The Application of The House of Quality Matrix in Developing Work Time Measurement Technology Prototypes

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Abstract

The first-generation of Vision Sensor-based working time measurement technology has been developed and tested for laboratory-scale usage. This technology consists of hardware components involving the Pixy CMUcam5 integrated with the Arduino Uno Rev 3 with AT Mega 328P and the Logitech C930E series webcam. In addition, a study on user satisfaction with this technology has been carried out, in which recommendations were obtained for improvement. Therefore, this study was carried out to develop a prototype product of working time measurement technology using the house of quality (HoQ) matrix, which is the first stage in the application of the Quality Function Deployment (QFD) methodology. The HoQ matrix was an attempt to convert the voice of customers directly to the technical requirements or specifications of the product to be developed. The result obtained was a HoQ matrix, which consisted of 18 product attribute items as user needs and 9 technical requirements. Based on the relative weight value, the priority of technical requirements consisted of increasing durability and usage time, user-friendly application program features, technology functional optimization, application program feature upgrades, and adjustable application program features, increased technology automation, easy to apply and operate technology design, improved connectivity and benchmarking prices in the market.

Keywords
Product Development, Quality Function Deployment, House of Quality Time measurement technology.

1. Introduction
In the work system, standard time is a parameter for measuring or analyzing the performance of workers (Groover 2007). Furthermore, it is used to improve low process efficiency and production target determination. In other to make work measurements more effective and efficient, automated vision sensor-based working time measurement technology was developed, where the measurement results are more precise and real-time compared to the manual method using a stopwatch (Yuliani et al. 2019a).

This technology consists of hardware components involving the Pixy CMUcam5 integrated with the Arduino Uno Rev 3 with AT Mega 328P and the Logitech C930E series webcam. Furthermore, the programming language used to support hardware motion was the Visual Studio 2015. The Pixy CMUcam5 is able to detect human movements by color sensing and generates output in the form of coordinates, while the Arduino Uno Rev 3 with AT Mega 328P measure and convert the generated coordinates as a command to start and end the working time measurement. Meanwhile, the measured cycle time is saved for further processing (Yuliani et al. 2019a).

A prototype of the vision sensor-based working time measurement technology is shown in Figures 1 and Figure 2.

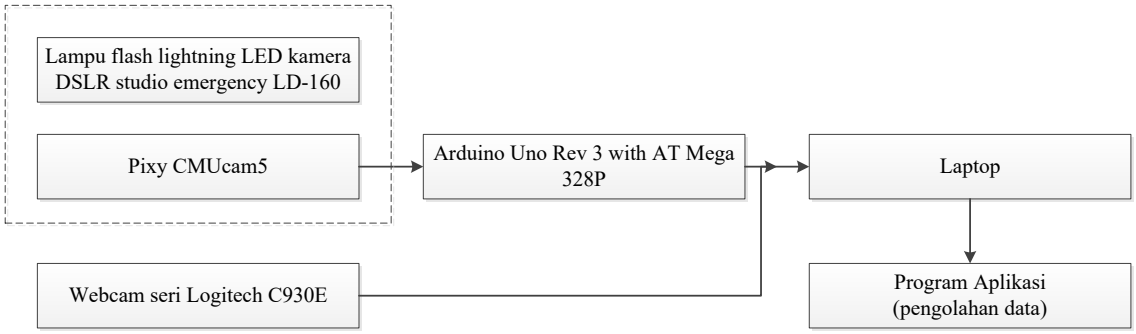

Figure 1. Hardware component integration concept (Yuliani et al. 2019a).

Figure 2. Integrated vision sensor technology with laptop (Yuliani et al. 2019a).

This technology has been previously tested in a study for its usability and user satisfaction, in which recommendations for improvement were contained (Yuliani et al. 2019).

Yuliani et al. (2019b) used the HoQ matrix in developing *Klikpak* food packaging products, which yielded 12 attributes of customer needs and 5 technical needs. Based on the relative weight value, the order of priorities consisted of 5 items: (1) improving quality, (2) planning the draft pattern, (3) planning of cost estimation, (4) Paper material selection, (5) Planning a new product development process.

1.1 Objectives

This study aims to develop a prototype product of working time measurement technology on vision sensors using the house of quality (HoQ) matrix which is the first stage in the application of the Quality Function Deployment (QFD) methodology. The HoQ matrix was an attempt to convert the voice of customers directly to the technical requirements or specifications of the product to be developed.

2. Methods

To easily carry out this study, the operational variables were first defined, followed by the characteristics of customer needs, shown in Table 1.

Table 1. Definitions of operational variables

Variable	Product dimensions	Question attribute	Measuring scale	Research instrument
Customer Needs	Performance	1. Automated technology	Interval	Questionnaire
		2. Fast, real time and precise technology		
		3. Synchronized technology		
		4. Integrated technology		
	Features	5. Application program features are easy to understand and use	Interval	Questionnaire
		6. The time setting feature can be adjusted		
		7. Completeness of application program features		
		8. Connected technology components		
	Durability	9. Long service life of equipment	Interval	Questionnaire
	Price	10. Affordable technology prices	Interval	Questionnaire
		11. Technology prices according to quality and benefits		
	Product design	12. Technology is easy to operate	Interval	Questionnaire
		13. Technology easy to assemble		
		14. Technology is easy to disassemble		
	Product quality	15. Reliable technology	Interval	Questionnaire
		16. Real time and precise output		
	Customer satisfaction	17. Overall performance is good	Interval	Questionnaire
		18. Standard working time output		

Based on the Focus Group Discuss (FGD), 18 characteristics of customer needs were generated as the basis for product development, which is shown in Table 2.

Table 2. Identification result of statement attributes

No	Characteristics Results of Customer Needs
1	Technology can function automatically when operated
2	Technology can measure cycle time in fast, real time and precision
3	Technology can synchronize software programs with hardware when it is operated
4	Technology can integrate the collection process with data processing when it is operated
5	Application program on technology equipped with a data export button to Microsoft Excel format (as the final output)
6	Technology is designed with measurements in seconds
7	Features Completeness in the application program related to the data collection and processing process
8	Technology components are easily connected to each other
9	The service life of the equipment is designed to last a long time
10	Affordable technology prices in the market
11	Technology prices according to quality and benefits
12	Technology is easy to operate
13	Technology is easy to assemble when it will be operated
14	Technology is disassembly when it will be operated
15	Technology can measure working time reliably
16	Technology results in a good standard working time
17	The overall technology performance is good when it is operated
18	The resulting standard working time output is good

In developing a prototype of working time measurement technology based on the voice of customers (Yuliani et al. 2020), the house of quality (HoQ) matrix was used, which is the first stage in implementing the Quality Function Deployment (QFD) methodology. The HoQ matrix was an attempt to convert the voice of customers directly to the technical requirements or specifications of the product to be developed.

The steps employed in this study include:

1. **Part A, Determination of the Customer Needs and Benefits Matrix**
   This matrix contains a structured list of customers (user) needs which are directly translated from the voice of customers (voc).
2. **Part B, Determination of the Planning Matrix**
   The planning matrix is the competitive assessment of a customer, which consists of the product customer satisfaction level based on the customer satisfaction level towards existing products, products to be developed (expectations), improvement factor values, sales points, overall weighting and the percentage of each customer need to the overall weight of customer needs (% of total weighting).
3. **Part C, Determination of the Matrix Technical Response**
   The characteristic or technical response matrix is a list of technical requirements needed to meet each customer's need, which are obtained from the specifications that need to be met.
4. **Part D, Relationships Matrix/Impact**
   The relationship matrix is the reciprocal between the attributes of customer needs and each technical requirement. This relationship is between each technical requirement and customer's need.
5. **Determination of the Correlation Matrix**
   The correlation matrix is the relationship between each technical requirement. It is used to identify the relationship between each technical requirement with one another.
6. **Determination of the Technical Importance Matrix**
   This is the final step in the preparation of HoQ 1 and there are 2 information:
   1. The rating that has been calculated from the technical response.
   2. Target, where the target in product development is set.

3. Results and Discussion

3.1 Customer Needs (HoQ part A)

Customer needs (The What's) are attributes of statements or aspects that they require. It is shown in Table 3.

Table 3. Customer needs (the what's)

Product Dimensions	No	Customer's Needs	Characteristics of Customer's Needs
Performance	1	Automated technology	Technology can function automatically when operated
	2	Fast, real time and precise technology	Technology can measure cycle time in fast, real time and precision
	3	Synchronized technology	Technology can synchronize software programs with hardware when it is operated
	4	Integrated technology	Technology can integrate the collection process with data processing when it is operated
Features	5	Application program features are easy to understand and use	Application program on technology equipped with a data export button to Microsoft Excel format (as the final output)
	6	The time setting feature can be adjusted	Technology is designed with measurements in seconds
	7	Completeness of application program features	Features Completeness in the application program related to the data collection and processing process
	8	Connected technology components	Technology components are easily connected to each other
Durability	9	Long service life of equipment	The service life of the equipment is designed to last a long time

Table 3. Customer needs (the what's) (cont.)

Product Dimensions	No	Customer's Needs	Characteristics of Customer's Needs
Product Prices	10	Affordable technology prices	Affordable technology prices in the market
	11	Technology prices according to quality and benefits	Technology prices according to quality and benefits
Product Design	12	Technology is easy to operate	Technology is easy to operate
	13	Technology easy to assemble	Technology is easy to assemble (assembly) when it will be operated
	14	Technology is easy to disassemble	Technology easy to disassemble (disassembly) when it will be operated
Product quality	15	Reliable technology	Technology can measure working time reliably
	16	Real time and precise output	Technology results in a good standard working time
Customer satisfaction	17	Overall performance is good	The overall technology performance is good when it is operated
	18	Standard working time output	The resulting standard working time output is good

3.2 Determination of the Planning Matrix (HoQ part B)

Table 4 shows the planning matrix (HoQ part B).

Table 4. Planning matrix

No.	Question attribute	Satisfaction	Expectation
1	Technology can function automatically when operated	4.917	4.583
2	Technology can measure cycle time in fast, real time and precision	4.750	4.667
3	Technology can synchronize software programs with hardware when it is operated	4.917	4.667
4	Technology can integrate the collection process with data processing when it is operated	4.750	4.750
5	Application program on technology equipped with a data export button to Microsoft Excel format (as the final output)	4.667	4.583
6	Technology is designed with measurements in seconds	4.583	4.583
7	Features Completeness in the application program related to the data collection and processing process	4.333	4.833
8	Technology components are easily connected to each other	4.500	4.917
9	The service life of the equipment is designed to last a long time	4.667	4.583
10	Affordable technology prices in the market	4.667	4.667
11	Technology prices according to quality and benefits	4.667	4.750
12	Technology is easy to operate	4.500	4.917
13	Technology is easy to assemble (assembly) when it will be operated	4.500	4.833
14	Technology easy to remove (disassembly) when it will be operated	4.583	4.917
15	Technology can measure working time reliably	4.583	4.667
16	Technology results in a good standard working time	4.500	4.583
17	The overall technology performance is good when it is operated	4.750	4.750
18	The resulting standard working time output is good	4.750	4.667

3.3 Technical Response (HoQ part C)

Technical responses (How's) are the translation of customer needs into technical requirements based on FGD. In this process, there is a translation process called Substitute Quality Characteristics (SQCs), which has a direction of improvement used to show performance in the product planning process of a prototype technology for measuring work time to be achieved according to customer needs. The repair direction symbol and technical response are shown in Table 5 and Table 6, respectively.

Table 5. Repair symbols

Symbol	Description
▼	Bad target
▲	The target is getting better
X	The best target

Table 6. Technical response (the how's) and improvement direction

No.	Technical response (How's)	Characteristics of the Technical Response (How's)	Symbol
1	Improved technology automation	Improve work time automation technology	▲
2	Technology functional optimization	Optimizing the functional work time technology (hardware and software)	▲
3	User-friendly application program features	Application program features are easy to apply (user friendly)	▲
4	Adjustable application program features	Developing application program features to be more flexible (Adjustable)	▲
5	Upgrade application program features	Upgrade application program features	▲
6	Improvement connectivity	Reducing components more effectively and efficiently (component connectivity improvement)	▲
7	Increased durability and usage time	Increase durability and work time technology usage time	▲
8	Market price benchmarking	Benchmarking market prices with competitors	▲
9	The technology design is easy to apply and operate	Designing work time technology for easy application and operation	▲

3.4 Determination of the Relationship Matrix (HoQ part D)

The relationship matrix is a reciprocal of the relationship between customer needs (in Software QFD Language: Demanded Quality or What's) and technical responses (in Software QFD Language: Quality Characteristics or How's) based on FGDs between researchers and participants. The relationship matrix symbols are shown in Table 7, the results of the relationship matrix are shown in Figure 3.

Table 7. Relationship matrix symbols

Symbol	Description	Score
Blank	Not related	0
▲	Little related	1
O	Related	3
Θ	Very related	9

Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / **Demanded Quality** (a.k.a. "Customer Requirements" or "Whats")	Improved technology automation	Functional optimization of technology	User friendly application program features	Udjustable application program features	Upgrade application program features	Improvement of connectivity	Increased durability and usage time	Benchmarking prices on the market	The technology design is easy to apply and operate
Automated technology	⊙	O	O	▲	▲	O	▲		O
Fast, real time and precision technology	O	⊙	O	⊙					O
Synchronized technology	⊙	O	O	⊙	▲	O			O
Integrated technology	⊙		O	O	▲	O			O
The application program features are easy to understand and use			⊙	O	O				▲
The time adjustment feature can be adjusted			O	⊙	O				▲
Completeness of application program features	O			O		⊙			▲
The technology component is connected	O					⊙			▲
The equipment usage life lasts longer	▲				▲		⊙	▲	
Affordable technology prices	▲						▲	⊙	O
The price of technology is in accordance with the quality and benefits								⊙	O
Easy to operate technology	O	O	O						⊙
Easy to assemble technology	O								⊙
Easily removable technology	O								⊙
Reliable technology		⊙			⊙	⊙			
Real time output and precision		⊙	O			⊙			
Overall good performance		⊙	O			⊙			
Standard working time output		⊙	O			⊙			

Figure 3. Relationship matrix

3.5 Determination of the Technical Correlation Matrix

The Technical Correlations Matrix is a policy determination on the relationship between technical responses based on FGD and QFD Software assistance. The technical correlation matrix symbols are shown in Table 8. The results of the correlation matrix provisions are shown in Tables 9 and Table 10. The target technical response characteristics are shown in Table 12.

Table 8. Symbols of the technical correlation matrix

Symbol	Description
++	Strong positive influence
+	Positive influence
−	Negative influence
▼	Strong negative influence

Table 9. Result technical correlations matrix (strong positive influence ++)

No.	Technical Response Characteristics (How's)	No.	Other Technical Response Characteristics (How's)
1	Improve the automation of working time technology	2	Optimize functional working time technology (hardware and software)
		3	The application program features are easy to apply (user friendly)
		4	Develop application program features to be more flexible (adjustable)
		5	Upgrade application program features
		6	Reducing components more effectively and efficiently (improvement of component connectivity)
		8	Benchmarking prices in the market with competitors
		9	Designing working time technology so that it is easy to apply and operate
2	Optimize functional working time technology (hardware and software)	3	The application program features are easy to apply (user friendly)
		4	Develop application program features to be more flexible (adjustable)
		5	Upgrade application program features
		6	Reducing components more effectively and efficiently (improvement of component connectivity)
		8	Benchmarking prices in the market with competitors
		9	Designing working time technology so that it is easy to apply and operate
3	The application program features are easy to apply (user friendly)	4	Develop application program features to be more flexible (adjustable)
		5	Upgrade application program features
		6	Reducing components more effectively and efficiently (improvement of component connectivity)
		8	Benchmarking prices in the market with competitors
		9	Designing working time technology so that it is easy to apply and operate
4	Develop application program features to be more flexible (adjustable)	5	Upgrade application program features
		6	Reducing components more effectively and efficiently (improvement of component connectivity)
		8	Benchmarking prices in the market with competitors
		9	Designing working time technology so that it is easy to apply and operate
5	Upgrade application program features	8	Benchmarking prices in the market with competitors
		9	Designing working time technology so that it is easy to apply and operate
6	Reducing components more effectively and efficiently (improvement of component connectivity)	7	Increase the durability and time of use of work time technology
		8	Benchmarking prices in the market with competitors
		9	Designing working time technology so that it is easy to apply and operate
7	Increase the durability and time of use of work time technology	8	Benchmarking prices in the market with competitors
8	Benchmarking prices in the market with competitors	9	Designing working time technology so that it is easy to apply and operate

Table 10. Result technical correlations matrix (positive influence ┼)

No.	Technical Response (How's)	No.	Other Technical Response Characteristics (How's)
1	Improve the automation of working time technology	7	Increase the durability and time of use of work time technology
2	Optimize functional working time technology (hardware and software)	7	Increase the durability and time of use of work time technology
4	Develop application program features to be more flexible (adjustable)	7	Increase the durability and time of use of work time technology
5	Upgrade application program features	6	Reducing components more effectively and efficiently (improvement of component connectivity)
		7	Increase the durability and time of use of work time technology
7	Increase the durability and time of use of work time technology	9	Designing working time technology so that it is easy to apply and operate

3.6 Determination of the Technical Interest Matrix

The technical importance matrix is the result of determining the level of difficulty and targets in the process of achieving technical requirements. The level of difficulty was generated from the weight value and relative weight. The difficulty level values between 1-5 include: (1) = focus achieved is low, (2) = focus achieved is quite low, (3) = focus achieved is high, (4) = focus achieved is very high (5) = focus achieved is absolutely high. The level of difficulty is shown in Table 11 and the target technical response characteristics are shown in Table 12.

Table 11. Level of difficulty

Difficulty (1=Easy to Accomplish, 5=Extremely Difficult)	4	3	6	5	8	1	9	7	2
Max Relationship Value in Column	9	9	9	9	9	9	9	9	9
Weight / Importance	263.9	284.2	179.1	189.3	94.5	365.1	47.9	102.8	301.0
Relative Weight	10.0	10.8	6.8	7.2	3.6	13.9	1.8	3.9	11.4

Table 12. Target technical response characteristics

No.	Characteristics of the Technical Response (How's)	Target or Limit Value
1	Improve work-time technology automation	Manufacturing standardization
2	Optimizing the functionality of work time technology (hardware and software)	Manufacturing standardization
3	Application program features are easy to apply (user friendly)	Manufacturing standardization
4	Developing application program features to be more flexible (adjustable)	Manufacturing standardization
5	Upgrade application program features	Manufacturing standardization
6	Reducing components more effectively and efficiently (component connectivity improvement)	Manufacturing standardization
7	Improve durability and work time technology usage time	Usability testing
8	Benchmarking market prices with competitors	Competitor benchmarking
9	Designing work time technology for easy application and operation	Manufacturing standardization

The complete house of quality (HoQ) matrix is shown in Figure 4.

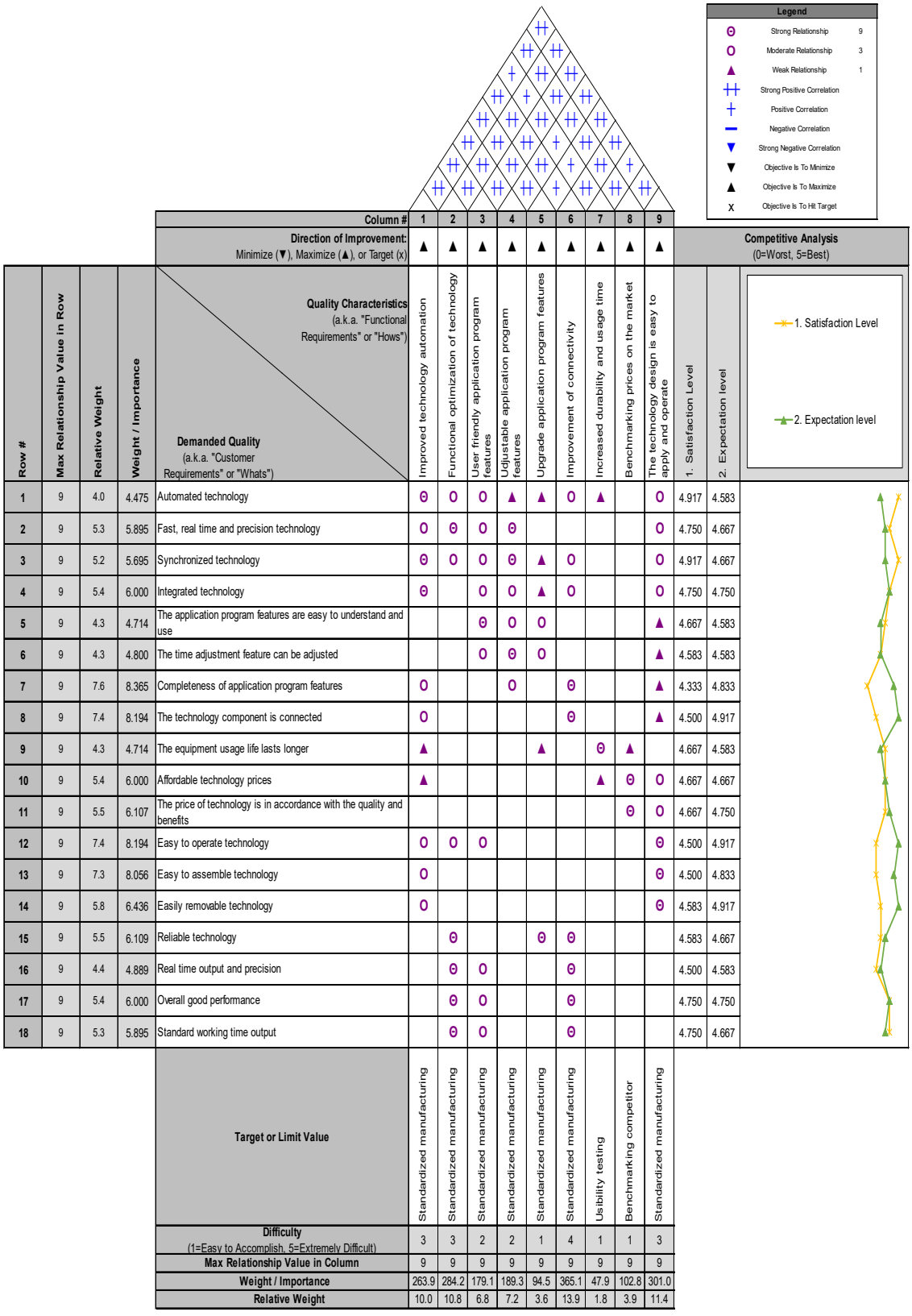

Figure 4. House of quality matrix

4. Conclusion

The house of quality matrix produces 18 product attributes as customer needs and 9 technical requirements. Based on the relative weight values, the priority order was set on 9 technical requirements, which includes increased durability and usage time, user-friendly application program features, technology functional optimization, application program feature upgrades, adjustable application program features, increased technology automation, Easy to apply and operate technology design, connectivity improvement and benchmarking market prices.

Acknowledgment

The authors are grateful to the Ministry of Research, Technology and Higher Education, Rector of Mercu Buana University, Director of Research and Technology, Publications and Domestic Cooperation, Head of Research Center, Dean of the Faculty of Engineering, Chair of the Industrial Engineering Study Program, CV. Marcom, and all those that helped in this research. This research was funded by the Ministry of Research, Technology and Higher Education Grant.

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