Penerbit UTHM

JAMEA

http://penerbit.uthm.edu.my/ojs/index.php/jamea

e-ISSN : 2716-6201

Journal of Advanced Mechanical Engineering Applications

Improvement of Transfer Wheel Marker Design Using the Quality Function Deployment (QFD) Method for School Field Line Marking

Yasmin Syaliana Roslan[1]*, Mohd Fahrul Hassan[1], Izza Hamdan[1], Mohd Hafiz Tuparman[2]

[1]Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, MALAYSIA

[2]Politeknik Tun Syed Nasir Syed Ismail,
Kementerian Pendidikan Tinggi, Hub Pendidikan Tinggi, KM1, Jln Panchor, 84600 Pagoh, Muar, Johor, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/jamea.2023.04.01.005
Received 30 November 2022; Accepted 28 December 2022; Available online 28 June 2023

Abstract: The line marking of sports fields is a must-do activity in every school in Malaysia since most of the schools only have one field that is used for many sports activities. There are many concept designs of sport line markings in the market, but the most common design used in Malaysia is a transfer wheel marker. However, the machine lacks many aspects, including clogging problems due to the loose grass, soil sticking to the marker wheel, and its unstable tyre, which may cause the line marking process time becomes longer and more difficult. Therefore, this study proposes to improve the design of the transfer wheel marker using the Quality Function Deployment (QFD) method. Based on the QFD method, a House of Quality (HoQ) in the first phase was applied, where a questionnaire was created using the information obtained from interviews with school teachers to quantify the needs. The collected data was then analyzed in the HoQ to determine the final ranking of engineering characteristics. With a relative weight of 14.45%, the handle height is ranked first as the characteristic that needs improvement. The second ranking order is the amount of wasted paint at 14.08% and the third ranking is tyre friction which is 11.86% relative weight. Hence, the identified three priority components will lead to the improvement of the transfer wheel marker design.

Keywords: Transfer wheel marker, line marking machine, school field, QFD

1. Introduction

School is known as a place where kids begin to develop their passion for sports. Sports are not only good for their physical health but also help to maintain their mental health. There are many sports available in Malaysia and to make sure kids have easy access to playing sports, schools in Malaysia are equipped with fields where sports like football, hockey, track and field, and rugby can be held. Every year, each school conducts a sports day and various games are contested. As we know, different sports have different line marking due to their rules. Therefore, a line marking machine is an important tool in each school. Since regular line markings on sports pitches have existed since the 19th century, many types of line marking machines have been introduced [1]. Line marking machines have undergone a revolution due to the usage of current plastics and design technology. They are available in various shapes, sizes, and systems. There are several types of line marking machines with different purposes and unique ways to handle them.

*Corresponding author: yasminsyaliana@gmail.com

However, small education centres like schools in Malaysia still stick to the basic design of line marking machines, named a Transfer wheel marker. These machines are designed to be used in grassy areas. It is a wheel-to-wheel marker that applies paint by transferring paint to the grass via three transfer wheels.

Based on interview sessions with a few teachers from different schools, it is known that the transfer wheel marker was used two to four times a year and each time, it takes three to four hours to draw lines for one sports pitch. This shows that users require a lot of time to create a pitch line since the machine used is lacking in many ways. The main concern for this machine is the clogging issue due to the loose grass and soil that sticks to the marker wheel and its unstable tyre, making it difficult to move. In connection with this matter, a method that does not conflict with customer needs is needed to improve the machine design.

Quality Function Deployment (QFD) is a visual connective process that helps teams focus on the customers' needs throughout the total development cycle. This efficiently recognizes customer requirements and transforms them into relevant technical requirements for each stage of the development of a product or process life cycle [2]. According to claims, QFD may cut start-up and research expenditures by 30% and production time by 50% [3]. QFD may assist businesses in making crucial trade-offs between what customers want and what they can afford to build. Less time will be spent on redesigning and changing the product/process by concentrating efforts on what will best please the consumers and the company. Additionally, it fully satisfies the client's expectations [4]. Nothing new is accomplished by QFD, but a systematic methodology takes the place of the erratic, intuitive decision-making processes that existed before. Therefore, QFD is chosen as a method to improve the Transfer wheel marker's design.

Many industries have continued to use the QFD method to improve their market system in recent years. In 2019, a group of students from Ahmad Dahlan University did a study about trashcan design using the QFD method for campus garbage separation. This study successfully proposed a trashcan design that fits all the customer needs [5]. Other than that, QFD was also used for the improvement of safety and quality of street food packaging design in 2021 by Effendi Mohamad and his team [6]. In the same year, Yohanes and his partner Muhammad Idris made a study about biomass stove design based on QFD and design for manufacture and assembly (DFMA) to find a solution for the lack of LPG gas in the community in Batu Panjang, Rupat Island, Riau [7]. Initially, QFD was being used in product development, but the need for quality in the education sector has forced various authors to apply it in the education sector too. In 2018, Ajit Kumar Singh and A.M. Rawani published review stating that the great outcomes of the application of QFD in various educational schemes are categorized as engineering education, management education, curriculum redesign and some other fields [8]. This shows that QFD is applicable in various sectors.

2. Methodology

2.1 Voice of Customer (VOC)

The first step that needs to be done before conducting the House of Quality (HoQ) is gathering the VOC. The VOC summarizes customers' expectations, preferences, and aversions. Customer feedback is important as it will help ensure that organizations provide the features that customers want and require [9].

Before creating a questionnaire, a pilot interview is conducted. To determine the issue encountered and the customer requirements (CRs) of the transfer wheel marker, an interview with the machine users are conducted. Four teachers from different schools were interviewed and the questions were created based on Garvin's eight (8) quality dimensions as follows:

- What is your opinion about the performance of the current design of the Transfer wheel marker?
- What additional features would you wish to add to the Transfer wheel marker?
- What is the size and weight of the Transfer wheel marker preferred?
- Do you think the shape of the current transfer wheel marker is satisfactory enough?
- Is the current transfer wheel marker can be used for a long time?
- Do you think that the current transfer wheel marker is durable?
- What do you think about the maintenance of the Transfer wheel marker?
- How much would you pay for a transfer wheel marker?

The data collected from the interview were converted into customer requirements (shown in Table 1) and used in the questionnaire to get respondents' perceptions. The questionnaire was distributed among teachers from Johor, Selangor and Perak to prove that most schools in Malaysia use the same type of line marking machine, that is, Transfer wheel marker.

2.2 Engineering Characteristics (ECS)

Engineering characteristics are the technical performance traits of a product at the system level that affect consumer attributes [10]. The ECs were based on VOC and must be quantifiable or measurable to be used for design [5]. The ECs are shown in Table 2.

Table 1 - List of customer requirements

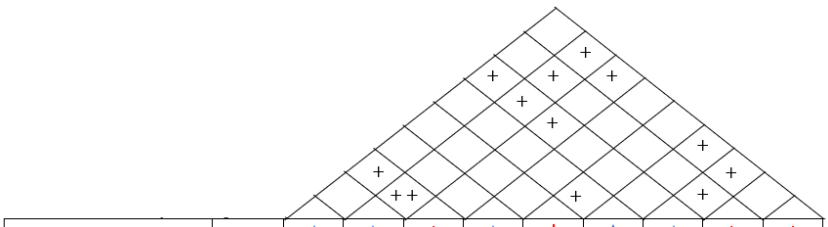
No	Customer Requirements (CRs)	No	Customer Requirements (CRs)
1	Type of wheel	7	Easy to maintain
2	Large tank size	8	Multipurpose
3	Lightweight	9	Produce perfect line
4	Ergonomic design	10	Does not collect soil and grass
5	Comfortable handle	11	Low maintenance cost
6	Stable and durable	12	Low selling price

Table 2 - List of engineering characteristics

No	Engineering Characteristics (ECs)	No	Engineering Characteristics (ECs)
1	Tyre friction (N)	6	Durability (years)
2	Size of tank (m^3)	7	Line produced per time (s^{-1})
3	Weight (kg)	8	Amount of wasted paint (L)
4	Height of handle (m)	9	Production cost (RM)
5	Heat absorbed by handle (kJ)		

2.3 House of Quality (HOQ)

The final step is to construct the House of Quality (HoQ) which shows the relationship between the voice of the customer and engineering characteristics. There are three main steps in HoQ. The first is to determine the correlation matrix which is placed on the roof of HoQ. It is indicated with a positive and negative sign to indicate whether each ECs are related to the other. Next is to identify the relationship matrix. It is the relationship between the intersection of the rows of CRs with the columns of ECs. The scale of 0, 1, 3 and 9 represents the strength of the relationship. The last procedure of HoQ is calculating the importance ranking. This ranking allows us to focus on ECs in order from the most to the least relevant to satisfy the CRs. The HoQ can be seen in Fig.1.



Improvement direction		↑	↑	↓	↑	↓	↑	↑	↓	↓
Engineering characteristics / Customer requirements	Importance weight factor	Tyre friction (N)	Size of tank (m^3)	Weight (kg)	Height of handle (m)	Heat absorbed by handle (kJ)	Durability (years)	Line produced per time (s^{-1})	Amount of wasted paint (L)	Production cost (RM)
Type of tyre	3.92	9								1
Large tank size	3.61	1	9	3				1	1	1
Lightweight	3.88	1	3	9						
Ergonomic design	3.61				9	1				
Comfortable handle	3.97				9	9				1
Stable and durable	4.14	3	1	1	1		9			
Easy to maintain	4.25			1					3	
Multipurpose	3.92							3		
Produce perfect line	4.19	1						9	1	
Does not collect soil/grass	4.19								9	
Low maintenance cost	4.08		1				3	1	3	
Low selling price	3.83									9
Raw score	500.7	59.38	52.35	54.14	72.36	39.34	49.50	57.16	70.5	45.97
Relative weight %		11.86	10.46	10.81	14.45	7.86	9.89	11.42	14.08	9.18
Rank order		3	6	5	1	9	7	4	2	8

Fig. 1 - House of quality of the transfer wheel marker

3. Results and Discussion

Based on the QFD in Fig. 1, the results of the important engineering characteristics ranking are shown in Table 3. Only the top three of ECs based on the ranks are selected to improve this machine.

Table 3 - Ranks of ECs

Ranks	Engineering Characteristics
1	Height of handle
2	Amount of wasted paint
3	Tyre friction
4	Line produced per time
5	Weight
6	Size of tank
7	Durability
8	Production cost
9	Heat absorbed by the handle

The QFD shows that the customer prioritized the height of the handle whereas, in the old design of the transfer wheel marker, the handle height was fixed, which does not fit everyone's height. It makes the user feel uncomfortable using the machine for a long period. Next is the amount of wasted paint. Wasted paint happens when soil or grass sticks on the transfer wheel and is mixed up with the clean paint in the tank. Once the paint is polluted, the line cannot be drawn smoothly. Therefore, they need to remove the tank's entire paint and replace it with new paint. This problem not only affects the amount of paint but also requires a lot of time and energy for cleaning. The final point that will be discussed is tyre friction, where the current machine uses a flat steel tyre that does not have any grip on the ground surface and makes it more challenging to move, especially on uneven ground.

3.1 Preliminary Concept Design

Based on the analysis, a preliminary concept design of the proposed line marking machine has been made. Fig. 2 shows the existing transfer wheel marker design used by the school. Meanwhile, the proposed design of the line marking machine can be seen in Fig. 3. The comparison between both machines is discussed in Table 4.

Fig. 2 - Old transfer wheel marker

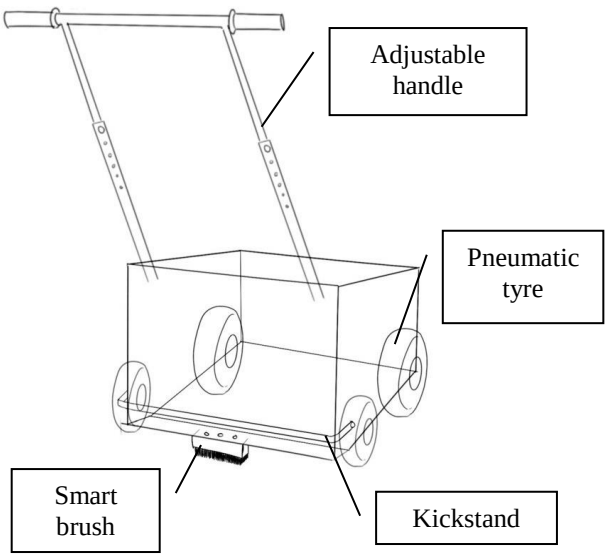


Fig. 3 - Concept design of new line marking machine

The new concept design proposed consists of three main improvements which focused on the top three ranks of ECs. The first innovation is an adjustable handle. It is made up of two rods connected by a screw with a 6-point height adjustment. The height can be adjusted from 90cm to 115cm with a 5cm increment at each point. This handle will fit

users' ergonomic height. Next is the smart brush system which is a replacement for the wheel to transfer paint to the ground. The smart brush is placed at the back of the tank with some holes to flow the paint from the tank to the brush automatically. With the slanted-shaped tank, the paint will always flow to the brush. To stop the paint from flowing, the user can use the kickstand to raise the back part of the tank. This brush system will prevent the paint from being polluted by soil and grass and at the same time reduce the amount of paint wasted by the machine. The width of the brush will follow the line width which is 3 inches. A final innovation for this machine will focus on its tyre. The flat steel tyre is replaced with a pneumatic tyre with thread which will help to grip the uneven ground while moving smoothly and ensure the line is produced perfectly and straighter. The front and the back tyre size is different due to the slanted tank. The front tyre needs to be double in size to support the tank.

Table 4 - Comparison of line marking machine

Old Transfer Wheel Marker	Characteristics	Smart Brush Line Marker
• Fixed height - 100cm • Not ergonomic • Easily detached from the body	Handle	• Adjustable 6-point height - 90cm to 115cm • Ergonomic • Does not detach easily
• Transfer wheel system • Collect loose soil and grass • Waste a lot of paint • Require extra energy to maintain • Wheel size is 3 inches wide	Paint transfer system	• Smart brush system • Does not collect loose grass and soil • Reduce the amount of paint used • Easy to maintain • Brush size is 3 inches wide
• Steel tyre with a smooth surface • Does not grip the ground • Have 2 tyres • Diameter of tyre is 10cm	Tyre	• Pneumatic tyre with thread • Grip the ground nicely • Have 4 tyres • Diameter of the back tyre is 10cm while the front tyre is 20cm

4. Conclusion

In conclusion, this research aims to provide ideas for improving a line marking machine using the QFD method. Transfer wheel marker is the type of line marking machine that is commonly used in sports field preparation in small education centres like schools in Malaysia, but the user of the basic transfer wheel marker faces some difficulties. Therefore, QFD can improve the difficulties according to the customer needs and engineering characteristics. The results of QFD were obtained with the help of users' responses in the survey form. Nine ECs were successfully ranked based on their priorities. The top three of ECs were chosen for the improvement plans among the nine engineering characteristics listed. The handle was made adjustable so that it can fit everyone's height and be more ergonomic. The next issue solved is the amount of wasted paint where the transfer wheel system is improved into a brush system. This system will reduce the paint usage and time required for maintenance. Finally, the customer's concern about the tyre is also resolved by changing the steel tyre into a pneumatic tyre that has a good grip on the ground and improves the line quality. The next action after this study is creating a detailed design of the machine by using the software. The aim is to have exact dimensions and suitable materials used for the machine.

Acknowledgement

The authors would like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for the support in implementing the research.

References

[1] "The Art of Linemarking," PitchCare, 11 Aug 2010. [Online]. Available: https://www.pitchcare.com/news-media/the-art-of-linemarking.html. [Accessed 8 Nov 2022].

[2] Vivianne Bouchereau, Hefin Rowlands, "Methods and techniques to help quality function deployment (QFD)," *Benchmarking: An International Journal*, pp. 8-19, 2000.

[3] Clausing, D., Pugh, S., "Enhanced quality function deployment," *Proceedings of the Design Productivity International Conference*, pp. 15-25, 1991.

[4] R. Wolniak, "The use of QFD method advantages and limitation," *Production Engineering Archives 18*, pp. 14-17, 2018.

[5] Endah Utami, Okka Adiyanto, Zahrul Mufrodi, "The Trashcan Design Using Quality Function Deployment

(QFD) Method for the Campus Garbage Separation," *Advances in Engineering Research*, vol. 189, pp. 26-29, 2019.

[6] Effendi Mohamad, Muhammad Faishal, Azrul Azwan Abdul Rahman, Shabilla Desviane, Alfian Ramawan, Mohamad Ridzuan Jamli, Okka Adiyanto, "Safety and quality improvement of street food packaging design using Quality Function Deployment," *The International Journal of Integrated Engineering*, vol. 13, no. 1, pp. 19-28, 2021.

[7] Yohanes, Muhammad Idris, "Biomass Stove Design Based Quality Function Deployment (QFD) and Design for Manufacture and Assembly (DFMA)," Journal of Ocean, Mechanical and Aerospace, vol. 65, no. 3, pp. 94-99, 2021.

[8] Ajit Kumar Singh, A.M. Rawani, "Application of QFD in education sector: A review," *International Journal of Mechanical Engineering and Technology (IJMET)*, vol. 9, no. 3, pp. 592-599, 2018.

[9] S. Amsler, "Definition of Voice of the Customer," Tech Target, July 2020. [Online]. Available: https://www.techtarget.com/searchcustomerexperience/definition/voice-of-the-customer-VOC. [Accessed November 2022].

[10] Rajan Ramaswamy, Karl Ulrich, "Augmenting the House of Quality with Engineering Models," *Research in Engineering Design*, vol. 5, pp. 70-79, 1993.