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Mapping the Voice of Customer into Functional Requirements Using Quality Function Deployment

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Abstract*— This paper presents a comprehensive framework for employing QFD in the early stage of design to transform voice of customer (VOC) into functional requirements (FRs), emphasizing the importance of customer-centric design principles in fostering innovation and competitiveness in any industry. Case study of design project for small hand-launched UAV and practical examples illustrate the effectiveness of the proposed methodology in capturing customer insights and translating them into tangible product features, thereby enabling the creation of product that not only meet but exceed customer expectations. The methodology begins with the identification and prioritization of customer attributes through qualitative and quantitative methods. These customer attributes are linked to technical characteristics and features essential for hand-launched UAV functionality through QFD matrices and cross-functional analyses. When relationships between customer attributes and functional requirements are demonstrated, more informed decisions can be made during the design phase.

Keywords: Axiomatic Design, Design for Six Sigma, Quality Function Deployment, Voice of Customer.

I. INTRODUCTION

Customer attributes (CAs) are the general ideas about the needs which the customer expects from final product [1]. It's common that customers use fuzzy expressions in characterizing these needs but understanding these needs is a good lead for high quality products. Mapping customer attributes to functional requirements (FRs) is done using the quality function deployment (QFD) method [2]. FRs are the minimum set of requirements that completely characterizes the functional needs of the product or the minimum set or requirements that the product must satisfy. One of the advantages of using QFD is that it facilitates discovering the relationships between product characteristics expressed by the customer and the quality characteristics expressed by the design team. The QFD method uses relationship matrix called house of quality (HOQ).

II. LITERATURE REVIEW

Quality Function Deployment (QFD) is a well know design tool that has been first developed in Japan by Mitsubishi in their shipyard at Kobe, Japan [3]. QFD helps provide products and services with higher quality by linking customer needs to functional requirements and make customer needs guide the design at the early stages of product development process which will help to avoid misalignment between customer expectations and final product.

QFD is composed of series of matrices named House of Quality (HOQ) [4]. HOQ, as shown in Figure 1, is composed of the following parts:

A. Customer Attributes (CA): representing the customer needs expressed in customers' languages or grouped by the design team into meaningful categories.
B. Relative importance rating of CA: a measurement scale shall be used to show the relative importance of CA.
C. Functional requirements: engineering attributes defined by the design team to interact with the CA.
D. Functional Requirements Correlation: the roof of the HOQ is used to show a measure of the probable correlation between any two of the functional requirements.
E. Direction of improvement: used to show what designers should seek for the value of a specific FR in order to improve the quality of the product.
F. Planning matrix: includes comparisons between competitors or and goals to improve the existing product.
G. Relative importance rating of FRs: calculated value for importance ratings for the FRS by summing all the values gained by multiplying the value of each cell of the relationship matrix by the value of the CA index.
H. Relationship matrix: each cell contains a symbol with relative value to show the cause-and-effect relationship between the CA and FR combined by this cell.
I. FRs competitive benchmark: comparison of competitors FRS.
J. FRs targets and limits contains a targets and limits for the FRs put by the design team and will be used as success indicators.

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Usage of HOQ has many advantages that could help increasing the quality of final product or services as follows:

- Customer requirements and needs are quantified and prioritized which will facilitate dealing with those requirements by the design teams. [5]
- Functional requirements are related to the customer's needs while considering the competitiveness of similar products and that will help taking better trade-off decisions.
- QFD will improve communication between all teams of the organization as all the focus will be directed towards customer satisfaction.

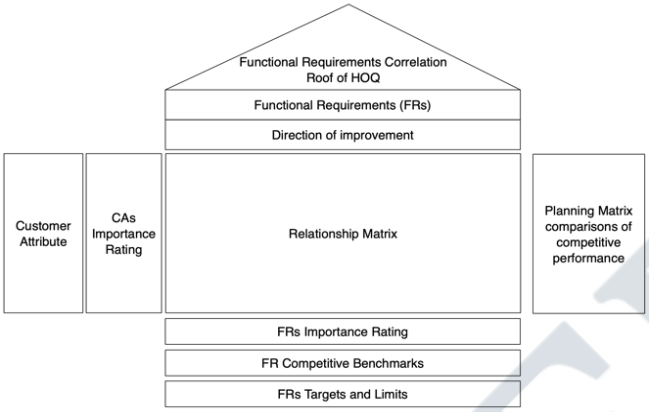

Figure 1. Quality Function Deployment (HOQ)

III. METHODS AND METHODOLOGY

A. Customer Attributes (CA) Identification and Analysis

CAs are probable benefits that the customer will gain from the product. CAs are collected by listening to the voice of customer (VOC) and they are presented as list of customer preferences, expectations and wants.

VOC can be captured using methods such as surveys, interviews, focus groups and market analysis [1].

Analysis of CAs is done to prioritize them using models such as kano model and Analytical Network Process (ANP)

B. House of Quality (HOQ) Setting Up

HOQ is considered as a central tool in (QFD) methodology to link between (CAs) and the (FRs). Developing HOQ is done by listing CAs on the first left column and FRs on the first top row.

Importance ratings for CAs are defined by the customer and reviewed by the design team then market survey is used to show a competitive benchmark analysis.

C. Interrelationship Matrix

Quantifying of the relationships between CAs and FRs is done using symbols with related values and measurement scale as shown in Table 1.

Table 1. HOQ symbols and values

Roof of HOQ	++	Strong Positive Correlation
	+	Positive Correlation
	−	Negative Correlation
	▼	Strong Negative Correlation
Direction of Improvement	▼	Objective Is to Minimize
	▲	Objective Is to Maximize
	x	Objective Is to Hit Target
Relationship matrix	9	Strong Relation
	3	Moderate Relation
	1	Weak Relation
		No Relation

D. Technical Evaluation

Importance ratings of the FRs are calculated and competitive benchmark is made to define final targets and limits for the FRs. This step is iterative as the design team needs to discuss the calculated FRs importance ratings after being compared with the competitive benchmark because the limits and targets shall be reasonable and achievable.

IV. RESULTS

A study case of design project for small hand launched UAV was selected to apply the methodology. CAs were collected through surveys conducted to all available professionals who work directly or indirectly in the field of purchasing, manufacturing and developing hand launched UAVs. Research and previous experiences of design teams showed the following FRs as input for the whole design process [6]. Each FR represents a group of parameters that serve to define the targeted FR. Table 2 shows a list of the collected CAs and list of recommended FRs by design teams.

Table 2. CAs and FRs for small hand launched UAV

Symbol	Customer Attributes (CAs)	Critical to satisfaction (CTSs) Substitute Quality Characteristics (SQCs) Functional Requirements (FRs)
A	Safe to operate	Production Facility Performance
B	Easy to operate	Transportation requirements
C	Easy to transport	Mission profile requirements
D	High stability	Ground control requirements

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Symbol	Customer Attributes (CAs)	Critical to satisfaction (CTSs) Substitute Quality Characteristics (SQCs) Functional Requirements (FRs)
E	All weather capable	Environmental conditions
F	High performance	Development project planning
G	Compatible with the operation field	Airframe structural design requirements
H	Low cost	Airframe stability
I	Adaptable configurable	Reliability of commercial components
J	Precise	Airframe layout
K	Undetectable	Communication system specifications
L	Powerful camera	Autopilot specifications
M	Fully autonomous	Payload specifications
N	Easy production	Engine specifications
O	Quick development	System weight
P	Certified	Airframe weight
Q	-	Power system specifications
R	-	Assembly techniques
S	-	Targeted airworthiness requirements (AWR)
T	-	Aircraft flight performance

To define the importance rating for CAs, the used surveys required the targeted audience to give a score representing the importance of each CAs. The design team calculated the average score of each CAs then the resulted importance rating for CAs were translated into weighted importance rating as shown in Table 3.

Table 3. CAs importance ratings and weighted importance ratings

CAs	Importance ratings	Weighted importance ratings	CAs	Importance ratings	Weighted importance ratings
A	10.0	8.8	I	6.0	5.3
B	10.0	8.8	J	5.0	4.4
C	8.0	7.0	K	8.0	7.0
D	5.0	4.4	L	10.0	8.8
E	8.0	7.0	M	5.0	4.4
F	8.0	7.0	N	5.0	4.4
G	5.0	4.4	O	8.0	7.0
H	8.0	7.0	P	5.0	4.4

The correlation between FRs was studied and presented in the roof of HOQ in Figure 2.

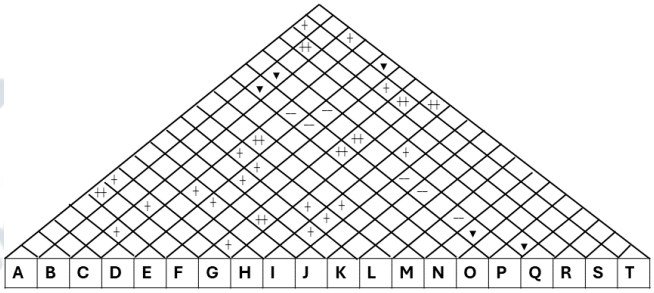

Figure 2. Quality Function Deployment (HOQ)

Direction of improving quality for each FRs is defined by a symbol that represent one of three cases which are:

- ▼ objective is to minimize the FR to increase the quality of the final product
- ▲ objective is to maximize the FR to increase the quality of the final product
- X objective is to hit a specific value of the FR to increase the quality of the final product

Table 4. direction of improving quality for FRs

FR	Direction of improvement	FR	Direction of improvement	FR	Direction of improvement
A	▲	H	▲	O	▼
B	X	I	▲	P	▼
C	X	J	X	Q	▲

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FR	Direction of improvement	FR	Direction of improvement	FR	Direction of improvement
D	X	K	▲	R	▲
E	X	L	▲	S	▲
F	▲	M	▲	T	X
G	▲	N			

The relationship matrix was set up and each cell given a value that represents the relation between the CA and FR joined by this cell. Table 5 shows the resulting relationship matrix.

Table 5. Relationship matrix

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A					3		9	9	9								9	1		9
B		9		9	3					3	3	9								
C		9		9	3					3					9	9			9	
D			9		9		3	9		3		9		3	1			9	3	9
E			9		9		3	1	1		3	9	1	9			3	3		9
F			9		9		3	3				9		3			3	3		9
G		3		9	9						1		3	9			3	3	9	3
H	9			3		9	9	1	3	3	3	3	9	3	9	9	1		1	3
I		3					9			9						3			9	
J			1	3	3			9	3			3	3					3		
K			3				9				9	1		9						
L									9		9		9				1			
M			3					1			1	9	3	3				1		
N	9						9			9				3	9	9			9	
O	9					9	3		9	3		3	1	3		3			1	3
P	3					9	1		3		1			3						9

After evaluating the CAs and FRs relationships, Importance ratings for FRs can be calculated using the following equation:

$$I_l = \sum_{m=A}^{m=P} R_{ml} * W_m$$

Where:

$m \ldots CA\ order$

$l \ldots FR\ order$

$I_l \ldots importance\ rating\ of\ FR$

$R_{ml} \ldots relationship\ value\ between\ CA\ and\ FR$

$W_m \ldots weighted\ importance\ rating\ of\ CA$

After calculating importance rating for each FR, Weighted importance ratings were calculated by dividing the value of importance rating for each FR by the summation of importance ratings for all FRs. Table 6 shows the results for the importance rating and weighted importance rating for each FR.

Table 6. FRs importance ratings and weighted importance ratings

FRs	Importance ratings	Weighted importance ratings	FRs	Importance ratings	Weighted importance ratings
A	178.95	4.0	K	223.68	5.0
B	171.05	3.8	L	346.49	7.7
C	204.39	4.5	M	195.61	4.3
D	215.79	4.8	N	281.58	6.2
E	292.11	6.5	O	170.18	3.8
F	165.79	3.7	P	202.63	4.5
G	372.81	8.3	Q	150.00	3.3
H	197.37	4.4	R	121.05	2.7
I	275.44	6.1	S	216.67	4.8
J	189.47	4.2	T	339.47	7.5
Total			100		

Depending on the results of the weighted importance ratings for the FRs, the design team can define the target value or the limits for each FR to be used to guide the tradeoff decisions in the next design phases.

V. CONCLUSION

CAs can be mapped into FRs that are considered as design requirements using QFD. Using QFD helps the design team to prioritize design requirements according to the customer needs represented by weighted importance ratings for CAs. In a case study for small hand launched UAV, the customer needs gave high priority to CAs like safe to operate, easy to operate and powerful camera (payload). When design team applied QFD to this case study, airframe structural design requirements, autopilot specifications, aircraft performance requirements, environmental conditions, engine specifications and reliability of commercial components scored highest priority level.

Conflict of Interest:

No potential conflict of interest was reported by the authors.

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