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NEW DESIGN OF HYDRAULIC PAVING BLOCK MACHINE USING QFD AND DFMA METHOD

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Abstract* : *Intense market competition makes companies continue to develop or create an innovate products based on the needs of the customer. This study aims to design a more effective and efficient design of the hydraulic paving block machine as well as to minimize the time and cost of assembly/production using the QFD integrated DFMA method. A private company engaged in manufacture the industrial machinery and manufacturing equipments, one of which is hydraulic psving block machine was used as a case study of this research. QFD was used to identify the company's problems. Based on the QFD phase I method, the result showed that there are 5 of 7 attributes that have high valued added by technical characteristic, i.e. cost and time of installation, cost of component and assembly, total components, and design efficiency. Meanwhile, there are 2 of 3 critical part attributes in the QFD phase 2, i.e. mold and frame. As a result, the QFD integrated QFD save the assembly time of the paving block hydraulic machine from 6,605.07 to 6.045.47 minutes, design efficiency increase as 1.39%, and save the cost of installation as one million rupiahs.

Keywords- QFD, DFMA, Design efficieny.

I. INTRODUCTION

The advancement of modern manufacturing technology has a significant impact on market competition [1]. The rapid development of technology forces companies to continue to innovate in product design. Understanding what customers' needs is a must for companies. The designer must be able to design products at a low cost and maximum functionality based on customers' desires.

A successful product depends on the schedule and cost, and how minimizes the lead time in production and develop the product [2]. The company's competitive advantage lies in the succession of product innovations in the global market, which reflects the increasingly diverse needs of customers. How the product is designed can determine whether the product successfully compete in the market or even failing. Therefore, an appropriate design method is very crucial for the success of a product [3]. A New product design that takes into account design aesthetics is very important to attract the customers. Therefore, designers are required to be able to design and develop products by combining ergonomics and design aesthetics using innovative methods based on customer desires. [4].

Quality function deployment, is a popular method that provides techniques to design and develop a product, and also improve customer satisfaction, minimize product development costs, and shortening the assembly and development cycles of product [5].

There are several studies for the last twenty years using QFD and DFMA methods as the solving problem of product design and development. Suresh et al, [6] argued that the DFMA methodology is most effective if applied before the detailed design stage of the process of product development. The application of design methodology for manufacturing and installation (DFMA) can be beneficial for manufacturing that is involved in the development and product design. Particularly, the initial design results have a significant impact on reducing the number of production costs and parts of the product.

Isanaka et al. [7] studied the Proton Exchange Membrane Fuel Cell with the aim of simplifying the manufacturing process and assembly of the fuel cell design. They reported that Weight loss and components by ninety percent and cost reduction by almost 80%.

Harlalka et al. [2] Applied method of DFMA in Indian consumer products. Although various case studies of DFMA have been published, very few discuss the category of durable goods of Indian consumers. They identified the various cost reduction opportunities in the food processor design produced. DFMA was developed with the aim of reducing the cost of production, and product design and development. Detailed suggestion to improve product design and assembly was presented in this paper. The DFMA methodology has improved the DFA index from 15.99 to 19.93. The integration

of DFMA and the Design for Environment method can be a powerful tool to reduce the cost of products in a sustainably.

Lu et al. [8] Pointed that DFMA can be increased construction productivity with advances in building materials, production, and installation technology, and logistics and supply chain management continues to be strengthened. Meanwhile Mora et al. [9] Focused on the ease of transportation and assembly of large-scale products at their final locations with the purpose to reducce the cost and installation time, and consequently have a positive impact on overall project costs. Furthermore, this study also applied the sequencing and grouping algorithms that were used to improve the process of transporting and assembling large items.

Mathews et al. [10] Proposed a DFMA approach with a systemic ergonomics analysis to avoid unnecessary reassembly cycles of the design. A paperboard tray-forming prototype line was used in their study. Vishnuprakash et al [11] improved the existing design from in ergonomics point of view. For this purpose, a tricycle for aged persons is considered as a case study. The DFMA method was used as a well-established technique to improve product efficiency and minimize production cost.

Naiju [12] presented a case study of a DFMA application in minimizing the cost of a pedestal fan, which if widely used in household and office space. To produce CAD models from buffer fans, this study used solid works software, then analyzed using DFMA software tools. After the redesign process, the new design was re-analyzed by the DFMA method. They claimed that the overall time savings in the installation is 34.40 seconds, which in terms of percentage is 15.17. Furthermore, they also argued that that the application of DFMA is not unique and its procedures are easily adapted for any industry aimed at building quality products for customers by reducing production costs. A Comparison of the cost of the fan base after the redesign with the first shows a reduction of $ 4.1061 per fan.

Meanwhile, Mesa et al, [13] studied the concept of sustainability in the classic of the DFMA, and then validated through the re-design of sheet metal industry clocks, and compare the existing products with newly ones. Naiju [12] used DFMA on redesigning shopping carts which are widely used in supermarkets and convenience stores for cost reduction. CAD models from various parts of the shopping cart are made using solid work and then analyzed using the DFMA software. Furthermore, Haralka [2] Focused on DFMA a case study on multi-component products containing sheet metal, electronics, and other components. This study discussed and redesign the improvement product lead time as 30%. Suresh [6] studied research carried out in ensuring sustainable product design with the integration of design for the environment and design for manufacture and assembly methodologies. This research applied a case study of a charging alternator pulley modern car.

The case study of this research is the company that manufactures machinery and equipment the machine of agricultural equipment, livestock, fisheries, paving block, brick printing, brick printing, stone breaking, etc. The company implements an ordering system to meet the specifications and capacity of the machine, so that in the process of design and manufacture the machine exactly according to the customer's needs. Hydraulic paving block machine product is a type that continues to be produced and in great demand.

The results of the initial survey through an interview with the company show that 3 components/parts are considered have a fairly difficult level of difficulty are mold, hydraulic, and framework. Then on the results of the questionnaire distribution and processing using the QFD method, it was found that the most important components/parts for immediate improvement are molds and frameworks because have a higher level of difficulty, importance level, and cost estimates than hydraulics. These components need immediate repair because the design is considered to have non-value-added components. This is necessary for further improvement and analysis using DFMA methods.

For the molded part, the observed problem is in the iron component of the hollow shaft. In the actual case that the mold has 10 hollow rods, the researchers assessed that this prolongs the cutting and assembly process and also requires special attention to the level of precision between the upper and lower mold. Meanwhile, the problem with the frame is on the frame poles. Because in the actual process, the cutting process was carried out at the corners o

f the four supporting poles and the four connecting irons at the top and bottom. This causes the cutting process takes a lead time and complicates the assembly process of each component. The relatively lead installation time causes the high cost of product installation. The following mold and frame pictures can be seen in Fig 1.

(a) Mold (b) Frame

Figure 1. Mold and Frame Parts on Hydraulic Block Paving Machines

In this situation, the existing product design is seen as ineffective and ineffective because the existing product design contains unnecessary components that should be eliminated but without reducing product function. Simpler product design, fewer components, and faster installation time are alternative solutions to problem-solving. The easier-to-assembly design will improve the efficiency of time, which leads to lower production costs. One of the most influencing factors for the total cost of manufacturing is the design factor.

In this study, QFD and DFMA methods are used to evaluate or improve the products with the purpose to provide the right solution to improve the hydraulic paving block machine design, minimize the assembly costs without changing the value and function of the company's products.

II. QUALITY FUNCTION DEPLOYMENT

QFD is a technique to improve the products or services based on customer's needs. Meanwhile, the technical requirements determine the customers' desires. This can be done by using the QFD method, which translates the user's

taste in the form of product attributes pertaining to the technical characteristics. QFD uses a matrix known as the House of Quality, where this matrix can translate user desires into design features [15, 16]

QFD method was founded by Akao in 1966. This is method to transform user demand into a design quality to disseminate the quality of function formation and use methods to achieve design quality into specific systems, components, and elements in the manufacturing process. Also, QFD also a process of translate customer requirements into a technical characteristic [17].

QFD is a popular method for improving quality to fulfill customer desires. This method incorporates all customer needs in every aspect of the product, transforming them into technical characteristics to meet customer's needs. QFD records good results in many areas, such as measurement of service level, product development, feature technical characteristics, supplier selection problems, building structure design, and industry development [18, 19]. Van et al. [20] argued that The application QFD has become a quality management tool widely used in product design and development. QFD is used to receive customer feedback during the planning, design, development, engineering, manufacture, and production stages.

a. QFD Phase one

In this phase, a model is created that can identify the extent to which customers expect the quality of bicycle products that can satisfy consumers. In this case, this is done by linking customer requirements (CR)/voice of the customer (VoC) with design requirements (DR). Fig 2 shows the steps for QFD phase one as follows:

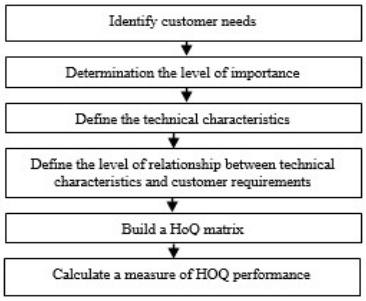


Figure 2. QFD phase one development.

b. QFD Phase two

In this phase, a data analysis model is applied for the material or components requirement that fulfills the value design criteria of QFD phase one by translates DR into CP. The QFD phase two development flow chart can be seen in Fig 3.

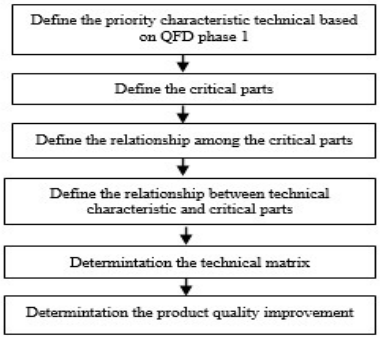


Figure 3. QFD phase two development

III.DFMA

DFMA is a method to determine the product design and assembly with optimum time and cost. DFMA can also be used to assist designers to improve quality, reduce installation costs, and measure product design improvements. DFMA concept was developed by Boothroyd and Dewhurst to reduce manufacturing costs and reduce assembly/installation time. Generally, the DFMA concept is used in the early s applied to minimize the costs [21].

DFMA has become a keyword in the global revival of prefabricated and industrialized construction. Some people though DfMA as a new method, as many concepts already exist such as lean construction, buildability, value management, and project delivery integration [8].

Initially, 115 design approaches of DfM and DfA emerged in the late 1960s and early 1970, with the practice and research of Boothroyd and Dewhurst. Therefore, many developments of DfMA in the manufacturing industry [8].

The purpose of this DFMA method is to determine the product design that eliminates unnecessary components or parts that have no added value in products based on the functionality desired by the user. The highest expected value can be obtained by providing maximum function, and as low cost as possible. DFMA is also used to study competing processes and products in terms of design, quality, selection of materials, components, production processes and then evaluate the difficulty of the assembly and/or manufacturing to design superior products based on the results of detailed analysis. Fig 4 shows the flowchart of product improvement using the DFMA method, as follows.

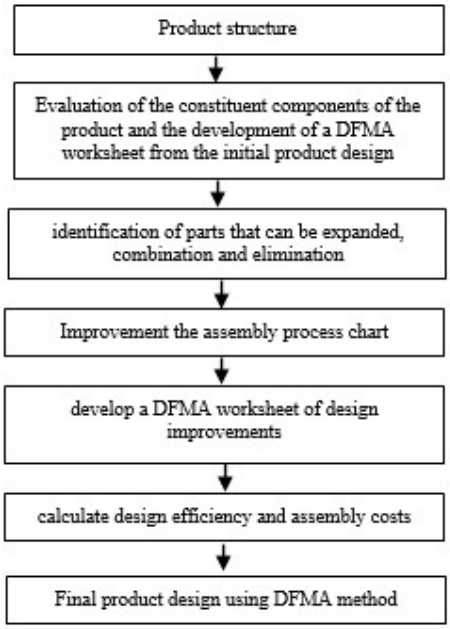


Figure 4. Flow chart of product improvement using DFMA

IV.METHOD

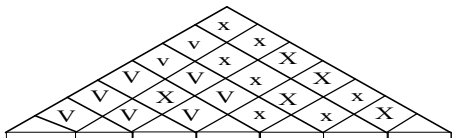
The type of this research is descriptive, which is aims to systematically, factually, and accurately describe the facts and

properties of a particular object with the purposes to find a solution.

The object of this study is to observe the hydraulic blocking machine which is manufactured by the Star Umrah Engineering company. A review was conducted on the sequence of production processes. The reason for choosing a hydraulic paving block machine is because of the results of interviews with a company, it is known that the machine is the type that continues to be produced and popular in the market. In this study, several survey tools were used. i.e. open and closed questionnaire, technical characteristics questionnaire (the relationship between technical characteristics and voice of the customer, and among the technical characteristics), and the critical part questionnaire (the relationship between technical characteristics and critical parts, and among the critical parts).

The sample size for open and closed questionnaires was 6 respondents. Respondents were selected based on their understanding of the product being studied and to fulfill the predetermined quota. The sample size of the technical characteristics questionnaire and the critical part selected was 1 respondent. The selected respondents were from the company, namely the supervisor who specializes in the assembly process of hydraulic paving block machines.

Degree of Relationship:
V = Strong Relationship, Weight = 4
v = Moderate Relationship, Weight = 3
x = Weak Relationship, Weight = 2
X = No Relationship, Weight = 1



Customer Requirement	Customer Importance	Assembly Time	Component Costs	Number of Components	Assembly Costs	Design Efficiency	Easy of Manufacturing	Durability	Net Sales	Importance Weight	Relative Weight
The small size of the compiler components complicates the assembly process of the Hydraulic Paving Block Machine	3	9	3	3	3	3	3	0	1,0	2,70	5,53
The thicker iron complicates the assembly of the Hydraulic Paving Block Machine	5	3	9	3	1	9	1	1	1,0	5,90	12,11
The heavier components complicates the assembly process of the Hydraulic Paving Block Machine	2	3	3	3	1	3	1	0	1,0	1,33	2,73
Strong components have no effect on the assembly process of the hydraulic Paving Block Machine	3	0	1	1	0	0	0	9	1,5	4,04	8,29
The deterioration factor of the compiler components have no affect on the assembly process of the hydraulic Paving Block Machine	5	1	0	0	0	0	1	0	1,0	5,72	11,74
The use of two hands is necessary in the assembly process of the hydraulic Paving Block Machine	4	3	0	3	3	3	3	1	1,0	4,62	9,48
The use of holding tools simplifies the assembly process of the hydraulic Paving Block Machine	5	3	1	3	3	0	3	0	1,2	11,84	24,30
The use of optical devices is is necessaryin the assembly process of the Hydraulic Paving Block Machine	4	0	1	0	1	0	0	0	1,2	5,28	10,82
Mechanical assistance is is necessary to facilitate the assembly process of the Hydraulic Paving Block Machine	5	0	3	3	3	1	0	0	1,0	5,90	12,11
Affordable component insertion location in the Hydraulic Block Paving Machine assembly process	2	1	0	0	1	0	1	0	1,0	1,39	2,85
The use of assembly equipment is necessary to facilitate the assembly process of the Hydraulic Paving Block Machine	5	9	1	9	3	3	3	0	1,2	7,08	14,53
The alignment of the component insertion position has no effect on the assembly process of the Hydraulic Paving Block Machine	5	0	0	0	0	1	0	0	1,0	6,09	12,50
The depth of component insertion affects the assembly process of the Hydraulic Paving Block Machine	4	1	1	1	1	0	0	0	1,2	6,05	12,41
Degree of Difficulty		4	3	4	3	3	2	2			
Degree of Importance (%)		21	15	19	13	15	10	7			
Cost Estimation (%)		19	14	19	14	14	10	10			

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

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

Degree of importance
1 - 10 = Not too Important
11 – 20 = Important
21 – 30 = Very Important

Figure 5. Summary of QFD phase I of hydraulic paving block machine

Degree of Relationship:
S = Strong Positive Relationship = 3
M = Moderate Positive Relationship = 2
W = Moderate Negative Relationship = 1
O = No Relationship = 0

Technical Characteristic	Critical Parts	Mold	Hydraulic	Framework
		S	M	W
Assembly Time	4	9	9	9
Component Costs	3	3	3	1
Number of Components	4	3	1	1
Assembly Costs	3	3	3	3
Design Efficiency	3	0	0	3
Easy of Manfacturing	2	1	0	1
Durability	2	3	0	3
Degree of Difficulty		5	4	5
Degree of Importance (%)		37	27	36
Cost Estimation (%)		36	29	36

Fig 6. QFD phase 2 of hydraulic block paving machine

4.2. Design for Manufacturing and Assembly

The improvement steps in the design of hydraulic block paving machine based on QFD phase II results in the highest critical parts performance measurement. The critical phase of the QFD phase II with the highest performance measures is as follows:

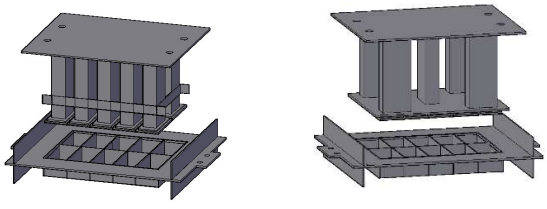
1. Mold with the importance degree of 35%
2. Frame with the importance degree of 33%

The focus of improvement using the DFMA method is for the critical two-part attributes and features. DFMA was used to improve the design of the hydraulic paving block machine. Then it was found that the existing design still has some drawbacks. 108 units of product assembling components take 6,605.07 minutes to complete each product unit.

After improvement using the DFMA method through the process of merging and replacement of the components, the product has increased in terms of assembly time, which is 6.045.47 minutes with a time difference of 559.60 minutes. DFMA was used to make the production process of hydraulic paving block machine products more economical and convenient. Improvements are made by redesigning components to reduce the assembly steps.

1. Mold

The following Fig 7 is the comparison of the existing and new design of paving block mold.

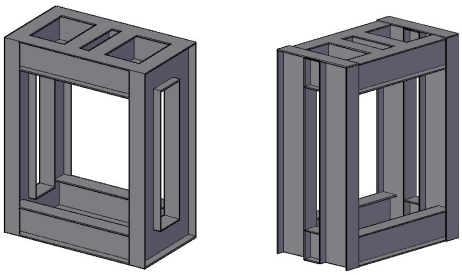


(a) Existing design (b) New design

Figure 7. Differentiation the hydraulic block paving of existing and new design

2. Frames

The following Fig 8 is the comparison of framework design.



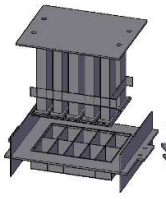
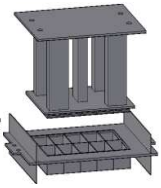
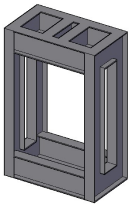
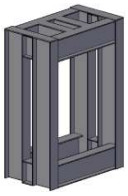
(a) Existing design (b) New design

Figure 9. Frame differentiation of existing and new design

TABLE 1. DIFFERENTIATION OF EXISTING AND PROPOSED PROCESS

Criterion	Existing design	New design	Difference
Assembly time	6.605 minute	6.045 minute	559 minute
Assembly cost	IDR 15.136.626	IDR 13.854.203	IDR 1.282.422
Design efficiency	31,06 %	32,45 %	1,39 %

TABLE 2. DIFFERENTIATION OF EXISTING AND NEW DESIGN

Part	Existing design	New design	Description
Mold design			Reduction in the hollow rod iron which was initially 10 to 5 units
Frame design			Reduction in the the elimination of sloping work on the support and connectors poles.

V. CONCLUSION

QFD phase one shows that the highest priority technical characteristics of hydraulic block paving machine are the technical characteristics of design efficiency, installation time, number of components, and assembly cost. Meanwhile, QFD phase two shows the product identification of hydraulic block paving machines indicates the most important critical parts for immediate improvement are molds and frames. Based on the result of the DFMA method, the total assembly time of an existing product is 6,605,07 minutes with an assembly cost of 15,2 million rupiahs. Meanwhile, the new design is 6.045.47 minutes with a total assembly cost of 13, 8 million rupiahs, which is saves the assembly time of 559.60 minutes, improves design efficiency by 1.39%, and saves the cost of assembly as 1,2 million rupiahs.

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REFERENCES

[1] X. Kang, M. Yang, Y. Wu, and B. Ni, "Integrating Evaluation Grid Method and Fuzzy Quality Function Deployment to New Product Development", *Mathematical Problems in Engineering Volume 2018,* Article ID 2451470, PP 1-15, 2018.

[2] A. Harlalka, C. D. Naiju, M.N. Janardhanan, and I. Nielsen, "Redesign of an in-market food processor for manufacturing cost reduction using DFMA methodology", *Production & Manufacturing Research,* Vol. 4, no. 1, pp. 209–227, 2016

[3] J Gaspar J, Fontul M, and E. Henriques, "User satisfaction modeling framework for automotive audio interfaces", *Int J Indus Ergon,* Vol. 44, pp. 662–674, 2014.

[4] C. Yang, J. Cheng, and X. Wang, "Hybrid quality function deployment method for innovative new product design based on the theory of inventive problem solving and Kansei evaluation", *Advances in Mechanical Engineering*, Vol. 11(5), pp. 1–17, 2019.

[5] Y.H. Wang, C.H. Lee, and A.J.C. Trappey. "Service design blueprint approach incorporating TRIZ and service QFD for a meal ordering system: a case study", *Comput Indus Eng*; Vol 107, pp. 388–400, 2017.

[6] P. Suresh, S. Ramabalan, and U. Natarajan, "Integration of DFE and DFMA for the sustainable development of an automotive component", *International Journal of Sustainable Engineering*,Vol. 9, pp. 107–118, 2016.

[7] S,P. Isanaka, T.E. Sparks, F.F. Liou, and J.w. Newkirk, "Design strategy for reducing manufacturing and assembly complexity of air-breathing Proton Exchange Membrane Fuel Cells (PEMFC)", *Journal of Manufacturing Systems*, Vol. 38, pp. 165–171, 2016.

[8] W. Lu, T. Tan, J. Xu, J. Wang, K. Chen, S. Gao, and Fan, "Desig n for Manufacture and Assembly (DfMA) in construction: the old a nd the new", Architectural Engineering and Design Management, Doi:10.1080/17452007.2020.1768505, 2020.

[9] B. Mora, I. Retolaza,M. A. Campos, A. Remirez, M. J. Cabello, and F. Martinez, "Development of A New Design Methodology for Large Size Products Based on Dsm And Dfma", *Systems Engineering And Design*, pp. 2315-2324, 2020.

[10] S. Matthews,V. Leminen, H. Eskelinen,A. Toghyani, and J. Varis," Formulation of novel DFMA rules for the advancement of ergonomic factors in non-linear iterative prototype assembly", *International Journal of Computer Integrated Manufacturing*, Vol. 8(31), 2018.

[11] P. Vishnuprakash, R. Rajesh, "Design and Concept Evaluation of Tricycle for Aged and Orthopedic Differentially Abled Persons", *International Journal of Computer Applications* (0975 – 8887), Vol. 15(111), 2015.

[12] C. D. Naiju, Pranav. V. Warrier and V. Jayakrishnan, "Redesigning of Shopping Cart for Cost Reduction Using DFMA', *MATEC Web of Conferences* 95, 10003, 2017.

[13] J. Mesa, H. Maury, R.A.L. Corredor, and J. Bris, "A novel approach to include sustainability concepts in classical DFMA methodology for sheet metal enclosure devices", *Res Eng Design,* Vol. 29, pp. 227–244, 2018.

[14] C. D. Naiju, V. Pranav, Warrier and V. Jayakrishnan,"Redesigning of Shopping Cart for Cost Reduction Using DFMA", *MATEC Web of Conferences ICMME* 2016, 2017.

[15] S. Eleftheriadis, P. D. Our, and D. Mumovic, D, "Participatory decision-support model in the context of building structural design embedding BIM with QFD", *Adv. Eng. Inform*, 2018.

[16] S. Li, D. Tang, and Q. Wang, "Rating engineering characteristics in open design using a probabilistic language method based on fuzzy QFD", *Comput. Ind. Eng,* 2019.

[17] A. Mart´ı Bigorra, and O. Isaksson, "Combining customer needs and the customer's way of using the product to set customerfocused targets in the House of Quality," *International Journal of Production Research*,Vol. No.8, pp.2320–233, 2017.

[18] M.A. Basset, F. Smarandache, R. Mohamed, A.E. Nasser H. Zaied, and F. Smarandache, "A Hybrid Plithogenic Decision-Making Approach with Quality Function Deployment for Selecting Supply Chain Sustainability Metrics", *Symetry,* Vol. 11-903, pp. 1-21, 2019.

[19] S. Zaim, M. Sevkli, A.H. Camgöz, O.F. Demirel, A.Y. Yayla, D. Delen, "Use of ANP weighted crisp and fuzzy QFD for product development", *Expert Syst. Appl.*, Vol. 41, pp. 4464–4474, 2014.

[20] L.H. Van, F.Y. Vincent, L.Q. Dat, C.C. Dung, S.Y. Chou, and N.V. Loc, "New Integrated Quality Function Deployment Approach Based on Interval Neutrosophic Set for Green Supplier Evaluation and Selection", *Sustainability,* 10,838, 2018.

[21] V.N. Malleswari, B.S. Babu, and P.L. Raj, "Improvement of Sewing Machine Design for Assembly Time Reduction Using DFA Methodology", *International Journal of Advanced Science and Technology,* Vol. 29, No.4, pp.7845 – 7857, 2020.