The Design of Auxiliary Tool for Flat Motorcycle Tires using the Axiomatic Design Method

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Abstract. Motorcycle users always deal with difficulties if their motorcycle tires are flat when riding in a place far from a tire repair shop. Distance is a problem that can make a flat tire quickly damaged when the motorcycle keeps forced to drive. Based on the aforementioned issues, a temporary flat motorcycle tire auxiliary tool is needed to serve as a tool that can deliver a motorcycle until it can be repaired at a tire repair shop. The method used in the design was the axiomatic design method. This method was used to determine design parameters using the mapping process. Surveys were conducted to identify customer attributes by distributing questionnaires to identify customer attributes which were then mapped into functional requirements and design parameters. The results of this study were 4 attributes based on consumer desires, among others, motorcycle wheels spinning with auxiliary wheels, easy to install, safe for bumpy roads, and robust enough to support the motorcycle body and rider.

1. Introduction
The motorcycle is a means of transportation that is commonly used to support human life. Many people use motorcycles to go to work, go to school, shop or just visit their relatives and others. Motorcycles use engine power as motion power. Like other machines, motorcycles can be damaged during the usage period. The small damage that often occurs is tired leaks. This research was carried out by creating a design of flat tire auxiliary tool product that is needed by the motorcycle when the tire is leaking. The benefits of this flat tire auxiliary tool will be greatly needed by motorcycle users who experience flat tires in places far from tire repair shops. This tool can be used as first aid on flat motorcycle tires.

There are several tendencies that can cause flat motorcycle tires, including rarely checking air pressure, not wise in choosing flat roads, and rarely checking tire conditions. At present, the middle to lower economic workers mostly use motorcycles to go to and go home from work, some of these workers said that they do not know the mechanics of the motorcycles [1].

The design of this flat motorcycle tire auxiliary tool considered the needs and safety of customers. Customer satisfaction is very important and companies should pay attention to user needs in making product design [2]. In addition to customer satisfaction, service quality also plays a role in helping companies build competitive advantage [3]. Product design is always related to the development of ideas and thoughts, development of techniques, production processes and market increase [4].

The design of this auxiliary tool for flat motorcycle tires used the axiomatic design method. Axiomatic Design is a method used to be able to describe and analysis the basic needs of the design that will be created through the Function requirements defined through the Design parameters [5]. Axiomatic Design has a systematic nature and a top-down approach, in which such properties are very suitable to
be used to compile complex problems into smaller and manageable work packages. There are several previous studies that used the axiomatic design method as a method used to analyze the basic needs of a product. Several studies using the axiomatic design method, namely research is; mechanical system [6]; schoolbag design based on student's needs [7]; the ergonomics design parameters of a virtual environment [8].

This study aims to design an auxiliary tool that serves to support flat motorcycle tires, in which the tool temporarily support while the motorcycle can be driven. The auxiliary tool was specifically designed for supra x 125 motorcycles. By using the axiomatic design method, surveys were conducted among the users to identify user attributes by distributing questionnaires to identify customer attributes, which were then mapped into functional requirements and design parameters.

2. Research Method

2.1. Subject and Object

The object of the research observed was the leak on rear tire in supra x 125 motorcycles. The survey was conducted using direct observation to the respondents. The appointed respondents or research subjects were supra x 125 motorcycle users with an age range of 18-30 years old. The number of target population filling the questionnaires was 50 respondents. The respondents were supra x 125 motorcycle users in Yogyakarta. The research data was collected by distributing open questionnaires to the subjects of the study which were sampled using the simple random sampling.

2.2. The Steps of Axiomatic Design Method

Axiomatic Design is a system design methodology using a matrix method to analyze the transformation from customer needs systematically into functional requirements, design parameters, and process variables [9]. The design of product with Axiomatic Design method was carried out through the following steps [10]:

- CA: Customer Attribute; namely a domain accommodating needs from the user's point of view.
- FR: Functional requirement; namely a domain holding all the functions to be achieved from a design or product. The researchers collected the data in the form of functions to be achieved in a product by observing the consumers. The making of functions was adjusted to the CA.
- DP: Design parameter; namely the manifestation domain of FR and how the function of FR domain is generated. Zigzagging process over the FR and DP hierarchical structures occurred (Figure 2). This zigzagging process aimed to answer the "what" and "how" questions as stated in the principle of Axiomatic Design.
- PV: Process Variable; namely the domain discussing how the design or product is produced. Or in simple language, PV is the domain of the production process of a design before becoming a product. Usually this PV position can be directly place with DP explanation, or something that can not explain in DP domain.

The design procedure was determined based on the relationship of the two domains at each level of the design process hierarchy as in Figure 1.

![Figure 1. Design concept of Axiomatic Design Error! Reference source not found.](image-url)
3. Result and Discussion

3.1. Customer Need
Based on the results of open and closed questionnaires, there are 4 customer attributes obtained from the tool designed. The first attribute is that the auxiliary tool can rotate with the wheel. The poor quality of tire can produce self-excitation in the wheel turning frequency and contribute to the surrounding of shock mounts, therefore the tire of a motorcycle auxiliary tool should rotate parallel to the motorcycle [11]. The second attribute is that the auxiliary tool should be easily installed on a motorcycle. The third attribute is the safety for riding on a bumpy road. A nice trip, convenience and safety that can be accepted by motorists are the attributes needed for all vehicles on the highway [12]. Furthermore, the fourth attribute is that the auxiliary tool should be powerful to support the motorcycle body and the rider [13].

3.2. Design Result
According to the identification using the questionnaires, obtained 4 attributes desired by supra x 125 motorcycle riders. In Figure 2 below, it shows that there are 3 levels of FR and DP hierarchy structures in the design of motorcycle tire auxiliary tool product, these 3 levels are level 0, level 1, and level 2. At each level, there are descriptions of each FR and DP. The relationship between each domain in the design of flat tire auxiliary tool product can be seen in Table 1. The table is the result of the zigzagging step which shows that there is a relationship between each element at each level.

Table 1 shows the meaning of FR and DP obtained from the process of interpretation from CA into PV. The interpretation process required the right analysis carried out until results were obtained describing the needs of flat motorcycle tire auxiliary tool users.

![Figure 2. Zigzagging process of FR and DP](image)

| Costumer Attribute | FR         | Functional Requirement | DP             | Design Parameter | PV              | Process Variable                       |
|--------------------|------------|------------------------|-----------------|------------------|------------------|----------------------------------------|
| Rotate with the wheel | FR1       | The tool rotates with motorcycle wheel | DP1             | Attached to the wheel | PV1              | Attached and rubbing against each other |
|                    | FR11      | Right and left rollers of the wheel | DP11            | Roller is made of elastic material | PV11             | Rubber material                         |
|                    | FR12      | Roller clamps the wheel | DP12            | Rollers and wheel have a minimum distance for clamping the wheel | PV12             | The minimum distance is 0.5 cm          |
| FR   | Requirement Description                                                                 |
|------|----------------------------------------------------------------------------------------|
| FR13 | Rollers move in opposite directions                                                    |
| DP13 | 2 rollers rubbing against each other in a clockwise direction, 2 rollers rubbing against each other in counter clockwise direction |
| PV13 | 2 upper and lower rollers rotating with each other in counter clockwise direction       |
| FR14 | Auxiliary wheels follow the motorcycle wheel                                           |
| DP14 | 1 rotation of motorcycle wheel is same with 2 rotations of auxiliary wheel              |
| PV14 | Diameter = 10 cm                                                                       |
| FR2  | The tool is easy to install and uninstall                                              |
| DP2  | Can be folded and easily stored                                                        |
| PV2  | Using a plug and play system                                                           |
| FR21 | The size of the shock is in accordance with the motor nuts                            |
| DP21 | The Nut and Shock is in hexagon shape                                                   |
| PV21 | Size = 6 mm                                                                             |
| FR22 | Permanent buffer equipped with shock                                                    |
| DP22 | Shock is made of magnetic iron                                                          |
| PV22 |                                                                                         |
| FR3  | Safe for bumpy roads                                                                   |
| DP3  | The tool has a minimum height that is safe for bumpy roads                             |
| PV3  | The minimum height is 20 cm                                                            |
| FR31 | Permanent flower lock on shock and buffer                                              |
| DP31 | Flower lock functions as a fastening lock of shock on rear tire nuts                    |
| PV31 | The diameter of flower key is 0.5 cm with a length of 1 cm                            |
| FR32 | Adjustable buffer height                                                               |
| DP32 | Buffer Height is adjusted to the height of the rear part of motorcycle                  |
| PV32 | Buffer height is 50 cm                                                                  |
| FR4  | Strong enough to support the motorcycle body and its rider                              |
| DP4  | The buffer is made of iron material                                                     |
| PV4  | Iron material                                                                            |
| FR41 | Strong connecting Iron                                                                  |
| DP41 | The diameter is adjusted to the shock size                                              |
| PV41 | The diameter of iron buffer is 2 cm                                                     |
| FR42 | Durable auxiliary wheel                                                                 |
| DP42 | The tire wheels are made of tubeless rubber                                              |
| PV42 | The thickness of the auxiliary tires is twice motorcycle tires                          |
3.3. The Design of Parameters According to the Desires of Supra Motorcycle Users

The design of this flat motorcycle tire auxiliary tool is new, in which has never been on the market before, so that this study developed the design of this product by considering the function of the product which can help motorcycle users and the safety of the product for its users. Based on the analysis using AD method, some of the most basic needs have been obtained. These basic needs can describe how the design of this flat tire auxiliary tool will be made.
3.4. Validity Test of Auxiliary Tool Product for Flat Motorcycle Tires

Validity test on flat motorcycle tire auxiliary tool product was conducted to assess and find out whether the proposed design meets the needs of supra x 125 motorcycle users or not. The test was executed by using the Stuart Maxwell's test for marginal homogeneity with the following hypothesis:

H₀: There is no significant difference between student requirements and design of the product for flat motorcycle tire.

H₁: There are significant differences between student requirements and design of the product for flat motorcycle tire.

| Attribute                                      | p-value | Sig. | Note      |
|------------------------------------------------|---------|------|-----------|
| The product rotates with wheel                  | 0.453   | 0.05 | H₀ accepted |
| The product is easy to install                  | 0.727   | 0.05 | H₀ accepted |
| The product is safe to use on bumpy roads       | 0.125   | 0.05 | H₀ accepted |
| The product is able to support the weight of motorcycle body and motorcycle rider | 0.289   | 0.05 | H₀ accepted |

According to the results of validity test, Table 2 shows that all H₀ are accepted, then all attributes are fulfilled, Table 2 also shows that there is no significant difference between the needs of supra x 125 motorcycle users and the design of the product for flat motorcycle tire auxiliary tool and p-value is more than 0.05 (p-value > 0.05).

4. Conclusion

This study aims to design an auxiliary tool which serves to support motorcycle tire when leaking. Basically, when designing a new product, there are many criteria that need to be considered based on consumer needs. The involvement of consumers is highly required in a product design process. Therefore, the design of a product must be consulted with consumers during its designing process, in the hope of obtaining an optimal design. The results of the study shows that the main needs of supra x 125 motorcycle users in using the product for flat motorcycle tire auxiliary tool are as follows: flat motorcycle tire auxiliary tool rotating with the wheel (DP1), flat motorcycle tire auxiliary tool is easily installed (DP2), flat motorcycle tire auxiliary tool is safe to use on bumpy roads (DP3), and flat motorcycle tire auxiliary tool is able to support the weight of motorcycle body and motorcycle rider (DP4). Validity test shows that H₀ can be accepted with a significance of 5% for each attribute, which means that there is no difference between the needs of supra x 125 motorcycle users and the design of flat motorcycle tire auxiliary tool.

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