International Journal of Technology

http://ijtech.eng.ui.ac.id

Research Article

Bitewing Holder and Support Product Design Using Quality Function Deployment

Rosnani Ginting [1,*], Humala Napitupulu [1], Aulia Ishak [1], Supranata [1]

[1]*Department of Industrial Engineering, Faculty of Engineering, Universitas Sumatera Utara, Medan, North Sumatra, 20222, Indonesia*

[*]*Corresponding author: rosnani@usu.ac.id; Tel.: 061-8213251; Fax.: 061-8213251*

Abstract: Conventional dental radiographic examination using bitewing is widely known to cause nausea and unclear radiographic images, due to pressure on the mouth wall and patient movement, respectively. This discomfort often leads to patient non-compliance, making it challenging to obtain accurate diagnostic results. These issues were observed in 10 dental clinics on Jalan Jamin Ginting. To address the problems, a product improvement design was implemented using Quality Functions Development (QFD). In Phase I, QFD produced technical specifications such as adding buffer foam and replacing iron material used in bitewing support with aluminium, while Phase II identified priority critical parts such as shortening the dimensions of the bitewing holder with a support. The product redesign includes the addition of buffer foam for enhanced comfort for patient, the substitution of iron with aluminium to reduce weight of the product, as well as the adjustment of bitewing holder and support dimensions to 3.5 cm and 19.5 cm, respectively.

Keywords: Bitewing; Design; Dimension; Product; Quality function deployment

1. Introduction

Medical devices are instruments, equipment, machines used in health services (Siddique et al., 2021). These devices serve as tools for the prevention, diagnosis, or treatment of disease, facilitating the detection, measurement, restoration, repair, or change of the body structure and functions for health purposes (Liu et al., 2019). An example is a radiograph, which is crucial for visualizing the hard tissues of the oral cavity, enabling differential diagnosis and evaluation of dental abnormalities (Yusro and Sianturi, 2018).

Bitewing is a radiographic tool designed to show the crowns of maxillary and mandibular teeth in one film. It is primarily used by dentists in examining the intraoral (oral cavity), detecting patient complaints, and monitoring the development of caries or cavities post-treatment (Moharrami et al., 2023). The procedure includes inserting the holder into the mouth cavity, positioning the film holder, and exposing the film to radiation for capturing the examination images. However, issues can arise during the usage, complicating the task of the dentist (Astuti and Febriansyah, 2017). Complaints about bitewing products present the need for an improved design to enhance functionality and patient comfort. Addressing these issues is critical to improving the ability of the dentist to administer effective treatment. Bitewing produced by PT. X, is sourced from an online marketplace. The detailed specification are shown in Figure 1.

The bitewing consists of several components with specific specifications. The bitewing holder has a length of 4.1 cm, weighs 50 grams, and is made of soft acrylic in yellow color. The bitewing support measures 20.3 cm in length, weighs 250 grams, and is made of iron with a silver color. The x-ray sensor has a diameter of 6.5 cm, weighs 100 grams, and is made of plastic in yellow color.

https://doi.org/10.14716/ijtech.v16i2.6557
Received July 2023; Revised August 2023; Accepted August 2023

The design of bitewing product improvements is based on complaints identified through survey (Bahia et al., 2023). Data was collected by distributing preliminary questionnaires to 10 dentists located on Jalan Jamin Ginting, Medan Selayang District to obtain feedbacks. The most frequent complain was nausea due to pressure on the mouth wall. Another significant issue was the clarity of radiographic images, which was often compromised by patient movement. This necessitates a plan for product improvement (Avikal et al., 2020). Supporting study by (Astuti and Febriansyah, 2017) also stated that bitewing products usage causes nausea in patients, presenting the need to shorten the dimensions of the holder.

To address the issue, the Quality Functions Deployment (QFD) method was adopted. QFD is a structured methodology used in product planning and development to ensure that consumer needs and desires are met (Siwiec et al., 2023). This was conducted by integrating user requirements with business goals, focusing on the wants and needs of customers. (Ginting, 2022). In Phase I of QFD, the degree of importance of additional customer needs and desires, referred to as technical characteristics, was determined (Abonyi and Czvetkó, 2022). Meanwhile, Phase II, the relative importance of design requirements, known as critical parts, was examined (Wu and Liao, 2021).

2. Methods

In this study, the sample comprised of 10 dentists as respondents, determined using the Harry King Nomogram method with an error rate of 5% (Hartono et al., 2017). These respondents were selected to address problems such as patient nausea due to pressure on the mouth wall and unclear radiographic images attributed to movement. (Sugiyono, 2018).

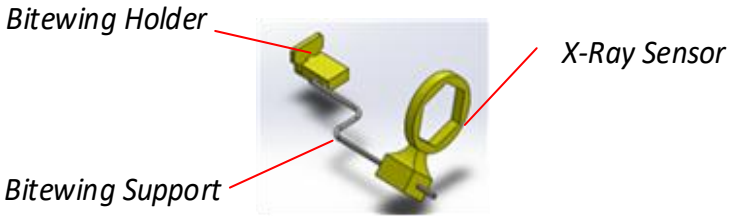


Figure 1 Bitewing Parts and Product

2.1. Quality Function Deployment Phase I

Phase I of QFD includes building a House of Quality (HoQ) matrix according to the stages outlined in the procedures of (Sugiono et al., 2022)

1. Determine Consumer Needs (Neira-Rodado et al., 2020)

Consumer needs were identified through surveys using open, closed, and canoe questionnaires. (Coşkun and Kazan, 2023)

2. Determine the Level of Importance of Attribute / Customer Importance (Gavahi et al., 2022)

The level of importance was assessed to understand the extent of consumers expectation (Sundaram and Zeid, 2023). This was based on the mode value from closed questionnaire (Habib et al., 2023), signifying the frequency of the most responses for each variable (Przystupa, 2023)

3. Define product characteristics (Avikal et al., 2020)

Technical characteristics were determined through discussions and interviews with the company.

4. Establish the relationship between technical characteristics (Shen et al., 2022)

The relationship between each technical characteristic was analyzed to determine the mutually supportive (positive) or contradictory (negative) status. The following show the the degree of these relationships:

a. Relationship level exists.
b. The degree of positive relationship is strong.
c. Moderate level of positive relationship.
d. No connection.

e. Moderate level of negative relationship.
f. The degree of negative relationship is strong.

5. Determine the Level of Relationship Between Technical Characteristics and Consumer Needs (Zhang et al., 2022)

Relation matrix was used to evaluate the relationship between consumer desires and the technical characteristics of the product. The level of relationship consists of a scale of strong, medium, weak, and not related at all. The assessment was performed based on the following rules:

a. 9 : Shows a strong relationship.
b. 3 : Indicates a moderate relationship.
c. 1 : Indicates a weak relationship.
d. 0 : Indicates no relationship at all.

6. Determine the planning matrix (Shang et al., 2022)

The planning matrix was designed to assess consumer satisfaction with the product. Furthermore, its preparation aimed to obtain the order or priority of the consumer variable needs. The planning matrix is the result of calculations from several types of data and consists of the following stages

a. Measuring the level of consumer satisfaction with the product (Ishak et al., 2020)
b. Calculating the value of the improvement ratio (improvement ratio) for each variable level of interest (expectation) (Rianmora and Werawatganon, 2021)
c. Set a "sales point" for each variable needs (de Oliveira et al., 2020)
d. Calculating the planning weight (absolute) for each variable (Ginting et al., 2015)
e. Calculating relative planning weights for each variable (Shvetsova et al., 2021).

7. Build a Phase I House of Quality Matrix (Fazeli and Peng, 2022)

The technical matrix on performance measures from HoQ Phase I consists of three aspects, namely the level of difficulty, importance, and estimated costs.

a. Difficulty Level Determination (Neira-Rodado et al., 2020)

The level of difficulty was determined from the relationship between technical characteristics. Furthermore, it was calculated by translating all the relationship weights and dividing each technical characteristic weight by the total weights.

b. Determination of the Degree of Importance (Hridoy et al., 2020)

The value of the degree of importance was calculated by first determining the total weight for each relationship between product attributes and technical characteristics.

c. Cost estimation (Murugan and Marisamynathan, 2022)

The basis for cost estimates is the level of difficulty factor. The more difficult a technical characteristic, the more expensive the cost allocation. Cost estimates, expressed in percent, were influenced by various considerations from the designer.

Building Phase I of the HoQ matrix set the stage for QFD Phase I (product planning). Data collected were integrated into the first step of QFD Phase II. Meanwhile, potential difficulties in QFD Phase I include obtaining data and conducting surveys.

2.2. Quality Function Deployment Phase II

The experimental procedure in this study was divided into several stages, as shown in the schematic diagram in Figure 1. In Phase II of QFD, also known as the design phase, product characteristics derived from the voice of the customer were compared with the essential requirements, in order to identify critical parts of a product (Lo, 2021). It is important to acknowledge that priority technical characteristics were translated into critical parts to meet customer needs. According to (Ginting, 2021), the following were stages of developing the Phase II QFD (Zulkarnain et al., 2023)

1. Establish Priority Technical Characteristics Based on QFD phase I (Yuliani et al., 2019)

The technical characteristics obtained from QFD phase I were used as input to conduct processing in phase II. Priority technical characteristics were determined based on the ranking of the largest weight of the level of difficulty, degree of importance, and estimated costs.

2. Determine the Critical Part (Purba et al., 2020)

Critical parts were identified as the main components or characteristics essential to the product.

3. Determine the Level of Relationship Between Critical Parts (Azizah et al., 2018)

The next step in preparing the design deployment matrix was to compare and analyze the relationship between each critical part.

4. Establish the Relationship Between Technical Characteristics and Critical Parts (Abonyi and Czvetkó, 2022)

The design deployment matrix was prepared to compare the relationship between critical parts and technical characteristics.

5. Determine the Technical Matrix (Lestari et al., 2020)

The technical matrix was determined based on performance measures from QFD phase II, which included the level of difficulty, the level of importance, and estimated costs.

The results of QFD Phase II, provided the final specifications for the proposed product, aiming to address bitewing problems. A practical challenge in QFD Phase II was conducting effective surveys to obtain accurate data.

3. Results and Discussion

This study introduces a novel method in the design of the bitewing product, by adopting QFD, a technique not previously utilized. Additionally, it addresses consumer complaints by applying an engineering approach to solve dentistry-related problems.

3.1. Quality Function Deployment Phase I

The analysis based on the House of Quality (HoQ) signifies that the primary focus of improvement should be on technical characteristics. Specifically, the convenience of use present a difficulty level of 4, degree of importance of 17%, and estimated cost of 17. To enhance product comfort, the inclusion of buffer foam is recommended.

According to (Anggita and Astuti, 2016), buffer foam can increase the comfort level of the user. Another area for improvement is the weight of the product which has a difficulty level, degree of importance, and estimated cost of 4%, 18%, and 17%, respectively. The proposed enhancement includes replacing the iron material used in bitewing support with aluminium. According to (Rohilla and Dhull, 2018) aluminium has a lighter density and stronger resistance than iron. By prioritizing these technical characteristics in QFD Phase I, the study aimed to address several patient complaints, such as nausea caused by pressure on the mouth wall and unclear radiographic images resulting from patient movement. The focus on improving the convenience of use and reducing product weight is shown on Figure 2.

Degree of Relationship:
V = Level of strong positive relationship, weight = 4
v = Medium positive relationship level, weight = 3
x = moderate level of negative relationship, weight = 2
X = Level of strong negative relationship, weight = 1
- = No relationship, weight = 0

Kano Category	*Customer Requirement*	*Customer Importance*	TECHNICAL CHARACTERISTICS: Convenience of use	Flexibility of use	Durability	Product Maintenance	Product size accuracy	Product weight	Product Coloring	*Satisfaction Performance*	*Improvement Ratio*	*Sales Point*	*Raw Weight*	*Normalized Raw Weight*
One Dimensional	The length of the bitewing holder is 3.5 cm	5	9	3	0	3	9	3	1	4,7040	1,0629	1,5	7,9718	15,12
One Dimensional	The length of the bitewing support is 19.5 cm	3	3	3	0	3	9	3	1	3,4590	0,8673	1,2	3,1223	5,92
Attractive	The diameter of the bitewing x-ray sensor is 6.5 cm	4	3	3	0	3	9	3	1	3,8500	1,0390	1,2	4,9872	9,46
Attractive	The weight of the bitewing holder is 50 grams	3	3	9	1	1	3	9	1	3,3510	0,8953	1,0	2,6859	5,09
Indifferent	The bitewing support weight is 200 grams	4	9	3	3	1	3	9	1	3,6490	1,0962	1,2	5,2618	9,98
Attractive	The bitewing x-ray sensor weighs 100 grams	4	3	3	1	1	3	9	1	3,6600	1,0929	1,2	5,2459	9,95
Indefferent	The material of the bitewing holder is soft acrylic	4	3	9	9	3	3	9	3	4,0690	0,9830	1,2	4,7184	8,95
Indifferent	The bitewing support material is aluminum	4	9	9	9	3	3	9	1	3,9640	1,0091	1,2	4,8437	9,18
Indifferent	The material of the bitewing x-ray sensor is plastic	3	3	3	9	1	3	9	3	3,4460	0,8706	1,0	2,6118	4,95
Indifferent	The color of the bitewing holder is yellow	4	0	0	1	1	0	0	9	3,9680	1,0081	1,0	4,0324	7,65
Attractive	The color of the bitewing support is silver	3	0	0	3	3	0	0	9	3,5500	0,8451	1,0	2,5353	4,81
Attractive	The color of the bitewing x-ray sensor is yellow	2	0	0	1	1	0	0	9	3,2430	0,6167	1,0	1,2334	2,34
Attractive	An added function to the bitewing is the support handle	3	9	3	3	1	3	9	1	3,8680	0,7756	1,5	3,4902	6,62
	Degree of difficulty		4	3	3	3	3	4	3					
	Degree of Interest (%)		17	15	12	12	13	18	13					
	Cost estimation (%)		17	13	13	13	13	17	13					

Degree of difficulty
1 = Not Difficult
2 = Moderate
3 = Difficult
4 = Very Difficult
5 = Absolute Very Hard

Cost estimation
0-10 = Cheap
11-20 = Moderate
21-30 = Expensive

Degree of Interest
1 - 10 = Less important
11 – 20 = Important
21 – 30 = Very important

Figure 2 House of Quality (HoQ) Phase I

3.2. Quality Function Deployment Phase II

QFD phase II is the stage of component planning (part deployment) or translation of technical requirements into component characteristics. Based on the deployment part, the difficulty level, degree of importance, and estimated cost were 5%, 35%, and 33%. These metrics signified that the most critical components requiring immediate attention were the dimensions of the bitewing holder and support. The proposed product improvements include shortening the dimensions and length of the bitewing holder to 3.5 cm and 19.5 cm, respectively.

Based on the identification of critical parts with QFD Phase II, patient complaints of nausea caused by pressure on the mouth wall and unclear radiographic images due to patient movement, can be addressed by prioritizing critical components. According to (Astuti and Febriansyah, 2017), an improved design is needed by shortening the dimensions of the bitewing holder with a support. The focus on shortening the dimensions of the bitewing holder with a support is shown on Figure 3.

Degree of Relationship:
V = Level of strong positive relationship, weight = 4
v = Medium positive relationship level, weight = 3
x = moderate level of negative relationship, weight = 2
X = Level of strong negative relationship, weight = 1
- = No relationship, weight = 0

V
v x

TECHNICAL CHARACTERISTICS	CRITICAL PARTS	Dimensions of the bitewing holder and stand	Quality bitewing support material	Bitewing x-ray sensor precision
Convenience of use	4	9	3	3
Flexibility of use	3	3	9	9
Durability	3	1	9	1
Product maintenance	3	1	3	3
Product size accuracy	3	9	3	9
Product weight	4	9	3	3
Product coloring	2	3	3	3
Degree of difficulty		5	5	5
Degree of Interest (%)		35	33	31
Cost estimation (%)		33	33	33

Degree of difficulty
1 = Not Difficult
2 = Moderate
3 = Difficult
4 = Very Difficult
5 = Absolute Very Difficult

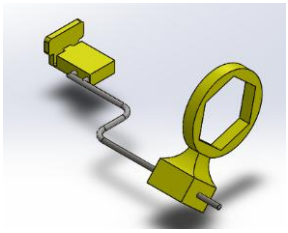
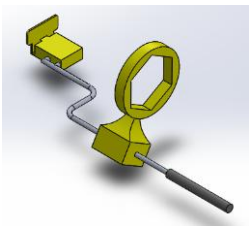
Cost estimation
0-10 = Cheap
11-20 = Moderate
21-30 = Expensive

Degree of Interest
1 - 10 = Less important
11 – 20 = Important
21 – 30 = Very important

Figure 3 House of Quality (HOQ) Phase II

Comparison of the initial and proposed product resulting from the QFD Phase I and II, are presented in Table 1.

Table 1 Product Comparison of Initial Product and Proposed Product

Aspects	Initial Product	Proposed Product
Picture		
Specifications	1. Length of the bitewing holder is 4.1 cm 2. Length length of the bitewing support is 20.3 cm 3. Diameter of the bitewing x-ray sensor is 6.5 cm 4. Weight of the bitewing holder is 50 grams 5. Weight of the bitewing support is 250 grams 6. Weight of the bitewing x-ray sensor is 100 grams 7. Material of the bitewing holder is soft acrylic 8. Bitewing support material is iron 9. Material of the bitewing x-ray sensor is plastic 10. Color of the bitewing holder is yellow 11. Color of the bitewing support is silver 12. Color of the bitewing x-ray sensor is yellow	(a) Length of the bitewing holder is 3.5 cm (b) Length of the bitewing support is 19.5 cm (c) Diameter of the bitewing x-ray sensor is 6.5 cm (d) Weight of the bitewing holder is 50 grams (e) Weight of the bitewing support is 200 grams (f) Weight of the bitewing x-ray sensor is 100 grams (g) Material of the bitewing holder is soft acrylic (h) Bitewing support material is aluminium (i) Material of the bitewing x-ray sensor is plastic (j) Color of the bitewing holder is yellow (k) Color of the bitewing support is silver (l) Color of the bitewing x-ray sensor is yellow (m) Additional functions on bitewing are support foam

4. Conclusions

In conclusion, Phase I QFD identified ease of use as the important technical characteristics, signifying a pressing need for product enhancement. The proposed improvement includes the incorporation of an additional function such as buffer foam. The technical characteristic with the highest score was the focus of another improvement, namely product weight. Product repair comprised replacement of iron material on the bitewing support with aluminium. This aimed to address complaints such as nausea due to pressure on the mouth wall and less clear radiographic images caused by patient movement. By and prioritizing these technical characteristics, user requirements were adequately met. Based on Phase II QFD analysis, the identification of critical parts present the bitewing holder and support dimensions as key areas for improvement. In line with the product improvements strategy, adjustment were proposed to shorten the dimensions and length of the holder to 3.5 cm and 19.5 cm, respectively. These modifications were designed to address user concerns regarding discomfort and image clarity.

Acknowledgements

The authors are grateful to Universitas Sumatera Utara (USU) for the invaluable assistance and contribution. The institution played a significant role in academic and personal development. Additionally, valuable opportunities and experiences were provided, contributing to growth.

Author Contributions

Rosnani Ginting: Conceptualization, formal analysis, data validation, writing – review & editing, visualization, supervision. Humala Napitupulu: Conceptualization, literature review, methodology, investigation, writing – original draft, writing – review & editing. Aulia Ishak: Writing – original draft, software, data collection, data analysis & interpretation. Supranata: Writing – original draft, software, data collection, data analysis & interpretation. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflicts of interest.

References

Abonyi, J & Czvetkó, T 2022, 'Hypergraph and network flow-based quality function deployment', *Heliyon*, vol. 8, no. 12, article12263, https://doi.org/10.1016/j.heliyon.2022.e12263

Anggita, D & Astuti, DA 2016, 'Review of various materials and shapes', Tinjauan material dan bentuk ragam, *Jurnal Teknik Industri*, vol. 3, no. 5, pp. 383–400

Astuti, T & Febriansyah 2017, 'Product design of film dental holder "Bitewing" for anterior dental radiography', *SANITAS: Jurnal Teknologi dan Seni Kesehatan*, vol. 8, no. 2, pp. 114–122

Avikal, S, Singh, R & Rashmi, R 2020, 'QFD and Fuzzy Kano model based approach for classification of aesthetic attributes of SUV car profile', *Journal of Intelligent Manufacturing*, vol. 31, no. 2, pp. 271–284, https://doi.org/10.1007/s10845-018-1444-5

Azizah, IN, Lestari, RN & Purba, HH 2018, 'Penerapan metode quality function deployment dalam memenuhi kepuasan konsumen pada industri komponen otomotif (Implementation of the quality function deployment method in meeting consumer satisfaction in the automotive components industry)', *Jurnal Teknik Industri*, vol. 19, no. 2, pp. 127–136, https://doi.org/10.22219/jtiumm.vol19.no2.127-136

Bahia, THA, Idan, AR & Athab, KR 2023, 'The effect of quality function deployment (QFD) in enhancing customer satisfaction', *International Journal of Professional Business Review*, vol. 8, no. 1, pp. 1–17, https://doi.org/10.26668/businessreview/2023.v8i1.1156

Coşkun, SS & Kazan, H 2023, 'Bayesian analysis of the relationship between process improvement practices and procurement maturity', *Computers and Industrial Engineering*, vol. 181, article 109297, https://doi.org/10.1016/j.cie.2023.109297

de Oliveira, LMV, Santos, HF, de Almeida, MR & Costa, JAF 2020, 'Quality function deployment and analytic hierarchy process: A literature review of their joint application', *Concurrent Engineering Research and Applications*, vol. 28, no. 3, pp. 239–251, https://doi.org/10.1177/1063293X20958936

Fazeli, HR & Peng, Q 2022, 'Generation and evaluation of product concepts by integrating extended axiomatic design, quality function deployment and design structure matrix', *Advanced Engineering Informatics*, vol. 54, no. 9, article 101716, https://doi.org/10.1016/j.aei.2022.101716

Gavahi, SS, Hosseini, SMH & Moheimani, A 2022, 'An application of quality function deployment and SERVQUAL approaches to enhance the service quality in radiology centres', *Benchmarking*, vol. 30, no. 8, pp. 2147–2166, https://doi.org/10.1108/BIJ-07-2021-0411

Ginting, R 2021, *Kuesioner: alat ukur kepuasan terhadap produk (Questionnaire: product satisfaction measurement tool)*, USU Press

Ginting, R 2022, *Metode Perancangan Produk (Konsep & Aplikasi) (Product Design Methods (Concept & Application))*, USU Press

Ginting, R, Siregar, I & Ginting, TUH 2015, 'Perancangan alat penyadap karet di Kabupaten Langkat Sumatera Utara dengan metode quality function deployment (QFD) dan model Kano (Design of rubber tapping tools in Langkat Regency, North Sumatra using the quality function deployment (QFD) method and the Kano' model)', *J@Ti Undip: Jurnal Teknik Industri*, vol. 10, no. 1, pp. 33–40, https://doi.org/10.12777/jati.10.1.33-40

Habib, T, Omair, M, Habib, MS, Zahir, MZ, Khattak, SB, Yook, S-J, Aamir, M & Akhtar, R 2023, 'Modular product architecture for sustainable flexible manufacturing in Industry 4.0: The case of 3D printer and electric toothbrush', *Sustainability*, vol. 15, no. 2, p. 910, https://doi.org/10.3390/su15020910

Hartono, M, Santoso, A & Prayogo, DN 2017, 'How Kansei Engineering, Kano and QFD can improve logistics services', *International Journal of Technology*, vol. 8, no. 6, pp. 1070–1081, https://doi.org/10.14716/ijtech.v8i6.689

Hridoy, RM, Parvez, MS & Mohsin, N 2020, 'Joining methods of Analytic Hierarchy Process (AHP), Kano model and Quality Function Deployment (QFD) to improve the tractor's seat design for tractor drivers in Bangladesh', *American Journal of Industrial and Business Management*, vol. 10, no. 5, pp. 1073–1083, https://doi.org/10.4236/ajibm.2020.105071

Ishak, A, Ginting, R, Suwandira, B & Fauzi Malik, A 2020, 'Integration of Kano Model and Quality Function Deployment (QFD) to improve product quality: A literature review', *IOP Conference Series: Materials Science and Engineering*, vol. 1003, no. 1, pp. 1–9, https://doi.org/10.1088/1757-899X/1003/1/012025

Lestari, R, Wardah, S & Ihwan, K 2020, 'Analisis pengembangan pelayanan jasa TV kabel menggunakan metode Quality Function Deployment (QFD) (Analysis of cable TV service development using the Quality Function Deployment (QFD) method)', *JISI: Jurnal Integrasi Sistem Industri*, vol. 7, no. 1, pp. 57–63

Liu, Y, Chen, PHC, Krause, J & Peng, L 2019, 'How to read articles that use machine learning: Users' guides to the medical literature', *JAMA - Journal of the American Medical Association*, vol. 322, no. 18, pp. 1806–1816, https://doi.org/10.1001/jama.2019.16489

Lo, CH 2021, 'Application of refined Kano's model to shoe production and consumer satisfaction assessment', *Sustainability*, vol. 13, no. 5, article 2484, https://doi.org/10.3390/su13052484

Moharrami, M, Farmer, J, Singhal, S, Watson, E, Glogauer, M, Johnson, AEW, Schwendicke, F & Quinonez, C 2023, 'Detecting dental caries on oral photographs using artificial intelligence: A systematic review', *Oral Diseases*, vol. 30, no. 2, pp. 1–19, https://doi.org/10.1111/odi.14659

Murugan, M & Marisamynathan, S 2022, 'Elucidating the Indian customers' requirements for electric vehicle adoption: An integrated analytical hierarchy process – Quality function deployment approach', *Case Studies on Transport Policy*, vol. 10, no. 2, pp. 1045–1057, https://doi.org/10.1016/j.cstp.2022.03.017

Neira-Rodado, D, Ortíz-Barrios, M, de la Hoz-Escorcia, S, Paggetti, C, Noffrini, L & Fratea, N 2020, 'Smart product design process through the implementation of a fuzzy Kano-AHP-DEMATEL-QFD approach', *Applied Sciences (Switzerland)*, vol. 10, no. 5, https://doi.org/10.3390/app10051792

Przystupa, K 2023, 'Research on the durability and reliability of industrial layered coatings on metal substrate due to abrasive wear', *Materials*, vol. 16, no. 5, https://doi.org/10.3390/ma16051779

Purba, HH, Sunadi, S, Suhendra, S & Paulina, E 2020, 'The application of quality function deployment in car seat industry', *ComTech: Computer, Mathematics and Engineering Applications*, vol. 11, no. 1, pp. 35–42, https://doi.org/10.21512/comtech.v11i1.6329

Rianmora, S & Werawatganon, S 2021, 'Applying quality function deployment in open innovation engineering', *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 7, no. 1, pp. 1–20, https://doi.org/10.3390/joitmc7010026

Rohilla, S & Dhull, U 2018, 'A review on optimization of the process parameters in friction stir welding of aluminium alloys (AA6082 and AA6105) by Taguchi technique', *International Journal of Advanced Engineering, Management and Science*, vol. 4, no. 9, pp. 676–680, https://doi.org/10.22161/ijaems.4.9.6

Shang, K, Teng, S, Buchari, E, Lirn, T & Herno, R 2022, 'Integration of safety quality function deployment in ferry services: Empirical study of Indonesia', *Research in Transportation Business & Management*, vol. 52, pp. 100938, https://doi.org/10.1016/j.rtbm.2022.100938

Shen, Y, Zhou, J, Pantelous, AA, Liu, Y & Zhang, Z 2022, 'A voice of the customer real-time strategy: An integrated quality function deployment approach', *Computers and Industrial Engineering*, vol. 169, no. November 2021, p. 108233, https://doi.org/10.1016/j.cie.2022.108233

Shvetsova, OA, Park, SC & Lee, JH 2021, 'Application of quality function deployment for product design concept selection', *Applied Sciences (Switzerland)*, vol. 11, no. 6, pp. 1–12, https://doi.org/10.3390/app11062681

Siddique, N, Paheding, S, Elkin, CP & Devabhaktuni, V 2021, 'U-net and its variants for medical image segmentation: A review of theory and applications', *IEEE Access*, vol. 9, pp. 82031–82057, https://doi.org/10.1109/ACCESS.2021.3086020

Siwiec, D, Pacana, A, & Gazda, A 2023, A new QFD-CE method for considering the concept of sustainable development and circular economy, *Energies*, vol. 16, no. 5, article 2474, https://doi.org/10.3390/en16052474

Sugiono, S, Pratomo, A & Willy, SN 2022, 'House-of-Quality approach for the design of a minibus to transport visually impaired and wheelchair-bound passengers', *International Journal of Technology*, vol. 13, no. 1, pp. 69–79, https://doi.org/10.14716/ijtech.v13i1.4290

Sugiyono 2018, *Metode penelitian (Research methods),* Alfabeta

Sundaram, S & Zeid, A 2023, 'Artificial intelligence-based smart quality inspection for manufacturing', *Micromachines*, vol. 14, no. 3, article 570, https://doi.org/10.3390/mi14030570

Wu, X & Liao, H 2021, 'Customer-oriented product and service design by a novel quality function deployment framework with complex linguistic evaluations', *Information Processing and Management*, vol. 58, no. 2, article 102469, https://doi.org/10.1016/j.ipm.2020.102469

Yuliani, ENS, Arwati, IGA & Riski, AR 2019, 'Product development of Klikpak food packaging with Quality Function Deployment (QFD) method', *Journal of Scientific and Engineering Research*, vol. 6, no. 7, pp. 173–178

Yusro, KA & Sianturi, RD 2018, 'Penerapan metode median filtering dan histogram equalization untuk meningkatkan kualitas citra radiografi (Application of median filtering and histogram equalization methods to improve the quality of radiographic images)', *Jurnal Riset Komputer (JURIKOM)*, vol. 5, no. 3, pp. 254–260

Zhang, X, Su, J & Herrera-Viedma, E 2022, 'A decision support model for estimating participation-oriented designs of crowdsourcing platforms based on quality function deployment', *Expert Systems with Applications*, vol. 202, p. 117308, https://doi.org/10.1016/j.eswa.2022.117308

Zulkarnain, Machfud, Marimin, Darmawati, E & Sugiarto 2023, 'Design of graphic concept model for specialty coffee packaging labels', *International Journal of Technology*, vol. 14, no. 3, pp. 606–617, https://doi.org/10.14716/ijtech.v14i3.5116