serves not only as a valuable resource for designers but also a way to summarize and convert feedback from farmers into information for designers also.

Different optimization approaches have been applied in QFD analysis in recent years. Park and Kim (1998) proposed 0–1 programming to optimize product design. This approach gives the most attention to the most important technical attributes and resources. However, when using this kind of method, much effort is put into

Received date: 2015-06-06 **Accepted date: 2015-08-25**

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the selected technical attributes, while other technical attributes may be overlooked. Linear programming is one of the first mathematical models to be used in QFD optimization. It is often used to allocate resources to the various engineering characteristics in order to maximize overall customer satisfaction. Many papers have been published in this field (e.g. Moskowitz and Kim, 1987; Askin and Dawson, 2000). Goal programming is also a very popular method for QFD optimization process (Karsak et al., 2003a/b; Chen and Weng, 2003). Dawson and Askin (1999) proposed a nonlinear mathematical programming model for determining the optimal engineering characteristics during new product development. In some cases, the values of the engineering characteristics are discrete. Dynamic programming can be used to solve the type of optimization problem where only a few alternatives are available for the engineering characteristics (Lai et al., 2004). To capture the vagueness in product design, fuzzy mathematics was introduced to QFD methodology (Kim et al, 2000; Vanegas and Labib, 2001; Karsak, 2004; Chen et al., 2004).

Quality function deployment (QFD) is one of the structured methods which could be aimed at satisfaction of the customer (Marsot, 2005; Wilkinson, 2007). It has advantages such as customer-oriented development process, better integration of design team, reduction of the produce development period, and effectiveness in policy decision-making. Hence a study was conducted to identify the farmers problems related to agricultural machinery usage by conducting a survey and also to know what's the farmers exactly expecting from agricultural machinery manufacturers. Hence a study was proposed to compile the farmer's requirements and designers possibilities by using a simple technique of Quality function deployment (QFD). The present study utilized the systematic strategy, QFD, to extract bottleneck techniques in design of agricultural machinery to satisfy the farmer's requirements also for growth of agro industry.

2 Materials and methods

The management of farming operations is currently rapidly changing towards a system perspective integrating the surroundings in terms of environmental impact, public entities and documentation of quality and growing conditions. The latest developments in Information and Communication Technologies and the prevailing lack of interoperability between agricultural tractors, implements and on-board computers has led to the development of international standard for securing a more effective communication between these entities. Hence the concept of QFD is introduced to translate customer desires into design requirements subsequently into characteristics of parts, then to process plans and ultimately in to production requirements. In order to establish these relationships, QFD usually requires four matrices: product planning, parts planning, process planning and production planning matrices, respectively. Four phases of matrices (Figure 1) are used to relate the input from the customer with products technical requirements, mechanical requirements, manufacturing operations, and quality control plans (Karsak et al., 2003a/b). The product planning matrix also called the house of quality (HOQ), translates customer need into product design requirements and it identify customer requirements (CRs) and establish priorities of design requirements (DRs) to satisfy the CRs (Hauser and Clausing, 1988).

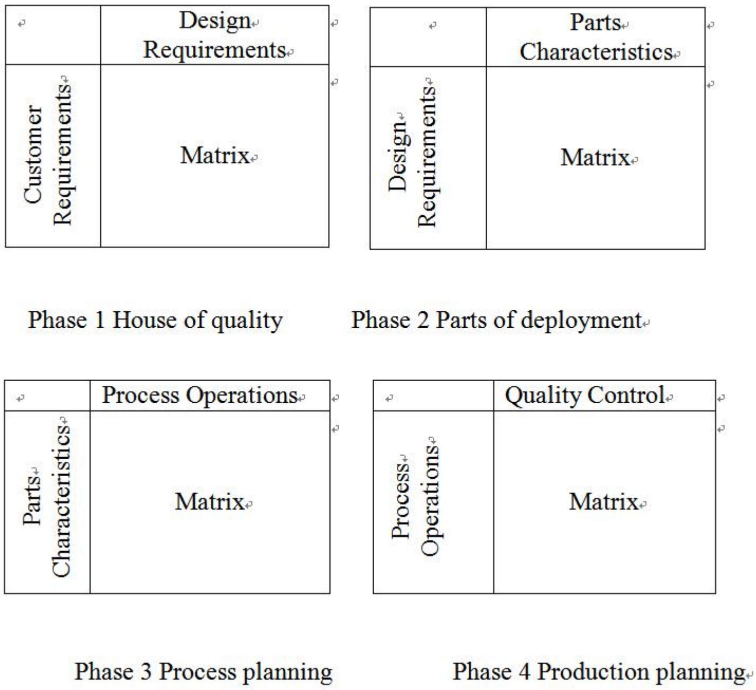

Figure 1 Four phases of quality function deployment process

There are four steps in building an HOQ, describes as follows: **Step 1**: CRs are also known as the voice of the customers. Customer requirements are usually collected by focus groups and expressed in customer own phrase. Quality deployment is included in this step to generalize customer requirements; **Step 2**: Drs are also known as the design requirements or engineering characteristics. Product characteristics are described in the language of the engineer; refered to customer as voice of the design team. The Drs are used to describe how well the design team has satisfied the demands from the customers; **Step 3** . Relationship matrixes. The relationship matrix indicates how much each DR affects each CR (Table 1). The rating scale can be presented in the score (5; 3; 1) or symbols (¤ strong;ö Medium;Λ Weak). A cell (I, j) in the relation matrix is assigned (¤ strong = 5; ö Medium = 3; Λ Weak = 1) to manifest a strong, medium or weak relationship between the i th CR and jth DR, respectively; **Step 4**. Priorities of the DR. the outcomes obtained from proceeding steps are used to figure a final rank order of DRs. The absolute and relative weighting of CRs and the relation ratings. For each DR, the absolute weighting rating is computed by the following relation.

$$AI_j = \sum_{i=1}^{m} R_{ij} W_i, 1 \le m \qquad (1)$$

The AI_j is absolute weight age rating of DR_j, j= 1… n, Wi= Degree of weightage of CR_i, i= 1… m, and R_{ij} = Relationship rating,, representing the strength of the relation between Cri and DR_j. The absolute weightage rating can be translated in to the relative weightage rating, RI_j,by

$$RI_j = AI_j \Big/ \sum_{i=1}^{n} AI_k, 1 \le n \qquad (2)$$

Table 1 Typical house of quality matrix with a 5-3-1 rating scheme

		Design requirements				Degree of importance
		DR1	DR2	DR3	DR4	
Customer requirements	CR1	¤		Λ		0.3
	CR2	Λ	ö		¤	0.2
	CR3			ö		0.1
	CR4		Λ	ö		0.1
	CR5	ö	ö		¤	0.3
Absolute importance		2.6	1.6	0.9	2.5	
Relative importance		0.34	0.21	0.12	0.33	

Note: ¤ strong = 5; ö Medium = 3; Λ Weak = 1

If the RI_j is larger, the DR is more important. In this study, the first two matrices (phase 1: house of quality and phase 2: parts of development) of the QFD process were concentrated on developing and modifications required as per the farmers requirements. The procedure consists of three phases:

Phase 1: House of quality. The matrix of HOQ was built comprising CRs and DRs. **Step 1**: CRs. A case study was conducted in Guntur District (one of the 9 coastal districts of Andhra Pradesh) which is about 100 kms and having fifty seven mandals and famous for dry land and wet land cultivation. The total geographical area of the district is 11328 sq kms, which forms 4.12% of the total state's area. One hundred dealers were selected from different reputed agricultural machinery production companies in India and also the number of farmers who were in the field of agricultural since many years are interviewed by a technical team to know their requirements and problems facing at the time of usage of farm products The dealers and farmers opinions were compared and finally the majority opinions were sorted out and given in Table 2 expressed as CRs, were developed to be a questionnaire. The quality items of CRs were listed in the first column of the matrix. **Step 2**: DRs. The DRs deployed by a cross-function team, comprising field surveyors, data collection team, problem identification team, research and development team, marketing team filled in the first row of matrix. **Step 3**: relationship matrix. The design team members filled in the relationship ratings of CRs and DRs. **Step 4**: priorities of the DRs. The relative weighting of function DRs were calculated.

Phase 2: Parts of deployment. To build a matrix like phase 1, nevertheless the two dimensions were succeeding as DRs and parts characteristics (PCs). DRs and their degree of importance were filled in column (step 1); PCs deployed by engineering group were filled in row (step 2). DRs and PCs made the second relationship matrix (step 3). Relationship ratings were filled in by the cross-function team; the relative weighting of parts could be calculated by step 4.

Phase 3: Bottleneck technique. Concentrate on the DRs corresponding to PCs and regarding to ranking of PCs to determine bottleneck techniques. This study defined the relative importance of PCs over 10 as a datum. If the correlation between the items of DRs and PCs was strong or the comparative weighting of PCs was stronger, it could be regarded as a bottleneck technique. It is a parts characterization and identification stage of the technical team based on farmer's requirement and desires.

3 Results and discussion

Phase I: House of quality: There were 32 copies of the questionnaire. The degree of importance of CRs is showed in Table 2. Among them, "Less moving parts" "Easy braking" "Suitability of work", "Quality of work", "repairing facility", "long life", "low price" and "Government subsidy availability" were the most important items. There were 18 DRs (Table 3) deployed by the engineering group of the cross-function team. After establishing CRs and DRs, the matrix of HOQ could be built. The corresponding relationship of CRs and DRs could be filled with symbols (¤ strong = 5; ö Medium = 3; Λ Weak = 1) one by one as the related matrix (Table 4). The final result was that the most important items of DRs were “Adjustments”, “Multipurpose use”; and “Easy maintenance”, “Working demo”, the corresponding weightings constituted the function elements near or over 10% in Table 3.

Phase 2: Parts deployment: In order to find out the PCs of the agricultural machinery, the parts deployment of the agricultural machinery was therefore conducted. After finishing parts deployment in just the some manner as the preceding the HOQ, the cross-function team filled the corresponding relations of DRs and PCs in association notation (¤ strong = 5; ö Medium = 3; Λ Weak = 1) as shown in Table 5. The final calculated result was that the “Number of moving parts”, “Type of material”, “Life”, and “Service facility”, were most important, and the relative importance ratings were 11.1%, 16.0%, 17.9%, and 17.9% respectively.

Phase 3: Determination of the bottleneck techniques: It showed that the weighting of DRs greater than or nearer 10 included four items, according to priority, which were they are Type of forces (12.0%), Analysis of forces (11.0%), working demo (9.7%) and long-term use (11.4%) (Table 5). Bottleneck techniques aimed at the four DRs to find out the strong relation items from correspondence to the correlation coefficients on the PC list individually, including number of moving parts, type of material, long life, and repair and servicing facility. As far as the corresponding weighting of part items, there were: number of moving parts(11.1%), type of material (16.0%), long life (17.9%), and repair and servicing facility(17.9%). Because of number of moving parts only got few correlation coefficients of strong item and lower weighting of PCs, it was eliminated. The remaining three items were defined as the bottleneck techniques after discussion

Table 2 Customer requirements obtained by interview and observations of agricultural machinery users

		Quality items	Degree of importance
Easy to use	Usability	Small size	4
		Light Weight	4
		Easy Braking	5
		Easy steering	2
		Power Saving	4
		Less moving parts	5
		Easy to Adjust	2
	Comfort	Comfortable seat	3
		Adjustable seat	4
		More stability	4
		Suitable	3
Capability	Safety	Less vibration	2
		Does not tilt	4
		Does not break	1
	Modifications	Easy to modify	4
		Multipurpose use	4
	Maintenance	Easy to maintain	1
		Easy to clean	4
Suitability	Suitability	Suitability of soil	4
		Suitability of work	5
		Quality of work	4
		Quantity of work	5
Repairs	Repairs	Availability of Spare parts	4
		Mode of repair	4
		Reaping Facility	5
Field demonstration	Live demo on field	Field demo required	4
		Lack working Knowledge	3
		Operational precautions	4
Others	Others	Long life	5
		Low price	5
		Govt. Subsidy availability	5

Table 3 Design requirements deployed by the cross function team

		Function items	Relative weighting
Basic properties	Dimension	Dimensions	2.1
		Weight	2.1
	Comfort	Vibration	3.6
		Noise generation	1.7
		Material of frame	3.3
		Material of other parts	3.75
	Safety	Safety features	1.24
		Brake	2.1
Function	Parts characteristics	Types of forces	6.8
		Analysis of forces	5.2
		Adjustments	12.0
		Multipurpose use	11.0
Live demo	Field demo	Working demo	6.5
		Knowledge generation	9.7
Others	Others	Long term use	4.7
		Maintenance	11.4
		Low price	5.2
		Repairing Facility	7.5

Table 4 House of quality diagram for new agricultural machinery

				Basic properties								**Function**				**Live demo**		**Others**				
				Dimensions		Comfort				Safety		Parts characteristics				Field demo		Others				
				Dimensions	Weight	Vibration	Noise	Material of frame	Material of other parts	Safety features	Brake	Types of forces	Analysis of forces	Adjustments	Multipurpose use	Working demo	Knowledge Generation	Long term use	Maintena	Low Price	Repairing Facility	Degree of importance
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
Easy to use	Usability	Small size	1	¤																		4
		Light weight	2		¤			ö	ö													4
		Easy braking	3								¤			ö								5
		Easy steering	4																			2
		Power saving	5																			4
	Comfort	Less moving parts	6			¤	ö															5
		Easy to adjust	7											ö								2
		Comfortable seat	8			¤			ö					¤								3
		Adjustable seat	9											¤								4
		More stability	10																			4
Capability		Suitable	11									ö	Λ		¤							3
		Less vibration	12				Λ			ö		ö	Λ									2
	Safety	Does not tilt	13					¤	ö													4
		Does not break	14					¤	ö													1
	Modifications	Easy to modify	15											¤								4
		Multipurpose use	16												¤			ö	¤			4
	Maintenance	Easy to maintain	17															Λ	ö			1
		Easy to clean	18														ö					4
Suitability	Suitability	Suitability of soil	19									ö	ö	ö			ö					4
		Suitability of work	20									ö	ö	ö	¤		ö					5
		Quality of work	21									Λ	Λ	Λ	¤		ö					4
		Quantity of work	22									ö	ö	ö	¤							5
Repairs	Repairs	Availability of spare parts	23																		¤	4
		Availability of technicians	24																		¤	4
		Reaping facility	25																		¤	5
Field demonstrations	Live demonstrations on field	Field demo required	26													¤	ö					4
		Lack working knowledge	27													¤	ö					3
		Operation precautions	28													ö	¤					4
Others	Others	Long life	29															¤				5
		Low price	30																	¤		5
		Govt. subsidy availability	31																	¤		5
Importance		Absolute weighting		20	20	35	16	32	36	12	20	65	50	115	105	62	93	45	110	50	75	961
		Relative weighting		2.1	2.1	3.6	1.7	3.3	3.75	1.24	2.1	6.8	5.2	12.0	11.0	6.5	9.7	4.7	11.4	5.2	7.5	100

Table 5 Parts of deployment matrix for new agricultural machinery

			Functional Deployment	Body Support			Drive System		Brake System Other		Other		
				Frame	Number of Moving Parts	Type of Material	Power Assistive System	Location of Handle	Braking Device	Parking Device	Life	Service	Cost
				1	2	3	4	5	6	7	8	9	10
Basic Properties	Dimension	Dimensions	1	ö	Λ	ö							
		Weight	2	ö		ö							
	Comfort	Vibration	3		ö	¤							
		Noise generation	4		ö	Λ							
		Material of frame	5			ö							
		Material of other parts	6			ö							
	Safety	Safety features	7						ö	¤			
		Parking Brake	8							¤			
		Absorbability	9			ö							
		Brake	10				¤		ö	Λ			
Function	Parts Characteristics	Types of forces	11		Λ								
		Analysis of forces	12		Λ								
		Adjustments	13					¤					
Live demo	Field demo	Working demo	14										
		Knowledge creation	15										
others	Others	Long term use	16								¤	¤	
		Low price	17								¤	¤	¤
		Maintenance	18										
Importance		Absolute Weighing		21	51.6	73.9	26	32.5	19.32	21.9	83	83	26
		Relative Weighing		4.5	11.1	16.0	5.6	7.0	4.2	4.7	17.9	17.9	5.6

4 Conclusions

A quality function deployment was successfully implemented in the design and selection of agricultural machinery. From this study it was concluded that, major group of farmers not satisfied with the available machinery due to bulky in construction, non suitability of multipurpose operations, and more maintenance. It was also observed that, due to lack of working knowledge of machinery, 9.7 percent of farmers are not showing interest to purchase advanced machiney and 11.4 percent of the farmers raised about long-term use and servicing and spare parts availability. In this study a relationship matrix was developed in-between farmer's requirements and designer considerations, so that by having this, the customer requirements may be fulfilled as well as the growth of agro-industries may be possible which helps to increase the job opportunities'.

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