Design of Anti Overload Bag product with the Nigel Cross Approach

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Abstract. The use of a backpack that is not appropriate has a significant negative impact on users. These negative effects can cause back pain and changes in body posture. Many students who carry backpacks on their backs exceed 10\% of the total body weight. Therefore, an innovative backpack product, Anti Overload Bag. This bag is equipped with sensors and alarms that will sound if the load that lifted does not match the load that it should be. In the process of making the product design, the Anti Overload Bag is first used a brainstorming technique to determine the characteristics of the product to be made, then draw conclusions from the brainstorming that has been collected. Then the sampling technique done by distributing open and closed questionnaires to determine the type of product. Then a market survey is conducted using a sampling technique, to determine the validity and reliability of the main products with products of competitors I, II, III. Sub problem steps to sub solutions are carried out to determine the Product Quality Function Deployment (QFD). The sub-solution step to the solution is determined to generate and evaluate alternatives by the sum of the paired matrices between attributes.

1. Introduction

Design is the application of technology and scientific principles to adjust equipment components, which must adjusted and implemented to achieve certain results [1]. Engineering design is all activities to build and define various solutions to existing problems that cannot be solved before or new solutions to problems that have been previously solved but in different ways [2].

2. Background

Many school students experience back pain for various reasons, such as sitting position, which is not good for a few hours or by carrying the wrong or too heavy backpack. Some survey results show that school students feel happy using a backpack because of this a lot of stuff can fit in them, regardless of the consequences. According to the American Pediatrician, the load a child is able to lift is 10-20 percent of their body weight. Children are individuals who are still growing. Their bone growth lasts until the age of 9 to 14 years. If at that age there is a disturbance in the bones, then bone growth will be disrupted [3]. The amount of interest in this backpack is the basis of product development in order to meet the desires of the user.

The use of a backpack that is not appropriate has a significant negative impact on backpack users. Low back pain (LBP) is one of the musculoskeletal disorders most often suffered and become barrier in
doing activities daily. Based on data from “The Global Burden of Disease Study 2010” issued by WHO, it was stated that LBP included in 10 diseases and injuries with the highest number in the world. The bag load more than 10% of body weight represents one of the risk factors for low back pain [4].

Therefore, to prevent the use of backpacks that are not compatible with the total body weight, a backpack has been invented that can detect an overload that is a load of luggage that exceeds 10% of the total body weight when worn.

3. Research Methodology
This study aims to show the use of Anti Overload Bag. This Anti Overload Bag used to detect overload that is not in accordance with the proper load. Research data obtained from the distribution of open questionnaires, closed questionnaires and market survey conducted in order to find the information needed related to the design of Anti Overload Bag products.

3.1. Brainstorming Method
Brainstorming done as a first step before determining the product to be designed. Brainstorming is a method commonly used to spawn ideas and ideas in effective time. Brainstorming model emphasizes students to organize the material being studied with a final form. The brainstorming model is a learning model to produce many ideas from all students in the discussion group tried to overcome obstacles and criticism [5].

3.2. Nigel Cross Approach Method
According to Nigel Cross in product design, product design steps which are required as in the following table.

| No | Stage in the design process | Relevant Method | Aim |
|----|-----------------------------|----------------|-----|
| 1  | Clarifying Object           | Objectives Tree| To clarify the objectives of the sub-design as well as the relationship with each other |
| 2  | Establishing Function       | Function Analysis| To determine the functions needed and the system new product design boundaries |
| 3  | Setting Requirement         | Performances Specification | To make accurate performance specifications of a design solution needed |
| 4  | Determining Characteristic  | Quality Function Deployment | To set targets to be achieved by the technical characteristics of the product so that it can realize the needs of consumers |
| 5  | Generating Alternatives     | Morphological Chart | To establish a complete set of alternative design solutions for a product and expand the search for potential new solutions |
| 6  | Evaluating Alternative      | Weighted Objectives | To compare the utility value of alternative design proposals based on different performance and weighting |
| 7  | Improving Details           | Value Engineering | To increase and maintain the value of a product to buyers and on the other hand reduce costs for producers |

3.3. Sampling Method
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.

Broadly speaking, the sampling method can be classified into two parts, namely probability sampling (sampling related to probability factors) and non-probability sampling (sampling that is not related to probability factors). The basic difference of the two types of sampling is not only the technical
implementation mechanism, but also the main target, namely probability sampling, which looks at the possibility of new areas be investigated, while non-probability sampling is more emphasized on the exploration and feasibility of applying an idea.

The sampling method used is the nonprobability sampling method. Simple random sampling technique or commonly abbreviated as Random Sampling is a method of sampling with each member of the population will be given the same opportunity then selected as a sample. Simple random sampling is a type of basic sampling that is often used to develop more complex sampling methods [6].

3.4. Questionnaire Method
Through this sampling method the number of samples is then determined, then open questionnaires, closed questionnaires, and AHP questionnaires are made. The questionnaire created to determine the tools and designs as expected by the bag users made in the product design process. Then after the questionnaire recapitulated, validity and reliability tests are performed which are useful for determining the design of Anti Overload Bag.

The questionnaire is a research or survey tool consisting of a series of written questions, which will be distributed to the appropriate respondents, with the aim of getting answers or opinions from certain groups of people through personal interviews or in the form of a list of questions [7].

Analytic Hierarchy Process (AHP) is a General Measurement Theory for finding discrete comparison scales and continuous pair comparisons. AHP decomposes complex multi-factor or multi-standard problems into hierarchical arrangements. Hierarchy is defined as the expression of complex multi-layer structure problems, where the first level is the goal, the second level is the factors, conditions, sub-conditions, etc. Until the last level of alternatives. Using a hierarchical structure, complex problems can be broken down into groups which are then arranged into a hierarchical form so that problems will appear more structured and systematic [8].

3.5 Quality Function Deployment (QFD)
Then QFD used to determine the characteristics of the product. QFD is a structured methodology used in the product planning and development process to determine the specifications of the needs and desires of consumers, as well as systematically evaluating the capabilities of a product or service in meeting the needs and desires of consumers. In QFD, quality control of a product based on the wants and needs of consumers. QFD has an advantage because it takes into account the desires of consumers, so the products produced will truly satisfy consumers [9].

QFD is a product development system that use data sets and teams to develop products based on desires consumer. QFD is a systematic approach that determines consumer demand then translate it accurately into technical design, manufacturing, and proper production planning [10].

Quality Function Deployment is a technique utilizing to guarantee the quality in each creating items stages, beginning by the plan quality itself [11]. Then in order to find solutions to each problem that arises from the manufacture of the product, steps are determined to generate alternatives, evaluate, and improve details. From all of these steps, it can be determined the characteristics of making products at the appropriate cost. The QFD approach may likewise be extremely useful for scholastics intending to approve recuperation viability in the administration business [12].

4. Result and Discussion
The result of this product design is an Anti Overload Bag that can used to detect overload. Design problems contained in the Anti Overload Bag include material thickness, machine speed, assembly time, tool weight, soldering time, cashing size, and additional function temperature.

4.1. Classification of Purpose, Function, and 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 the classification of goals & functions, and determination of needs. The conclusion of the 3 steps in designing an Anti Overload Bag product is:
List of overall product design goals for Anti Overload Bags, among others:
- Backpack type bag
- Bags that have a size of 30 cm × 15 cm × 45 cm
- The bag is black
- The bag has a plain style
- The bag has canvas material
- The bag has 5 storage places
- The bag has a zipper as the bag cover
- The bag has a sensor that can give a signal/information if it is overloaded
- The bag has a rectangular sensor
- The bag has a sensor with the size of 8 cm × 6 cm

The Destination Tree diagram can be seen in Figure 1 below.

Figure 1. Destination tree diagram

The division of functions into essential sub-functions.
- Sub-function Anti Overload Bag
- Sub sensor function
- Assembly sub function.

Determine the level of generality to operate.
- The product has a comfortable and ergonomic design
- The product has good durability
- The product has quality ingredients
4.2 **Determination of Characteristics**

In this section, the sub problem of the multifunctional bag specifications will be found a sub solution with the steps of the Nigel Cross design, to determine the product characteristics. House of Quality Anti Overload Bag can be seen in Figure 2 to Figure 5 below.

| Bag Type     | 5 |
|--------------|---|
| Bag Size     | 4 |
| Bag Color    | 4 |
| Bag Style    | 4 |
| Number of Storage | 4 |
| Bag Cover Type | 4 |
| Additional Function Shape | 4 |
| Additional Function Size | 4 |
| Bag Material | 4 |
| Bag Additional Function | 4 |

**Figure 2.** Resistance matrix between product attributes and technical characteristics.

**Figure 3.** Matrix of relationships between product attributes and technical characteristics.

**Figure 4.** Relationships among fellow technical characteristics.
### Consumer Perception

| Level of Difficulty | 1 = Not Hard | 2 = Moderate | 3 = Hard | 4 = Very Hard | 5 = Absolutely Very Hard |
|---------------------|--------------|--------------|----------|---------------|--------------------------|
| Example              |              |              |          |               |                          |

### Degree of Relationship

- **V** = Strong Relationship Level, weight = 4
- **v** = Moderate Relationship Level, weight = 3
- **x** = Weak Relationship Level, weight = 2
- **X** = No Relationship, weight = 1

### Consumer Perception

| Engineering Characteristics | Bag Type | Bag Size | Bag Color | Number of Storage | Bag Cover Type | Additional Function Shape | Additional Function Size | Bag Material | Bag Additional Function | Level of Difficulty | Degree of Importance (%) | Cost Estimation (%) |
|-----------------------------|----------|----------|-----------|-------------------|---------------|---------------------------|--------------------------|--------------|-------------------------|---------------------|------------------------|---------------------|
|                             | 5 V x x X X X v X | 4 V X X X X v X | 4 X x X X X X X | 4 X x X X X X X | 4 X X V X X V V x | 4 V X v X V v v V | 4 X v X V X X X | 4 x X X X V V x | 4 3 4 3 4 3 | 15 12 15 12 15 18 13 | 17 13 17 13 13 17 13 |

**Figure 5.** Quality function deployment of Anti Overload Bag

**Conclusion:** Attributes of Anti Overload Bags based on the results of the questionnaire in accordance with consumer desires are as follows:

- Bag type is backpack
- Bag size is 30 × 15 × 45 cm
- Bag color is black
- Bag style is plain
- Number of storage is 5
- Bag cover type is zipper
- Additional function shape is rectangle
- Additional function size is $8 \times 6$ cm
- Bag material is canvas cloth
- Additional function is weigh detector

The comparison of Anti Overload Bag products with competitors for the same attributes based on customer perception is as follows:

- For Bag Type: Group V products are superior compared to competitors 1 and competitors 2
- For Bag Size: Group V and competitor 2 products are in the same position and are superior to competitor 1 product.
- For Bag Color: Group V and competitors 1 products are in the same position and are not superior to competitors 2 products.
- For Bag Style: Group V and competitors 2 products are in the same position and are not superior to competitors 1 products.
- For Number of Storage: Group V and competitor 2 products are in the same position and are superior to competitor 1 product.
- For Bag Cover Type: Group V and competitor 2 products are in the same position and are superior to competitor 1 product.
- For Additional Function Shape: Group V products are superior compared to competitors 1 and competitors 2 products.
- For Additional Function Size: Group V, competitors 1 and competitors 2 products are in the same position
- For Bag Material: Group V product are superior compared to competitors 1 and 2 products.
- For Additional Function: Group V and competitor 2 products are in the same position and are superior to competitor 1 product.
- Level of Difficulty: the characteristics of the technique are quite difficult to do, starting from determining the material, engine speed, length of assembly, weight of the tool, soldering time, casing size to the temperature of the function in making additional functions.
- Degree of Interest: all the technical characteristics are quite important, for example the composition of the product, the quality and strength of the material making up the product and the accuracy of the machines used during product processing. Product composition and material strength have the highest degree of importance.
- Cost Estimation: the estimated cost of the design product classified as expensive, starting from the cost of making the frame, the cost of the machine used, and other costs.

4.3 Sub-Result
The sub-result is the resolution of each problem that occurs, including the selection of attributes for Anti Overload Bag which is done by using Nigel Cross steps, while maintaining the superiority that is already owned and improving the quality of the product.

In this section, there are 3 steps taken so that the sub-solution becomes a solution, namely generating alternatives, evaluation of alternatives, and improving details. Following are the conclusions of the three steps in the process of designing an Anti Overload Bag.

4.3.1 Alternative Generation. Alternative generation stage aims to collect as many alternatives as possible that can be used to solve problems in designing Anti Overload Bag products, to then find the
best solution or alternative. This is done using the morphological map method (Morphological Charts) with the steps as shown below:

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

The Morphological Chart shows all the possible solutions or alternative relationships that can be used in the design of Anti Overload Bags as in Table 6.2. Morphological Chart Anti Overload Bag product 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. The combination formula used is $10C_3 = 120$ ways.

So the total possible combinations to reach the alternative are 120 ways.

**Table 2.** The combination of design solutions for anti overload bag products

| No  | Characteristic                              | Achieving the Function          |
|-----|--------------------------------------------|---------------------------------|
| 1   | Anti Overload Bag Type                     | Sling Bag                       |
| 2   | Anti Overload Bag Size                     | 30×15×30                        |
| 3   | Anti Overload Bag Color                    | Army Green                      |
| 4   | Anti Overload Bag Style                    | Plain                           |
| 5   | Anti Overload Bag Number of Storage Type   | 5                               |
| 6   | Anti Overload Bag Cover Type               | Zipper                          |
| 7   | Anti Overload Bag Additional Function Shape| Rectangle                       |
| 8   | Anti Overload Bag Additional Function Size | 8×6                             |
| 9   | Anti Overload Bag Material                 | Waterproof Fabric               |
| 10  | Anti Overload Bag Additional Function       | Weigh Detector                  |

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

Rating ratings 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 Material and Additional Functions. After pairing the comparison matrix with the AHP scale then weighting is performed for each level. Weighting for each attribute needed to know how the influence of these attributes in product design. Weighting 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 seen in the table below.
Table 3. Weighting of pairwise comparative matrices between level II primary attributes

| Element                | Design | Material | Additional Function |
|------------------------|--------|----------|---------------------|
| Design                 | 1,000  | 3,1115   | 2,8102              |
| Material               | 0,3214 | 1,0000   | 0,7665              |
| Additional Function    | 0,3558 | 1,3046   | 1,0000              |
| Total                  | 1,6772 | 5,4161   | 4,5767              |

Table 4. Weighting of pairwise appeal matrices between secondary design level III attributes

| Element          | BT       | BS       | BC       | BSt      | NOS      | BCT      | AFS      | AFS'     |
|------------------|----------|----------|----------|----------|----------|----------|----------|----------|
| Bag Type         | 1,0000   | 0,9752   | 0,7746   | 1,2884   | 1,3702   | 1,0155   | 1,5715   | 0,6608   |
| Bag Size         | 1,0254   | 1,0000   | 1,3702   | 0,4143   | 0,5961   | 0,7909   | 2,8036   | 1,9784   |
| Bag Color        | 1,2910   | 0,7298   | 1,0000   | 1,4332   | 1,3886   | 0,3658   | 0,8145   | 1,7482   |
| Bag Style        | 0,7762   | 2,4140   | 0,6977   | 1,0000   | 1,8752   | 0,7809   | 2,8036   | 1,9784   |
| Number of Storage| 0,7298   | 1,6775   | 0,7201   | 0,5333   | 1,0000   | 0,9936   | 1,8436   | 1,4142   |
| Bag Cover Type   | 0,9847   | 0,8913   | 2,7339   | 1,2805   | 1,0065   | 0,9482   | 3,0824   | 1,0000   |
| Additional Function Shape | 0,6363   | 0,8859   | 1,2277   | 0,3567   | 0,5424   | 1,0546   | 1,0000   | 2,3294   |
| Additional Function Size | 1,5133   | 0,7427   | 0,5720   | 0,5055   | 0,7071   | 0,3244   | 0,4293   | 1,0000   |
| Total            | 7,9567   | 9,3164   | 9,0962   | 6,8119   | 8,4681   | 6,6568   | 10,5395  | 13,5599  |

After that, the performance parameters of each attribute are determined. Performance parameters can seen in Table 5. below.

Table 5. Performance parameters of each attribute

| Characteristic        | Parameter | 5 | 4 | Score | 2 | 1 |
|-----------------------|-----------|---|---|-------|---|---|
| Bag Type              | Capacity  | Very Big | Big | Moderate | Small | Very Small |
| Bag Size              | Size      | 30×15×45 | 30×15×30 | 30×20×40 | 30×30×50 | |
| Bag Color             | Contrast  | Very Contrast | Contrast | Enough Contrast | Lack | Not Contrast |
| Bag Style             | Model     | Plain | Batik | Simple | Floral | Casual |
| Number of Storage     | Size      | 5   | 6   | 4     | 3     | 10   |
| Bag Cover Type        | Model     | Zipper | Zipper | Waterproof Polyester | Buttons | Magnet |
| Additional Function Shape | Model     | Rectangle | Round | Square | Oval | Circle |
| Additional Function Size | Size     | 8×6  | 10  | 5×5   | 5     | 6×6  |

4.4 Result

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 that has been obtained from the alternatives that are then communicated to consumers through products with all the advantages of its attributes compared to competitors' similar products, this can be done by using the Value Engineering method. The steps in improving details are as follows:

- Make a list of product components and identify the functions of each component as in Table 5.
Table 6. Data components of anti overload bag products

| Component   | Function                      |
|-------------|-------------------------------|
| Fabric      | It is used as the main material in making anti-overload bags |

- **Determine the Value of the Identified Function**

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 is as shown in Table 7.

Table 7. The value of each function

| Function      | Score | Explanatory                                                                 |
|---------------|-------|-----------------------------------------------------------------------------|
| Design        | Good  | The anti overload bag has a simple design for its shape and size according to its users, namely consumers who use it to cool drinks or food |
| Material      | Good  | Anti overload bags use components, namely plastic and rubber as grip materials and plastic as tool materials |
| Additional Function Tool | Good  | The anti overload bag is designed with an additional function of saving energy, using solar panels as a substitute for electrical power. |

- **Calculate the Cost of Each Component**

The price of the main raw material, supplementary material, and supporting material for the manufacture of the product been estimated in advance to determine the selling price of the product produced. Component prices assumed as shown in Table 8.

Table 8. Cost of each anti overload bag product component per product unit

| Component   | Component Price (IDR) | Components Required | Total Price (IDR) |
|-------------|-----------------------|---------------------|-------------------|
| Fabric      | IDR 33.000 / meter    | 2 meter             | IDR 66.000        |
| Thread      | IDR 11.100 / piece    | 2 piece             | IDR 22.200        |
| Zipper      | IDR 15.000 / piece    | 1 piece             | IDR 15.000        |
| Foam        | IDR 15.000 / meter    | 2 meter             | IDR 30.000        |
| Arduino Nano| IDR 48.000 / piece    | 1 piece             | IDR 85.000        |
| Load Cell   | IDR 68.000 / piece    | 1 piece             | IDR 67.500        |
| H × 711     | IDR 18.000 / piece    | 1 piece             | IDR 18.000        |
| LCD 16 × 2  | IDR 25.000 / piece    | 1 piece             | IDR 25.000        |
| Ile Modal   | IDR 12.000 / piece    | 1 piece             | IDR 12.000        |
| Case Box    | IDR 25.000 / piece    | 1 piece             | IDR 8.000         |
| Button      | IDR 25.000 / piece    | 1 piece             | IDR 4.000         |
| Buzzer      | IDR 25.000 / piece    | 1 piece             | IDR 8.000         |
| Cabel       | IDR 25.000 / piece    | 1 piece             | IDR 10.000        |
| **Total**   |                     |                     | **IDR 370.700**   |

- **Alternative Evaluation**

Based on the evaluation of alternatives that have been done, it can be concluded that from the alternatives available, there is the best alternative with a total cost of IDR 370,700,-

5. Conclusions

The conclusions obtained in the manufacture of Anti Overload Bag products are as follows: Bag Type is Backpack, Bag Size is 30 × 15 × 45 cm, Bag Color is Black, Bag Style is Plain, Number of Storage is 5, Bag Cover Type is Zipper, Additional Function Shape is Rectangle, Additional Function Size is 8 × 6 cm, Bag Material is Canvas Cloth, Additional Function is Weigh Detector.
For attributes of the Anti Overload Bag product can divided into several sections. The primary attributes of Anti Overload Bag products are design, materials and additional functions. Secondary attributes of Anti Overload Bag products are bag type, bag size, bag color, bag style, number of storage, bag cover type, function shape, additional function size, bag material and additional functions. For QFD, it found that all the characteristics of are quite easy to do, for material thickness, machine speed, weight assembly time, soldering time, casing size and temperature of additional functions.

The comparison of Anti Overload Bag products with competitors for the same attributes based on customer perception is as follows: For Bag Type : Group V products are superior compared to competitors 1 and competitors 2. For Bag Size : Group V and competitor 2 products are in the same position and are superior to competitor 1 product. For Bag Color : Group V and competitors 1 products are in the same position and are not superior to competitors 2 products. For Bag Style : Group V and competitors 2 products are in the same position and are not superior to competitors 1 products. For Number of Storage : Group V and competitor 2 products are in the same position and are superior to competitor 1 product. For Bag Cover Type : Group V and competitor 2 products are in the same position and are superior to competitor 1 product. For Additional Function Shape : Group V products are superior compared to competitors 1 and competitors 2 products. For Additional Function Size : Group V , competitors 1 and competitors 2 products are in the same position. For Bag Material: Group V product are superior compared to competitors 1 and 2 products. For Additional Function: Group V and competitor 2 products are in the same position and are superior to competitor 1 product.

For Level of Difficulty: the characteristics of the technique are quite difficult to do, starting from determining the material, engine speed, length of assembly, weight of the tool, soldering time, casing size to the temperature of the function in making additional functions. Based on the value engineering step through improving details, it is found that from the alternatives there are the best alternative with a total cost of IDR 370.700,-

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