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Ergonomics and Analytical Hierarchy Process Intervention in Transport : Motorcycle Sidecar Design to Increase Safety

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Abstract

This study explores the implementation of ergonomics principles and the Analytical Hierarchy Process (AHP) as interventions to enhance the safety of motorcycle sidecar designs. Recognizing the critical role of ergonomics in optimizing human-machine interactions, the research investigates how ergonomic considerations can be integrated into the design process to mitigate safety risks associated with motorcycle sidecars. Additionally, the AHP methodology is employed to systematically prioritize and evaluate various design elements, incorporating expert opinions and stakeholder preferences. The research methodology involves a comprehensive analysis of existing sidecar designs, ergonomic assessments, and the development of a structured AHP framework. Through the integration of these two approaches, the study aims to identify and prioritize key safety parameters, such as stability, visibility, and rider comfort. The AHP approach is carried out with five variables supporting key safety parameters including anthropometry, ease of controlling, ease of use, comfort, and safety. Practical implications of the interventions are explored, considering both rider and passenger perspectives, with a focus on minimizing the potential for accidents and injuries. The findings of this research contribute valuable insights into the application of ergonomics and AHP in motorcycle sidecar design, offering a systematic and holistic approach to enhance safety. The result found from a combination of comprehensive analysis between ergonomics and AHP is that the Streamline Shape Sidecar is the best design choice in terms of safety and ease of use based on both rider and passenger perspectives. The outcomes have the potential to inform future design practices, industry standards, and regulatory guidelines, ultimately fostering the development of safer and more user-friendly motorcycle sidecars.

Keywords: anthropometry, ergonomics, sidecar motorcycle, AHP

1. INTRODUCTION

The use of motor transportation continues to increase along with the growth of the community's population. A review of behavioural issues contribution to motorcycle safety [1], dangerous driving in emerging adults [2], Motorcycle taxis' varying degrees of complementarity and substitution with public transport [3], motorcycle protective clothing compromise rider safety [4], the burden of unhelmeted motorcycle injury [5], determinants of standard motorcycle safety helmet [6], profile of low and middle-income countries with increases versus decreases in road crash fatality population rates and necessity of motorcycle safety [7], underage teenagers to ride motorcycles without a permit [8], motorcycle safety after-dark [9], Perception between vehicle safety risks and safety belt usage behavior in truck driver, characteristics of human movement and injury in a side collision [10]. The general function of shortening the time to move from one place to another coupled with a relatively cheap price compared to other motorized vehicles makes motorcycles the most popular alternative by the people of Indonesia. The increasing number of motorcycles in line with increasing number of accidents involving motorcycle. In addition, the absence of a law clearly regulates the way people piggyback on children under the age of 12 (twelve) years old with two-wheeled motorcycles on the road. So, many people still ignore traffic safety when riding motorcycles. It is often to use motorcycle to carry more than 2 passengers. In addition, there are still people who ride motorcycles to the intransport goods that exceed capacity. In addition to disturbing other motorists, the activity also endangers the lives of motorists and other motorists. Therefore, it is necessary to have additional tools that can help motorcycles carry more than 2 passengers or can even transport large items. The solution offered to solve this problem is to design a sidecar design on a motorcycle.
The objectives and benefits of having a sidecar on a motorcycle are:

1. Helping motorcycle users to transport more passengers (figure 1)
2. Helping motorcycle users to transport large and heavy goods
3. Improve road safety. Quickest Way to Reduce Road Deaths: To Implement Traffic Rules

This research was conducted to discuss the physical dimensions of motorcycle passengers related to motorcycle design and other detailed parts such as other protective equipment whose effectiveness depends on the relative position of the passenger's body parts.
Motorcycle design provides its own problems for ergonomics experts because it has narrow constraints so it is difficult for them (ergonomicists) to design a motorcycle that suits the user's body size in general. There are two forms of problems found in designing an ergonomic motorcycle, namely:

1. Variation in the value of the body size of motorcycle passengers.
2. The relationship of the passenger's body attitude with the effectiveness of work when the passenger is on the sidecar.

All aspects related to the operation of a motorcycle, both comfort and safety aspects, must be considered as considerations when designing a motorcycle. Anthropometry of the motorcyclist population is very important as a basis in designing the motorcycle itself.

Figure 1. Motorcycles with dangerous passengers and goods on the highway.
(Source: Current research document)

Research on motorcycles has been conducted previously by [11] (see figure 2 and figure 3) "Mobile, Portable and Ergonomic Design of Porang (Amorphophallus Oncophillus)" is to improve the cultivation and processing of Porang (Japanese favorite food, konyaku, shirataki).

The problem arises when there are no Porang Cutting Tools and Dryers so that porang farmers have very low productivity. The problem is solved when methods and tools for Cutting and Drying Porang on a Mobile and Ergonomic Motorcycle appear (figure 2 and figure 3). This tool is used for processing with higher production capacity [11].

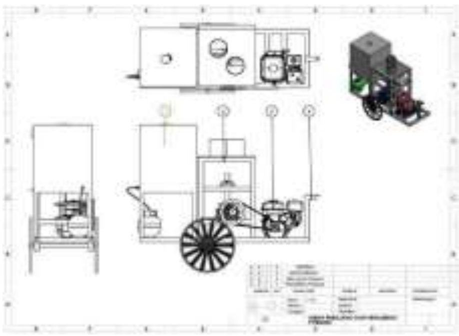

Figure 2. Design of porang cutters and dryers on motorcycles [11]

Figure 3. Cutter and dryer porang (Amorphophallus Mueleri) that is motorcycle pulled and ergonomically designed [11]

Another study is a mobile, portable, and ergonomis smoked fish maker motorcycle. This fumigation device uses a motorcycle, with a higher production capacity (figure 4 and figure 5). The innovation of this tool is to combine several smoke reduction functions to be harmless but safe, comfortable and healthy for its users and effective for processed seafood products. Its innovative advantages are that the practice is shaped like a sturdy and slender; Ergonomics can be designed and redesigned according to the size of the user.

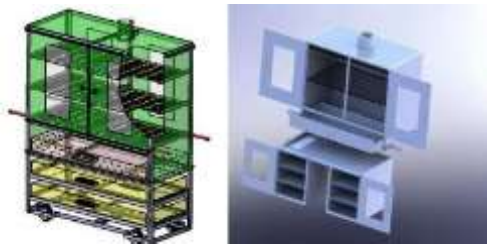

Figure 4. Appropriate technology for portable and ergonomic fish smoking devices [12]

Figure 5. A fish smoker on a motorcycle [12]

The objectives and benefits of having a sidecar on a motorcycle are:

1. Helping motorcycle users to transport more passengers (figure 1)
2. Helping motorcycle users to transport large and heavy goods

3. Improve road safety. Effects of Passengers on Older Driver Safety [13]

This research was conducted to discuss the physical dimensions of motorcycle passengers related to motorcycle design and other detailed parts such as other protective equipment whose effectiveness depends on the relative position of the passenger's body parts. Furthermore, It is combined with Analytical Hierarchy Process (AHP) in order to found the order of priority ranking which criteria are most Influential to people. The AHP offers a thorough framework for dealing with such issues. It is a method for representing the elements of any problem in a methodical manner. Several criteria in determining alternatives are also involved according to the existing conditions of the community such as anthropometry, ease of controlling, ease of use, comfort, and safety.

2. METHODS

2.1. Stages of Research

This research was conducted with real experiments (not laboratory simulations), it is quantitative. The prototype of the sidecar motor was tested on the consumers who use the motor.
Implementation of consumer tests:

1. Trials were carried out to load 1 and 2 child passengers on the sidecar, observed movements in the way of ascending/descending and sitting position.
2. Riders try to ride an empty sidecar bike, and get used to riding for about 30–60 minutes.
3. The rider tries to ride a sidecar bike loaded with goods, then loaded with a child. through an uncrowded residential street. Performed straight maneuvers, turning left and right.
4. Trying to attach and remove the sidecar.
5. Recording is carried out for the number of movements, timing, difficult or dangerous positions.
6. The user fills out the questionnaire that has been provided.
7. The sample must represent a class of people, while the collection is random in that group.
8. The results of the collection & processing of questionnaires will be statistically tested which includes: data normality tests, data reliability tests, data validity tests so that they can represent the analyzed population.
9. The conclusion of the consumer test was used to design the sidecar.

2.2. Analytical Hierarchy Process (AHP)

The method used in this research is the Analytical Hierarchy Process (AHP) to determine decision making in the identification of important factors in the selection of complex situations into a hierarchy of many problems (multicriteria) [14]. Its simplicity is defined by comparing alternative pairs based on specific criteria. Expert

Choice is the most well-known [15] and super decisions [16]. In this study, we used Expert Choice program version 11.

2.3. Anthropometry

The dimensions of the motorcyclist's body are taken using an anthropometer with a degree of accuracy of up to 1 mm. The weight of the subject (motorcycle passenger) when wearing the shirt. The subject did not wear shoes when the measurement were taken. During the measurement the subject is asked is asked to sit on a chair made of wood in a perpendicular position.

The height from the footing is set by the subject himself until the subject is comfortable with his sitting position. Table 1 shows anthropometric data of children sitting on the sidecar.

Table 1. Antrhopometric data of the children sitting on the sidecar (Source: Current research measurements)

Category	Male (n= 15)		Female (n= 15)	
	Average	Standard Deviation	Average	Standard Deviation
Age (years)	8,3	2,86	8,3	2,86
Standing height (cm)	115	61	105	60
Sitting height (cm)	53	48	52	42
Eye height (cm)	53	39	51	37
Shoulder height (cm)	47	21	46	23
Weight (kg)	24	39	15	38
Knee height (cm)	48	29	45.5	26
Buttocks-knee distance (cm)	53	27	51	24
Hip width (cm)	32	22	33	27

3. RESULTS AND DISCUSSION

3.1. Analytical Hierarchy Process (AHP)

In figure 6. Shows the hierarchical structure of the analysis performed.

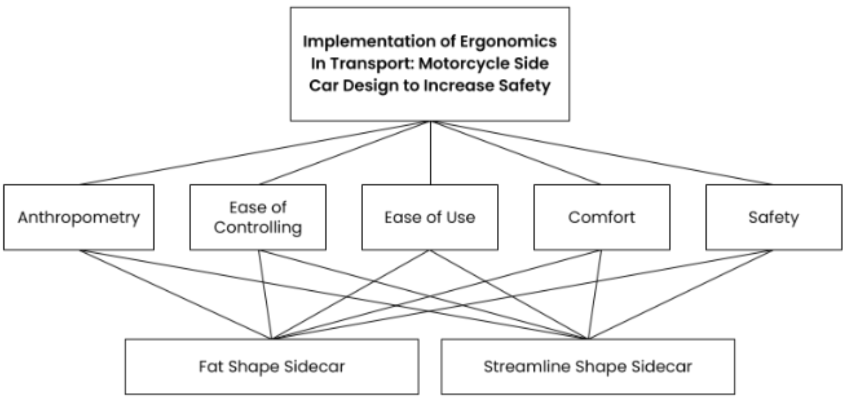

Figure 6. Hierarchical Structure of Prioritization

In figure 7. shows the results of the AHP analysis which is displayed in the form of visualization of respondents' results that have been combined using the system in the Expert Choice 11 application. Figure 7. Showing the results in the form of anthropometry is the most influential factor in determining alternative uses of motor forms with a value of (0.275) followed by safety factors with values (0.246), ease of use (0.166), ease of controlling (0.158), and finally comfort (0.156) with an inconsistency level of (0.09).

Figure 7. Priority of Criteria for Sidecar Motorcycle Design

Then, in figure 8. shows the results of the alternative determination of the motorcycle side design which shows that the streamlined shape sidecar design is the top priority in determining the design with a value (0.550) followed by the fat shape sidecar in the second position with a value (0.450). This calculation is done with an inconsistency value of (0.09).

Figure 8. Alternative Priorities for Sidecar Motorcycle Design

Sensitivity Analysis

To show that the results produced by AHP analysis are solid and rigid, sensitivity analysis is carried out. In this analysis, an experiment was carried out using scenarios to find out whether there were changes in results that occurred if the values in each scenario were changed. A sensitivity analysis as perfomerd to help understand the effect of changes in the weight of key criteria on alternative ratings. It is useful to perform a "what will happen if" analysis to see how the final result will change if the weight of the criteria is different [16].

There are two scenarios studied and become a benchmark for sensitivity to influence criteria with alternative result :

- Scenario 1 : Sensitivity analysis of anthropometry criteria
- Scenario 2 : Sensitivity analysis of safety criteria

Scenario 1

In scenario 1 visualized in figure 9., it can be seen that there is no change at all in the changes in the weight of the criteria made earlier.

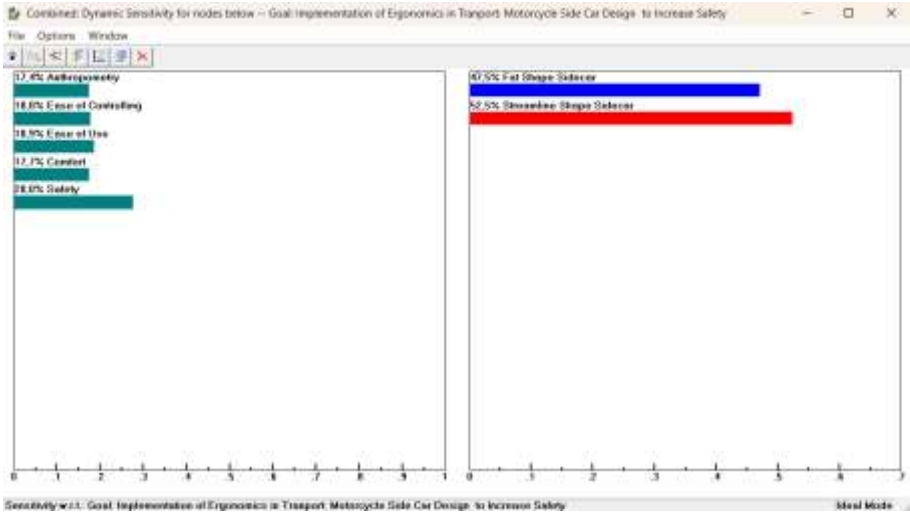

Figure 9. Scenario 1

By changing the value of the anthropometry criterion to lower, it does not make the results of the AHP change.

Scenario 2

Just like before, In scenario 2 visualized in figure 10., it can be seen that there is no change at all in the changes in the weight of the criteria made earlier.

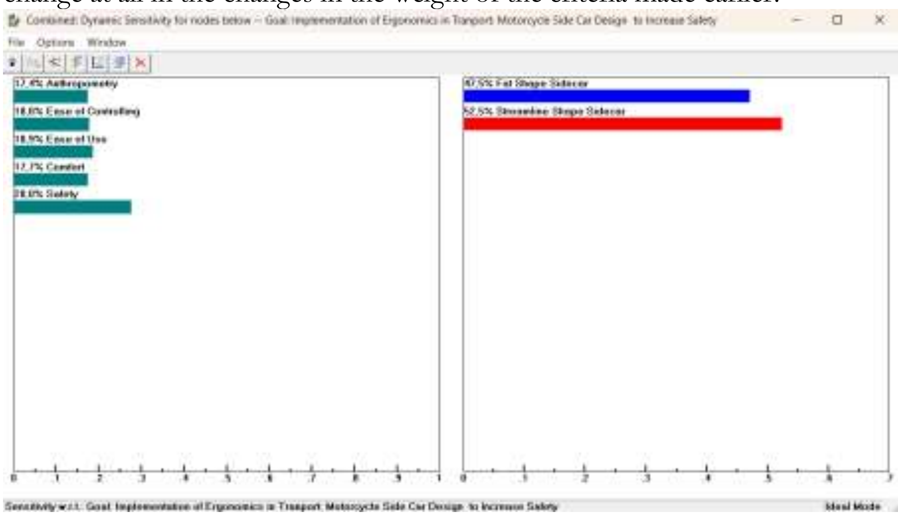

Figure 10. Scenario 2

By changing the value of the safety criterion to lower, it does not make the results of the AHP change.

By doing these 2 scenarios, it was found that by changing the value of the dominant criterion even though it was lower, it did not make the alternative results of the AHP change. This shows that the results of the AHP based on respondents are strong and consistent and rigid.

3.2. Sidecar Repair

The prototype of the sidecar has been made and conducted road tests for a year. The research now collects consumer opinions conducted. Adjustments to the sidecar need to be made because the motor used is also newer, as well as some improvements to eliminate the weaknesses that still exist.

The sidecar on the Honda motorcycle frame, will be connected to a newer motor. For this reason, the mechanical connection needs to undergo changes.

3.3. Sidecar User Anthropometry Data

To obtain anthropometric measures we can make a scheme that shows how minimal and maximum this sidecar can used by children based on anthropometry that has been processed (see figure 11).

Male
P_{95}

Female
P_{95}

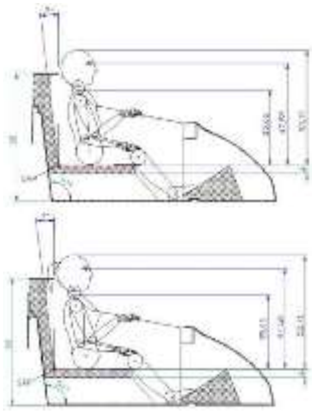

Figure 11. Anthropometry of children aged 5, 8, 12 years in a sidecar
(Source : current research measurement)

In the above data is known that children aged 5 and 8 years can easily ride on the sidecar in the position of 1 transported person. As well as in a position where the legs can be straightened easily in a sidecar. Whereas in 12-years-olds, the legs begin to bend when inside the sidecar.

3.4. Child Passenger Test

Passenger tests were conducted on boys aged 5 years shown in figure 12.

Figure 12. Test passenger 5 years old boy
(Source : Current research document)

Five-year-old boys also easily ride the sidecar by sidecar by stepping on the foot steps that have been provided in 3 steps like a 5-years-old girl. When the motor is running the child sits comfortably, sometimes it is not berthed. The child descends the sidecar in 3 steps. For a 5-year-old boy, the height of the sidecar and foot steps is not difficult to climb the sidecar.

Figure 13. Test Passenger for 8- years old girls
(Source : Current research document)

8-year-old girls are actually able to ride the sidecar in 2 steps without the need to touch the foot step (see figure 13). But because the foot step made to be stepped on, there was a suggestion of the child to step on it. This is evident from the picture above (figure 13), when the child descends the sidecar in just 2 steps, the left foot comes out of the sidecar and then the foot touches the ground, without the need for foot steps. But because children feel that it will be safer to wear foot steps, foot steps are also stepped on before climbing and when descending the sidecar.
To ride a sidecar is easy for an 8-year-old girl to do. Children performs 3 steps in riding the sidecar and also when going down the sidecar. Meanwhile, a 12-year-old

child could easly ride a sidecar in 2 steps, without the need to climb a foot step.

3.5. Redesign

The dimensions of the existing sidecar body have been quie wide, but the length is better when added 5 cm. The extension is useful for increasing legroom when transporting 2 children in a tandem configuration.
The body shell on the existing sidecar made of fiberglasss is a unity of structure. A mass-produced sidecar body must be a non-large part of the shape for easy printing. The division is divided into four parts, namely the front, back, left side and right side (see figure 14).

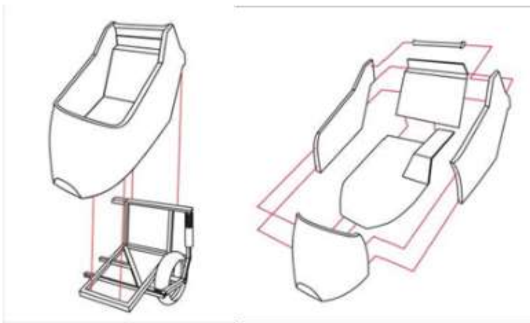

Figure 14. Split shell image to simplifiy the procution process
(Source : Current research document)

The fat shape of the side car is not compatible with the slim shape of the bike and tends to be sporty. The shape as a result of the finished size cannot be reduced, but the field could be "manipulated" to look slim. Manipulation of the look can be done by giving the plastered decoration that is displayed on most motors. An elongated motif with 2 or 3 colors will "streamline" the appearance of the sidecar (see figure 15).

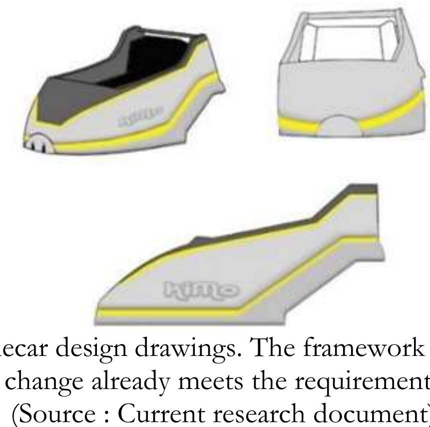

Figure 15. New sidecar design drawings. The framework in principle does not change already meets the requirements
(Source : Current research document)

3.5.1. Body Design

The dimensions of the existing sidecar body have been qiute wide, but the length is better when added 5 cm. The extension is useful for increasing legroom when transporting 2 children in a tandem configuration.

The body shell on the existing sidecar made of fiberglass is a unity of structure. A mass-produced sidecar body must be an non-large part of the shape for easy printing. The division is divided into four parts, namely the front, back, left side and right side.

The fat shape of the side car is less than comassionate with the slim shape of the bike and tends to be sporty. The shape as a result of the finished size cannot be reduced, but the field can be "manipulated" to look slim.

Figure 16. The condition of the old motorcycle is a motorcycle with dangerous passengers and goods on the highway (left picture), more comfortable and safer (right picture).
(Source : current research document)

The new condition is a motorcycle with separate passengers (see figure 16), which is more comfortable and safer as delivered by Robertsen and Minter (1996).

3.5.2. Wheel Size

From some consumer opinions regarding the size of the sidecar wheels that are different from the motor wheels are different. This is logical because a vehicle has 2 wheel sizes. In this redesign, it is tried to apply and analyze what are the advantages and disadvantages of using the same sidecar wheels as the motor wheels, namely 17 x 2.50.

The selection of "small" tires for 8 x 3.25 is based on the saving of the required space. The width of the wheel cap is 23 cm, it can be placed under the seat, also the length of the swingarm (arm) complete withwheels is h 54 cm, it fits perfectly with the size of the frame and body. If the wheels use a size of 17 x 2.50 like the wheels of the motor, then the overall width of the sidecar increases by about 15 cm, because the high wheel caps are positioned on the outside of the seat. Similarly, the length of the swingarm and wheels that are 70 cm will g cause the front face frame to be also wide, sehingga the shape of the front body cannot shrink. If the sidecar that has now been commented on is fat by some consumers, then by using wheels the size of a motorcycle, the shape is even fatter.

4. CONCLUSION

The conclusion of this study is that from the AHP analysis, it found that streamline design sidecar is the best choice to develop the implementation of sidecar in motorcycle. Based on the test, Controlling the sidecar motor is not too difficult but it needs habituation, especially the turning time and downhill road. This convenience gets the numbers 3-4 from scale 5, where scale 5 is the ease of controlling the motor without a sidecar. How to climb and get out of the sidecar for children aged 5 – 12 years is very easy, compared to riding a motorcycle saddle, a value scale of 5. The comfort of sitting in the sidecar when the motor is running, is very good compared to sitting on the saddle of the motorcycle in a row with his parents, a value scale of 5. The ease when carrying goods is very good compared to carrying goods with a motorcycle, with a value scale of 5. The safety of carrying goods with a sidecar is not good because the goods are easy to snatch, with a scale of 2-3. To increase the safety value, it is necessary to think about making a lid while protecting from heat and rain. The sidecar motor is a solution to increase the carrying capacity of the motor safely. Easy and quick installation/release connection mechanics can restore the maneuverability of the motor in the midst of heavy city traffic.

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