Product Design of Total Dissolved Solid

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Abstract. Development of measuring devices total dissolved solid microcontroller-based with several variations of the conductivity sensor has been carried out. In the process of making this TDS product design the technique is first used brainstorming to determine the characteristics of the product to be made, then draw conclusions from the results of brainstorming that has been collected. Then the technique is done sampling by distributing open and closed questionnaires to determine the type of product. After the open and closed questionnaires are finished distributing, then conducted survey is market using a technique sampling, as well as determining the validity and reliability of the main products with products of competitors I, competitors II and competitors III. The steps problem to the sub problems are determined in order to classify the objectives that will be made in the design of the TDS product. Sub problem to sub solutions are carried out to determine the Quality Function Deployment (QFD) Product. The step sub-solution to the solution is determined to generate and evaluate alternatives by the sum of the paired matrices between attributes. Product design uses the nigel cross approach.

1. Introduction
Product Design, or commonly referred to as product design, is a set of product development that is a process in the work of marketing and business vision, which includes improving the vision or objectives of the product into technical specifications, new development concepts, and the embodiment of product engineering new. The product development process certainly starts from the manufacturer's understanding of consumers' perceptions and expectations of the product itself [1]. Customer satisfaction assessment methods are used to assess consumer desires for existing products. The concept of customer satisfaction is used to measure the level of consumer satisfaction in the SERVQUAL method. The attributes of a product are basically very closely related to customer satisfaction, where the higher the customer assessment of a product attribute, the higher the customer satisfaction is felt. A development product can be said to be successful if it gets a positive response from consumers followed by the desire and actions to buy the product [2].

1.1. Purpose
The purpose of writing this journal is to show the use of TDS. TDS serves to detect levels of metals present in water. TDS is a device used to measure levels of dissolved substances in water. The designed TDS has an additional function which can measure temperature and metal content simultaneously. Using TDS can detect large levels of dissolved solids in the water so that it can assess the suitability of the water for consumption [3].
2. Research Methods

2.1. Approach Nigel Cross

To design products approach is carried out Nigel Cross which is divided into 7 steps, namely:

- **Clarification of Objectives** [4]
  Clarification of objectives is carried out to determine the design goals. The method used is the objective trees (objectives trees). With the goal tree, we will be able to identify the goals and sub-objectives of the design of a product and the relationship between the two, namely in the form of diagrams that show a hierarchical relationship between goals and sub-goals. Branching on the goal tree is a relationship that shows the way to achieve certain goals. The steps taken in the goal clarification phase are as follows make a list of design goals, arrange the list in the order of objectives from higher-level to lower-level, draw a diagram of the destination tree, to show hierarchical relationships.

- **The Function Determination**
  Objective tree method looks at the purpose of the problem which has many levels of difference that are both general and detailed. The designer is always possible to increase and decrease levels in the problem and also can decrease several levels.

- **Determination of Needs** [5]
  After determining the function, the next step is to determine the needs. This step aims to make accurate manufacturing specifications for the design. In setting boundaries about what a designer must achieve, performance specifications limit the extent of solutions that might be accepted. Therefore, a designer must make limits on the targets to be achieved, but these limits should not be too narrow. On the other hand, the specifications are too broad, can give the designer a little idea that fits its purpose. Specifications that are too broad will lead to inappropriate solutions.

- **Characteristics of Determination**
  QFD is a way to improve the quality of goods and services by understanding the needs of consumers and then relate them to technical provisions to produce goods or services at each stage of making the goods and services produced. QFD (Quality Function Deployment) is a planning tool needed to help businesses focus on the needs of their customers when developing design and fabrication specifications.

- **Alternative Generations**
  Generation is a design process that is useful for generating alternatives that can achieve solutions to design problems. The method used is a morphological chart. Morphological chart is a list or summary of a systematic change analysis to find out how the shape of a product is made. In this chart a combination of various possible solutions to form different or varied products is made. Different combinations of sub solutions can be selected from the chart may lead to new solutions that have not been identified before. Morphological charts contain complete elements, components, or sub solutions that can be combined.

- **Alternative Evaluation** [6]
  Evaluation is a process of determining the best alternative of the various alternatives that arise, so that a good design is obtained and can meet the desires of consumers. Alternative evaluation steps are:
  Make a list of design goals. This list is a modification from the initial list. The destination tree can also be used for this purpose, Compile a list of goals and sub-goals from high to low levels. The method used is weighted objectives, Make a relative weight of each goal. Giving weights can also use different values from each destination tree so that the total number of weights is worth 1. Creating implementation parameters / usability values for each destination. Both qualitative and quantitative objectives should be made on a simpler scale, Calculate and compare the relative values of each design alternative. Multiplication of each parameter score
by the weight of the value. The best alternative has the largest amount of value. Comparison and analysis of the value profile might be better in the design than just simply choosing the largest value.

- Improved Details [7]
  Much of the design work in practice is not associated with the creation of radical new design concepts, but rather making modifications to realize product design. This modification seeks to develop a product, improve its appearance, reduce weight, reduce costs, and enhance its appeal. All forms of modification can usually be divided into two types, namely modifications aimed at increasing the value of the product for buyers and reducing costs for producers.

The questionnaire instrument was used in two stages, viz preliminary questionnaire (open questionnaire) for get a general picture of the characteristics / attributes that consumers need and followed by a closed questionnaire divided into two part, namely: the first part as consumer preference which states the level of consumer interest in product attribute X and the second part as consumer perceptions that express views good / bad performance of the product attributes at this time [8]. Research data obtained from the distribution of open questionnaires, closed questionnaires and surveys market conducted in order to find the information needed related to the design of TDS product design. Brainstorming is done as a first step before determining the product to be designed. Brainstorming is a method used to generate ideas that most ideas will be discarded. There are 8 main rules in brainstorming which include the group must be non-hierarchical, the group leader acts as a facilitator, the group is expected to generate as many ideas as possible, it is not justified to criticize any ideas, ideas that seem strange still to be accepted, try all ideas stated briefly and clearly, the atmosphere during the brainstorm took place relaxed and free, activities should take place in no more than 20-30 minutes [9].

Sampling is a very popular method of data collection because of its enormous benefits in saving time and money in data collection activities. Sampling is the process of drawing a sample from a population through a specific mechanism through which the characteristics of the population can be known or approached. The method sampling used is the method nonprobability sampling. The technique sampling used is simple random sampling where samples are taken randomly, that is, each member of the population has the same opportunity to be selected as a sample member, the commonly used method is to use a random table, or can also be used the lottery method [10].

3. Results and Discussion
In the product design of metal content detection devices in group V water, there were problems that arose regarding consumer desires for shape, weight, sensors, materials, outputs, main functions, and additional functions. Of the problems that arise will be sought subproblems from existing problems. There are 3 steps that can be taken so that problem this breaks down into sub-problems, namely the classification of goals, classification of functions, and determination of needs.

3.1. Classification of Goals & Functions, Determination of Needs
To find solutions to the problems above, there are 3 steps needed so that the problem will be divided into sub-problems, namely classification of goals & functions, and determination of needs. Conclusions from 3 steps in the design of TDS products are:

- List of objectives designing TDS are The metal detectors in water are square, The metal detectors in water has 500 grams, The metal detectors has an LCD output display, The metal detectors in water uses an energy source from a battery, The Metal detectors in water have an input electrode receptor, Tool metal content detector in water using the main sensor that is metal sensor metal, content detector in water using an additional sensor that is temperature sensor, metal content detector in water made of metal. Additional material functions detector in water
made of rubber, Additional functions of the tool Detection of metal content in water that is to measure the temperature of the destination tree can be seen in Figure 1. below this.

- Function division into essential sub-functions TDS, sub-function design Sub function design TDS Features
- Determine the level of generality to be operated
  Products can be used long term, the product has a cheap price, the product has a temperature sensor to measure water temperature.

3.2. Determination of Characteristics
In this section, a sub-problem of the TDS specification will be found a sub-solution with the steps of the design Nigel Cross, to determine product characteristics. Quality Function Deployment TDS can be seen in Figure 2.
### Material of Metal Detector
- Plastic and metal

### Weight of the Metal Detector
- 500 gr

### Shape of the Metal Detector
- Square

### Energy Resource
- Battery

### Sensor of Metal Detector
- Metal Sensor

### The Display of Metal Detector
- LCD

### Input Receiver
- Electrode

### Material of Additional Function
- Silicon

### Additional Function
- Measure temperature

### Level of Difficulty

| Level | Description | Percentage |
|-------|-------------|------------|
| 1     | Easy        | 1 – 20%    |
| 2     | Quite Easy  | 21 – 40%   |
| 3     | Difficult   | 41 – 60%   |
| 4     | Very Difficult | 61 – 80% | |
| 5     | Absolutely Difficult | 81 – 100% | |

### Cost Estimation

| Cost | Description          |
|------|----------------------|
| 1 – 15 | Cheap                  |
| 16 – 30 | Expensive             |
| 31 – 45 | Very Expensive        |

### Degree of Importance

| Degree | Description       |
|--------|-------------------|
| 1      | Very Low          |
| 2      | Low               |
| 3      | Medium            |
| 4      | High              |
| 5      | Very High         |

### Consumer Perception

| Score | Description          |
|-------|----------------------|
| 1     | Very Bad            |
| 2     | Bad                 |
| 3     | Enough              |
| 4     | Good                |
| 5     | Very Good           |

### Relative Importance

| Characteristic | Importance |
|----------------|------------|
| Total Dissolved Solid | Medium Negative Relationships |
| Electrode | Medium Negative Relationships |
| Receiver | Medium Negative Relationships |
| Battery | Medium Negative Relationships |
| LCD | Medium Negative Relationships |
| Temperature | Medium Negative Relationships |

### Figure 2. Quality function deployment TDS

Conclusion:
TDS attributes based on the results of the questionnaire in accordance with the wishes of consumers. Characteristics of TDS products obtained from the design objectives are:

- Total Dissolved Solid has a square shape.
- Total Dissolved Solid weighs 500 grams.
- Total Dissolved Solid has output an LCD display.
- Total Dissolved Solid has a battery as an energy source.
- Total Dissolved Solid electrodes has a receivers input.
- Total Dissolved Solid has a metal sensor as the main sensor.
- Total Dissolved Solid has a temperature sensor as an additional sensor.

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• Total Dissolved Solid made from the main function of metal.
• Total Dissolved Solid made from additional functions in the form of rubber.
• Total Dissolved Solid has the additional function of measuring temperature.

Difficulty level: all technical characteristics are in the easy category. Degrees of Interest: all the technical characteristics fall into important categories. Estimated Cost: all the technical characteristics belong to the inexpensive category.

4. **Sub Solution**
Sub solution is the solution of each problem that occurs, including the selection of attributes for TDS which is done by using steps Nigel Cross, while maintaining the superiority that has been owned and improving the quality of the product.

4.1. **Alternative Generation**
Generation stage aims to collect as many alternatives as possible that can be used to solve problems in the design of TDS products, to then find the best solution or alternative. This is done using the morphological map method (Morphological Charts) with the steps including:

- Making a list of functions or objectives that are important to the product.
- Make ways to achieve essential functions.
- Identify a combination of design solutions that can be applied.
- Identify the feasibility of a combination of sub-solutions.

The Morphological Chart shows all possible solutions or alternative relationships that can be used in the design of the TDS as in Table 1. Morphological Chart of TDS products is displayed in the form of a matrix of 10 x 3, where there are 10 functions that must be achieved and there are 3 alternatives that may be applied. Total possible combinations to reach the alternative are 120 ways.

### Table 1. Combination of TDS product design solutions

| No | Characteristics       | How To Achieve Function |
|----|-----------------------|-------------------------|
| 1  | Shape                 | cube oval beam          |
| 2  | Weight                | 500 gr 1000 gr 80 gr   |
| 3  | Display               | LCD LED Graphic        |
| 4  | Energy sources        | Battery Electric Sun    |
| 5  | Input receiver        | Electrode Sensor Copper electrode |
| 6  | Main sensor           | Metal sensor Logam Detector Water content sensor |
| 7  | Materials of additional features | Metal Non ferrous metals rubber |
| 8  | Additional sensor     | temperature sensor water solid sensor Solar panels |
| 9  | Additional features   | Thermometer Mineral content cautage Solar recharging |
| 10 | Materials of additional features | Rubber metal synthetic |

4.2. **Alternative Evaluation**
Evaluation aims to compare the utility values of alternative product designs made or made on the basis of performance on the basis of weighting objectives, where the results of the alternative generation step will be evaluated by re-examining the alternative to be selected so that the best alternative is produced. The method used is a method of weighting of Interest (Weighted Objectives) with AHP scale.

Rating ratings are performed using Pair Wise Comparison and AHP scale, with data obtained from the importance value for each attribute in QFD. Level I is a Paired Comparative Matrix between Primary Attributes, Level II is a Paired Comparative Matrix between Secondary Design Attributes, and Level
III is a Paired Comparative Matrix between Secondary Attributes of Additional Materials and Functions. After pairing the comparison matrix with the AHP scale then weighting is performed for each level. Weighting for each attribute is needed to know how the influence of these attributes in product design. Weighting is done by dividing the ranking value of each attribute to the total rating value itself. The results of the weighting of each comparison matrix can be seen in the table below.

**Table 2.** Weighting of paired appeal matrices between level II primary attributes weighting of paired appeal matrices

| Element                  | Design | Additional Functions |
|--------------------------|--------|----------------------|
| Design                   | 1.0000 | 0.7399               |
| Additional Functions     | 1.3515 | 1.0000               |
| **Total**                | 2.3515 | 1.7399               |

**Table 3.** Between secondary design level III attributes

| Element                        | Shape  | Weight | Display | Energy Resources | Receiver Input | Main Sensor | Materials of Additional function | Total   |
|--------------------------------|--------|--------|---------|------------------|----------------|------------|-----------------------------------|---------|
| Shape                          | 0.0979 | 0.0948 | 0.1335  | 0.1615           | 0.0840         | 0.0610     | 0.0972                            | 0.1043  |
| Weight                         | 0.0738 | 0.0715 | 0.2835  | 0.1599           | 0.0678         | 0.0501     | 0.0153                            | 0.1031  |
| Display                        | 0.1575 | 0.0542 | 0.2149  | 0.3058           | 0.1693         | 0.3938     | 0.2640                            | 0.2228  |
| Energy resources               | 0.0344 | 0.0253 | 0.0399  | 0.0567           | 0.0576         | 0.0945     | 0.0687                            | 0.0539  |
| Receiver input                | 0.1181 | 0.1069 | 0.1287  | 0.0999           | 0.1014         | 0.0596     | 0.2116                            | 0.1180  |
| Main sensor                    | 0.4684 | 0.4164 | 0.1593  | 0.1753           | 0.4962         | 0.2919     | 0.2938                            | 0.3287  |
| Materials of Additional function | 0.0498 | 0.2310 | 0.0402  | 0.0408           | 0.0237         | 0.0491     | 0.0494                            | 0.0691  |
| **Total**                     | 1.0000 | 1.0000 | 1.0000  | 1.0000           | 1.0000         | 1.0000     | 1.0000                            | 1.0000  |

After that, the performance parameters of each attribute are determined. Performance parameters can be seen in Table 4. below.

**Table 4.** Performance parameters of each attribute

| Characteristics            | Parameter | Score | 5 | 4 | 3 | 2 | 1 |
|----------------------------|-----------|-------|---|---|---|---|---|
| Shape of products          | Shape     | Cube  | Beam| Oval| Ball| Formless |
| Weight                     | Massa     | 500 gr| 800 gr| 1000 gr| 1200 gr| 1500 gr |
| Display                    | Quality   | Very good | Good | Enough | Bad | Very Bad |
| Energy resources           | Quality   | Very good | Good | Enough | Bad | Bad |
| Receiver input             | Quality   | Very good | Good | Enough | Bad | Bad |
| Main sensor                | Quality   | Very good | Good | Enough | Bad | Bad |
| Materials of Additional function | Quality | Very good | Good | Enough | Bad | Bad |

5. Solution
The final stage of the design process aims to increase the value of the product for consumers and reduce costs that must be incurred by producers. The solution has been obtained from the existing alternatives and then communicated to consumers through products with all its attributes advantages compared to competitors’ products are similar. This can be done by using Value Engineering (Value Engineering). Langkah-step in improving details is as follows:

- Make a list of product components and identify the functions of each component as in Table 5 below.
Table 5. TDS product component data

| Function            | Score | Information                                                                 |
|---------------------|-------|------------------------------------------------------------------------------|
| Design              | Good  | TDS has a square main design for its shape and size according to the size of the components that will be used in it. |
| Additional function | Good  | TDS uses a component, namely a temperature sensor, to detect the temperature in water. |

- Determines the identified function value. Based on the functions that have been identified, the values are determined based on consumer perception. The values of each function are assessed based on the suitability of the design to the consumer's desire for it as shown in Table 6.

Table 6. Value of each function

| Function            | Score | Information                                                                 |
|---------------------|-------|------------------------------------------------------------------------------|
| Design              | Good  | TDS has a square main design for its shape and size according to the size of the components that will be used in it. |
| Additional function | Good  | TDS uses a component, namely a temperature sensor, to detect the temperature in water. |

- Calculates the cost of each component. The price of the main raw material, supplementary material, and supporting material for the manufacture of the product has been estimated in advance to determine the selling price of the product produced. Component prices are assumed as shown in Table 7.

Table 7. Cost of each TDS product component per product unit

| Component         | Price           | The Number of Components | Total Price |
|-------------------|-----------------|--------------------------|-------------|
| Electrode         | IDR 25.000/unit | 1 unit                   | IDR 25.000  |
| Cable             | IDR 15.000/50 m | 7 m                      | IDR 15.000  |
| Rubber            | IDR 80.000/ml   | 900 ml                   | IDR 80.000  |
| LCD               | IDR 58.000/unit | 1 unit                   | IDR 58.000  |
| Metal Sensor      | IDR 28.500/unit | 1 unit                   | IDR 28.500  |
| Battery           | IDR 22.500/4 unit | 4 unit              | IDR 22.500  |
| Temperature Sensor| IDR 14.000/unit | 1 unit                   | IDR 14.000  |
| **Total**         | **IDR 243.000** |                         |             |

- Looking for ways to reduce costs without reducing value. From the results of the evaluation, value engineering can only be done by finding replacement components whose prices are relatively cheaper than before. After conducting the survey, a replacement component is obtained with the price as shown in Table 8.

Table 8. Cost evaluation results for each TDS product component

| Component         | Price           | The Number of Components | Total Price |
|-------------------|-----------------|--------------------------|-------------|
| Electrode         | IDR 25.000/unit | 1 unit                   | IDR 25.000  |
| Cable             | IDR 15.000/50 m | 7 m                      | IDR 15.000  |
| Rubber            | IDR 80.000/ml   | 900 ml                   | IDR 80.000  |
| LCD               | IDR 58.000/unit | 1 unit                   | IDR 58.000  |
| Metal Sensor      | IDR 28.500/unit | 1 unit                   | IDR 28.500  |
| Battery           | IDR 22.500/4 unit | 4 unit              | IDR 22.500  |
| Temperature Sensor| IDR 14.000/unit | 1 unit                   | IDR 14.000  |
| **Total**         | **IDR 243.000** |                         |             |
- Evaluate alternatives and select changes. The way to reduce costs is through replacing stretchers and TDS boxes from different stores at prices that are lower than the estimated price, so the initial price is estimated at around IDR 243,000.00 to IDR 210,000.00.

6. Conclusions
The attributes of the TDS product can be divided into several sections. The primary attributes are the shape of the device, the weight of the device, the display output of the tool, the energy source of the tool, the metal detector input receiver, the metal detector main sensor, the additional function sensor, the metal detector material. The secondary attributes of TDS products are metal detector, additional function materials, and additional functions. For QFD it is found that all the characteristics of the technique are quite easy to do, for product composition, duration of assembly, strength of material, weight of cutting material, weight of making PCB circuit, charging duration, and service life. Based on the value engineering step through improving details, it is found that from the alternatives there are the best alternatives with a total cost of IDR 426,905.00.

Acknowledgment
The author would like to thank profusely to all those who have helped. The author thanks the production system laboratory assistant for his guidance so we can finish this research well.

References
[1] Ginting R 2013 Perancangan Produk (Yogyakarta: Graha Ilmu)
[2] Ginting R and Khatami M 2019 Talenta Conference Series: Energy and Engineering (EE) 2 (3) pp 183-194
[3] Ginting R, Batubara T Y and Widodo 2017 Jurnal Sistem Teknik Industri 19 (2) pp 1-9
[4] Sembiring Y, Rambe M, Jabbar A and Ginting R 2013 Jurnal Teknik Industri USU 3 (1), p.219356
[5] Irwan F and Afdal A 2016 Jurnal UNAND 5 (1) pp 85-93
[6] Wiliaury, Melisa. Santosa A and Kattu G S 2015 Intra 3 (2) pp 38-44
[7] Yunal and Oblivia V 2013 Agora 1 (1) pp 337-347
[8] Zamora, Ronaldi, Harmadi and Wildian 2015 Jurnal Sain tek 7 (1) pp 11-15
[9] Cross N 1996 Engineering Design Methods: Strategies for Product Design (New York: John Wiley and Sons)
[10] Sulaiman and Fahmi 2017 Jurnal Teknovasi: Jurnal Teknik dan Inovasi 4 (1) pp 32-41