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Designing A Household Waste ShredderMachine Using The Quality Function Deployment Method

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ABSTRACT

Household waste, especially inorganic waste, is becoming an increasingly pressing challenge in waste management in the community, which can have a negative impact on the environment if not handled properly. This research aims to design a portable, effective, and efficient household waste shredding machine by developing essential attributes such as automatic, ergonomic, easy to operate, durable, safe to use, low cost, easy to disassemble, not easily damaged, and easy to move. The method used is Quality Function Deployment (QFD), which enables the identification and fulfilment of user expectations through in-depth analysis of the voice of the customer. The results showed that of the attributes developed, the most dominant attributes were safety in use and ease of operation, followed by portability and durability. Meanwhile, users considered attributes such as ease of disassembly and low cost less critical. The resulting machine design is able to fulfil all the criteria set by users. It provides an innovative solution to improve the efficiency of inorganic waste management at the household level to provide convenience, safety, and portability in its use. From the weighting of attribute values, the most dominant order to the last is the attribute of easy to move with a value of 10,542, easy to disassemble 9,404, safe when used 8,821, ergonomic 8,151, easy to operate 6,630, durable 6,248, low cost 5,439, the machine is not easily damaged 5,283, automatic 5,110.

Keywords: Portable Shredder, Inorganic Waste, Quality Function Deployment, Ergonomic Design, Waste Management.

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ABSTRACT

Sampah rumah tangga, khususnya sampah anorganik, menjadi tantangan yang semakin mendesak dalam pengelolaan limbah di masyarakat, yang dapat berdampak negatif terhadap lingkungan jika tidak ditangani dengan baik. Penelitian ini bertujuan untuk merancang desain mesin pencacah sampah rumah tangga yang portabel, efektif, dan efisien dengan mengembangkan atribut penting seperti otomatis, ergonomis, mudah dioperasikan, tahan lama, aman saat digunakan, biaya murah, mudah dibongkar pasang, tidak mudah rusak, dan mudah dipindahkan. Metode yang digunakan adalah Quality Function Deployment (QFD), yang memungkinkan identifikasi dan pemenuhan harapan pengguna melalui analisis mendalam terhadap suara pelanggan. Hasil penelitian menunjukkan bahwa dari atribut yang dikembangkan, atribut yang paling dominan adalah keamanan saat digunakan dan kemudahan pengoperasian, diikuti oleh portabilitas dan daya tahan. Sementara itu, atribut seperti kemudahan dibongkar pasang dan biaya murah dianggap kurang penting oleh pengguna. Desain mesin yang dihasilkan mampu memenuhi semua kriteria yang ditetapkan oleh pengguna dan memberikan solusi inovatif untuk meningkatkan efisiensi pengelolaan sampah anorganik di tingkat rumah tangga untuk memberikan kemudahan, keamanan, dan portabilitas dalam penggunaannya. Dari pembobotan nilai atribut yang urutan paling dominan hingga yang terakhir yaitu atribut mudah di pindahkan dengan nilai 10.542, mudah dibongkar pasang 9.404, aman saat digunakan 8.821, ergonomis 8.151, mudah di operasikan 6.630, tahan lama 6.248, biaya murah 5.439, mesin tidak mudah rusak 5.283, otomatis 5.110.

Keywords: Mesin Pencacah Portabel, Sampah Anorganik, Quality Function Deployment, Desain Ergonomis, Pengelolaan Limbah.

INTRODUCTION

Waste is the biggest problem in all countries, especially Indonesia. The amount and type of waste in Indonesia continue to increase every year, along with the increase in population. According to SIPSN data (National Waste Management Information System) quoted from the official SIPSN website, the amount of waste produced in Indonesia will reach 24.67 million tons per year in 2021, with a percentage of 13.38% or 3.3 million tons. However, compared to the previous year, only 50.43% of waste was processed in Indonesia, namely 12.44 million tons/year. With this amount, Indonesia can produce around 67,590 tons or 0.25 kg/person/day. The waste generated on a household scale is enormous in the form of organic and inorganic waste. The waste produced continues to accumulate and is difficult to decompose, especially inorganic waste, which is very difficult to decompose. Inorganic waste generally takes decades to hundreds of years to decompose completely, resulting in inorganic waste accumulating and polluting the local environment. A waste chopping machine is a tool designed to speed up shredding. In general, inorganic waste shredding machines are expensive and significant and take up much space. Garbage shredding machines are quite costly, making it difficult for married people to buy such waste shredding machines. This is what causes much inorganic waste on a household scale to pile up and be difficult to decompose [1].

A waste shredding machine is a machine used to reduce the dimensions of waste. The working principle of a waste chopper machine is that the waste is collected and then put into the machine, and then in the chopper tube, the waste will be chopped; there is a stationary knife and a rotating knife in the chopper tube, then the shredded waste will come out of the output hole of the chopper machine, and The hope is that the size of the waste that comes out will be smaller so that the subsequent processing process will be more straightforward [1]. Several types of chopping machines include plastic choppers, animal feed choppers, grass choppers, paper shredders, and leaf choppers. This waste-chopping machine is designed with a driving motor, a top cover, a filter for shredding, and components that make up the chopper, such as a chopper knife [2].

Previous research used the QFD method to develop shredding machine products for grass and waste vegetables n d using the QFD method, the results of which stated the product specifications of vegetable chopping machines and grass required by technicians based on the QFD method, seven attributes desired by technicians are obtained, namely: strong and durable, blades do not rust easily, wide shape, safe when used, easy to disassemble, easy to use, materials must be cat [3]. for Previous research which used the QFD method to design a young papaya chopper using the QFD method, where results were obtained in the form of a young papaya chopper produced in this research that can speed up the production process with the concept and dynamo drive so that the overall design of this tool can efficiently produce chopped young papaya [4]. Next, there is also Previous research which used the QFD method to design an automatic waste chopping machine for both organic and non-organic waste on an ergonomic basis using anthropometric and QFD methods, the results of which stated that this research produced an appropriate machine design with the user's desired specifications, namely including a machine using light steel so that it speeds up the chopping process, is durable, easy to move, because there are ergonomic, automatic, speed settings [5].

From the explanation explained above, the formulation of the problem in this research is How to design a tool that functions as an inorganic waste chopping tool, how to implement the quality function deployment method in designing the tool, how can the design of this tool be a solution to the problems faced by users of waste chopping tools in their use, while the research objective to be achieved in this research is to design a tool that functions as tool inorganic waste chopper, to implement the QFD method in designing the tool, to determine whether the design of the tool can be a solution to the problems faced by users in chop up waste to provide added value h and be able to plan the cost budget needed to make the product.

METHOD

Benchmarking

Benchmarking is for the best competitors or companies that do something with the best quality and affordable price and then do the best. It is necessary to have several attributes and explanations to explain several attributes with the function and use of waste-chopping tools in benchmarking [6]. So that when the product to be produced can compete, you can take action for benchmarking. The following is a benchmarking of plastic shredding equipment products using designs and brands from waste managers from various villages in the Gresik area.

Voice of Customer

Consumer needs are a fundamental and crucial stage in compiling product attributes, which are the basis for product development [7]. The analysis stage to obtain customer input is the Voice of Customer; the QFD process requires collecting customer data interpreted as characteristics or elements of a product or service. This research involves collecting data through interviews and coming to waste management in Winginanom Gresik District. In theory, it is called the data voice of the customer [8].

Voice of Engineering contains technical characteristics, namely products or services planned to be developed to meet consumer needs. Usually, this decrease in Voice of Engineering is due to the requirements of the previous stage, namely Voice of Customer. Voice of Engineering is a description of the company's technical capabilities in terms of fulfilling consumer desires [9].

Determination of *Planning* and *Technical Matrix*

Planning with the aim of *importance to the customer* on consumer attributes in assessing the attributes of subjectively designed waste chopper users, namely matrix planning. Various data from this plan is about data from the VOC. It contains qualifications of the quantitatively expected level of importance of product attributes. This planning assessment is according to the target value for *sales points*, performance improvement ratio, current technical response and the weight of attributes that are considered essential for consumers [10].

This research was conducted in the waste management area of Wringinanom District, Gresik, focusing on the design of waste-chopping equipment for six months. The stages include a preliminary survey to collect information on tool users, a literature study to analyze theories and solutions, problem formulation, and setting research objectives. Data was collected through interviews and questionnaires from 31 respondents. Valid data is processed using the Quality Functional Deployment (QFD) method, while invalid data will be collected again. Then, consumer needs are grouped, a planning matrix is drawn, and a waste chopper design is created. This will allow for inaccuracies in sample calculations due to errors during sampling that can be tolerated, namely 5%. By using the Slovin equation [11].

RESULTS AND DISCUSSION

Benchmarking

Table 1 explains *benchmarking*, which contains user complaints regarding existing waste chopper tools, which are too short and do not have wheels to move the chopper.

Table 1. Table *Benchmarking*

Types of products	Variable	Consumer complaints
	Plastic waste shredder	Tool too short
		Has no wheels to move
		Design less attractive
		The price is quite expensive

	It cannot be disassembled

Voice of Customer

Consumer needs are a fundamental and crucial stage in compiling product attributes, which is the basis for product development [7]. Stage analysis is used to obtain customer input, namely Voice of Customer. The QFD process requires collecting customer data, interpreted as product or service characteristics or elements [12]. This research, which collects data through an interview process and comes to waste management in the Winginanom Gresik sub-district, is, in theory, called the voice of customer data. The data obtained from the questionnaire includes the attributes of waste shredding machines, namely automatic, ergonomic, easy to operate, durable, safe when used, low cost, easy to disassemble, not easily damaged, and easy to move.

Test Reliability and Validity

In Table 2 and Table 3, data results of the reliability test and validity of the instrument show the level of importance and satisfaction with the waste chopping tool. Which is described as follows :

Table 2. Reliability Test Results Data

No	*Cronbach's Alpha* Level of importance	Status	*Cronbach's Alpha* Satisfaction level	Status	*N of Items*
1	0.614	*Reliabel*	0.620	*Reliabel*	9

In Table 2, the data from the reliability test results show that the Cronbach alpha value is 0.6, the Cronbach alpha value is 0.614 for the importance level, and the Cronbach alpha satisfaction level is 0.620. This shows that both level instruments are said to be reliable because they are above 0.6 [13].

Table 3. Validity Test Result Data

No	Attribute	r Table	r Calculate the level of importance	r Calculate satisfaction level	Validity Test
1	Automatic	0.355	0.459	0.424	Valid
2	Ergonomic	0.355	0.516	0.421	Valid
3	Easy to operate	0.355	0.525	0.444	Valid
4	Durable	0.355	0.578	0.459	Valid
5	Safe when used	0.355	0.456	0.642	Valid
6	Low cost	0.355	0.469	0.481	Valid
7	Easy to disassemble	0.355	0.576	0.57	Valid
8	The machine is not easily damaged	0.355	0.425	0.48	Valid
9	Easy to move	0.355	0.452	0.607	Valid

In table 3, the validity test results in data explain the validity test results of the nine attributes of the level of importance and nine attributes of the level of satisfaction of the waste chopper, which is above the r table, and the results state that they are valid for all attributes [13].

Voice of Engineering

In Table 5, the data Voice of Engineering explains what needs to be done in the technical characteristics of the customer's data voice.

Table 4. Voice Of Engineering

No	VOC Attributes	VOE	Note. VOE	Source
1	Automatic	Auto button	Controlling the on and off of a machine	[5]
2	Ergonomic	Dimensions adapt to the user	The dimensions of the machine adapt to the user so that a large number of products can be produced	[5]
3	Easy to operate	It is not difficult to operate the machine	Machine operation does not require much power	[5]
4	Durable	Angle iron frame	This is the most important part for the longevity of the machine	[5]
5	Safe when used	The container is provided with a cover	This is important for chopper machine users	[14]
6	Low cost	Affordable material prices	The price of materials for making a chopping machine is cheap	[14]
7	Easy to disassemble	The lid can be opened and assembled with bolts	For easy cleaning	[3]
8	The machine is not easily damaged	Good frame and blade material	The machine does not rust easily and does not damage the machine	[3]
9	Easy to move	Drive wheel	It is a part to make it easier to move the machine	[5]

Relationship Matriks

Technical correlation is a technique that shows the relationship between technical responses and others. This technique determines the policies taken regarding technical responses, which makes it easier to create the technical response policies currently being implemented. This can make it easier to create a matrix with the symbols above [15]. The following is an image *of the technical correlation* of the attributes of the waste shredder contained in Figure 1.

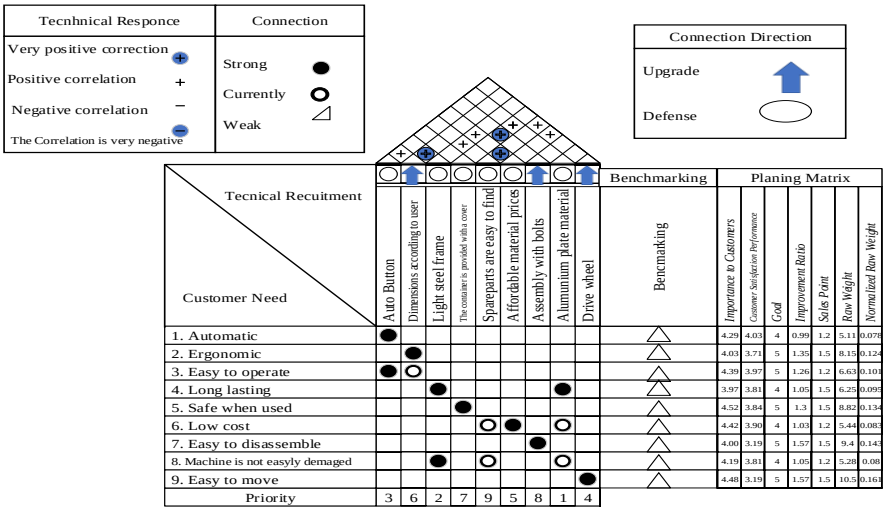


Figure 1. Relationship Matrix

Figure 1 relationship matrix explains that Correlation Voice of engginering engineering in waste shredding equipment products shows a strong relationship between dimensions suitable for the user with a steel frame for ergonomics, easy-to-find spare parts with affordable material prices and a container with a lid. With bolt assembly for easy cleaning. The automatic buttons are also strongly linked to dimensions according to the user. At the same time, the steel frame is connected to spare parts that are easy to find, and the material prices are affordable. Apart from that, the container with a cover is strongly linked to the aluminium plate material, and the spare parts are easy to find with the drive wheel. The correlation between the Voice of the customer and the Voice of engineering shows a strong relationship between automatic and button automatic, ergonomic with dimensions

according to the user, and easy to operate with automatic buttons. Durable due to its strong angle iron frame and aluminium plate, while safe when used due to the cover container. Low cost is strongly related to affordable material prices, and easy disassembly is related to bolt assembly. The machine is not easily damaged due to its strong angle iron frame and is easy to move due to the driving wheels. A moderate relationship occurs between easy-to-operate with dimensions suitable to the user and low cost with easy-to-find spare parts and aluminium plate material. The machine is not easily damaged and is quite substantial due to the aluminium plate material, and spare parts are easy to find.

Importance To Customer, Customer Satisfaction, and *Goal*

The following is the calculation of the level of importance (*importance to the customer*) of the automatic attribute. After the calculation example, there is a table *importance to customer* all attributes in Table 7.

Table 7. Data *Importance to Customer, Customer Satisfaction Performance, Goal,* and *Improvement Ratio*

No	Attribute	Importance to Customers	Customer Satisfaction Performance	Target/Goal consumers	Improvement Ratio
1	Automatic	4.29	4.03	4	0.993
2	Ergonomic	4.03	3.71	5	1.348
3	Easy to operate	4.39	3.97	5	1.259
4	Durable	3.97	3.81	4	1.050
5	Safe when used	4.52	3.84	5	1.302
6	Low cost	4.42	3.9	4	1.026
7	Easy to disassemble	4.00	3.19	5	1.567
8	The machine is not easily damaged	4.19	3.81	4	1.050
9	Easy to move	4.48	3.19	5	1.567

In Table 7, data *on customer satisfaction performance* explains how to calculate satisfaction level values from 9 attributes' *voices of customers* of waste shredding equipment products. The target value reflects the level of user satisfaction with the improvements made by the development team to meet user needs and become a performance target. This has benefits for users and developers. *Based on nine attributes, the improvement ratio* measures optimizing user satisfaction through waste chopper design. The stages involve dividing the value of *the goal* with *competitive*.

Sales Point, Raw Weight, dan *Normalized Raw Weight*

The results of the attributes of point of sale, Raw Weight, and Normalized Raw Weight are presented in Table 8 as a consideration in selling waste shredder machines..

Table 8. Determination of value *Sales Point Raw Weight,* dan *Normalized Raw Weight*

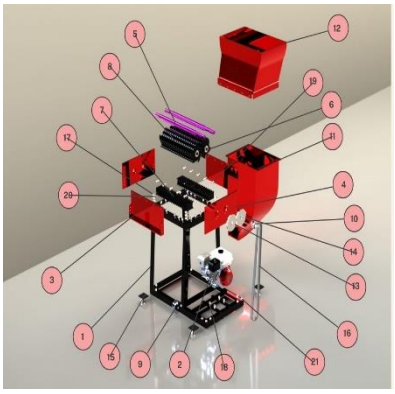
No.	Attribute	Sales Points	Raw Weight	Normalized Raw Weight
1	Easy to move	1.5	10.542	0.161
2	Easy to disassemble	1.5	9.404	0.143
3	Safe when used	1.5	8.821	0.134
4	Ergonomic	1.5	8.151	0.124
5	Easy to operate	1.2	6.63	0.101
6	Durable	1.5	6.248	0.095
7	Low cost	1.2	5.439	0.083
8	The machine is not easily damaged	1.2	5.283	0.081
9	Automatic	1.2	5.11	0.078

Explanation of Table 8 *Sales Point Raw Weight* and *Normalized Raw Weight.* , namely a calculation of the weight of each attribute of consumer needs. This process occurs after analyzing sales points, improvement ratios, and consumer interest levels. The percentage value of Raw

Weight, which ranges from 0 to 1, explains the Normalized Raw Weight and is used to normalize and calculate the weight value of each attribute that consumers want.

Trash Shredder Design

The design of the new chopping machine is presented in Figure 2, showing the parts of the chopping machine.



Gambar 2. BOM mesin pencacah sampah

Explanation in Figure 2 regarding the parts that make up a waste shredder, namely bottom frame (1), Honda GX 160 (2), support plate (3.4), shaft drive (5), bearing (35x55x16)(6), static knife (7), cutter (8), Drive shaft (9,10), ex plate (11), in plate (12), left and right helical gear (13,14), wheel(15), belt shaft (16) , flange screw M10x1.5x35(17), fla nge screw M10x1.5x5 0 (1 8), fla nge screw M10x1.5x 40 (1 9), fla nge nut M10x 1.5 (20), flange screw M10x1.5x 3 0(21).

CONCLUSION

To obtain a waste chopper design that suits the user's wishes, a redesign was carried out, taking into account characteristics such as automatic (4.29), ergonomics (4.03), ease of operation (4.39), durability (3.97), safety use (4.52), affordable material costs (4.42), ease of dismantling (4.00), machine resistance to damage (4.19), and ease of moving (4.48). In this way, the resulting product will be safe and satisfying for its users. This research results in the weighting of attribute values from the most dominant order to the last, namely the attribute is easy to move with a value of 10,542, easy to disassemble 9,404, safe when used 8,821, ergonomic 8,151, easy to operate 6,630, durable 6,248, cheap cost 5,439, machine not easily damaged 5,283, automatic 5.110.

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