Development of Collapsible Motorcycle Helmet for Motorcycle Users in Indonesia

Lianching Christiane Nasali(✉), Yansen Theopilus, and Hanky Fransiscus

Industrial Engineering, Parahyangan Catholic University, Bandung, Indonesia
{lianching_20220028,yansen_theopilus,
hanky.fransiscus}@unpar.ac.id

Abstract. The number of motorcycles in Indonesia continues to grow. However, the low use of helmets phenomenon is still occurring, so it can be one of the accident triggers, with an average of 3 people dying daily. SNI helmets are important, but today's helmet specifications still do not meet user needs. Therefore, this research aims to determine user needs to design a high-fidelity prototype of a collapsible motorcycle helmet based on user needs and evaluation of the product. The research uses product design steps and usability testing as an evaluation tool with task scenario and USE Questionnaire methods, and it also uses the SNI 1811–2007 standard test with adaptation. Obtained results of collapsible motorcycle helmet design with a mechanism is folding by being rolled using a folding shaft located at the ear with a stopper pressing mechanism. Criteria evaluation results in effectiveness of 88.10%, usefulness of 5.66, and satisfaction of 6.24. The results of the usability testing that obtained areas were declared good. Some improvements include the size of the product prototype used, the size of the constituent components, and other things. With the results of the collapsible motorcycle helmet product design, it is hoped that it can be a reference and contribute to the addition of scientific development in the context of product design, especially in collapsible products.

1 Introduction

The number of motorcycles and population increase every year in Indonesia. The highest number of vehicles from 2017 to 2019 were motorcycles compared to other vehicles reaching 12.55% [1]. With the increasing number of motorcycles, the number of motorcycle accidents in Indonesia is also increasing based on research conducted from 2007 to 2010 [2]. The number of motorcycle accidents in Indonesia from 2008 to 2018 increased to 84.6%, totaling 109,215 cases [3]. The use of helmets in Indonesia is much worse than in other countries in ASEAN, such as Vietnam, Malaysia, and Thailand. The use of helmets in Vietnam is 90% of adults and 30–50% of children [4], Malaysia is 93.4% of adults and 30.5% of children [5], and Thailand is 67% include adults and children while the adults proportion 2.8 times higher than children [6]. Motorcycle accidents are caused by several factors, including human error, type of vehicle, and road conditions [7]. Not using a helmet is one of the human error factors, based on the RI Law No. 22 of 2009 in Article 57 paragraph (2) concerning road traffic and transportation, which

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states that the equipment that needs to be considered for motorcycles is a helmet that has Indonesian national standards. (SNI) and Article 106 paragraph (8) state the obligation to use helmets that meet SNI for motorcycle drivers and passengers [8].

With the policy in force and the increasing need for helmets, helmet sales have a good opportunity. The potential for motorcycle sales will continue to increase because at least one motorcycle requires two helmets as a safety device [9]. The increasing number of helmet sales also has a complementary relationship with the increase in motorcycle sales, as in 2010, there was an increase of 2 million helmets in 2011 [10]. However, helmets offered by various manufacturers are currently still found to be lacking due to their large size, so they interfere with the user's activities while riding or storing their products. Problem identification was also carried out by conducting interviews, observations, and benchmarking on respondents related to why motorcycle users often do not use helmets. Starting when the user chooses a helmet, it is found that helmets with SNI are relatively expensive. In addition, SNI helmets also usually have a helmet size that is relatively larger than the standard helmet, while respondents are looking for a helmet with a small size where they choose a half-face helmet because of its spacesaving size. Many helmets do not fit the head's size, but the helmet's outer side is the same because the size changes occur in the inner part of the helmet, so the size is sometimes not balanced with the user's body. When storing helmets at home or in vehicles, there are also obstacles in the storage process because there is often no proper place for good storage, often found in the rearview mirror or just stored arbitrarily. This also impacts the process of carrying the helmet, which often interferes with the helmet carrier's activities or work. In disposal activities, helmet owners are often confused about how to dispose of them because of their large size, and helmet waste storage is rarely found.

[11] states the addition of the number of motorcycles each year will affect the increase in helmet sales it is also supported by the statement of the Indonesian Helmet Industry Association (AIHI) that the market potential of helmets can be calculated easily because each motorcycle requires at least two helmets as a safety device so that the market potential in helmet sales will continue to increase. Thus the design of helmet products that have innovations by meeting consumer needs still has potential in the market. So, when viewed from the problems of helmets by consumers and also the market potential, the design of innovative helmet products that can be folded to save space while still carrying out their functions is still required.

2 Literature Review

Helmets are mandatory equipment for motorcycle users while riding, which has the primary function as a protective device for the head and chin from minor or severe collisions or accidents [12]. Helmets must be able to protect the head against the wind, sunlight, noise, dust, water pollution, dust, [13] insects, stones, and protection of the teeth and jaw. The protection provided by the helmet is to protect and reduce the impact of the vital area, which is the head. Found that the use of helmet may reduced fatal and serious head injuries by 20–45% [14]. A study found that motorcycle riders with helmets had three times more safety in avoiding head injuries than those without helmets [15]. That risk number is also shown that Indonesia people have higher risk of brain injury if they don't use SNI helmet than those who use SNI helmets [16]. The main factors that caused injury by not wearing a helmet at the time of the accident due to physical discomfort, which is the leading cause of the accident for the following reasons, the weight of the helmet (77%), feeling hot (71.4%), neck pain (69.4%)), feeling suffocated (67.7%), limited movement of the head and neck (59.6%) [17]. Other factors that cause injury based on the results [18] are the age of the motorcyclist, gender, age of the vehicle, road characteristics, lane characteristics, traffic and road conditions, type of vehicle, driving experience, and time of the accident. One way to increase awareness and use of helmets requires strict rules and regulations obtained from research [12] and comparing regulations on helmet use in several states in Texas and Arkansas [19].

A product is something that a company sells to its customers, and product development is a set of activities that begins with the perception of a market opportunity and ends with the product's production, sale, and delivery. There are six stages in the product development process, including planning, concept development, system-level design, detail design, testing and refinement, and production ramp-up [20]. The planning process initiates an idea supported by the mission statement based on the problem that occurs. In concept development, the identification of user needs using several methods such as interviews, focus group discussions, direct or indirect observation, contextual inquiry, questionnaires [21], secondary data, benchmarking, etc., then developing product specifications, and evaluating alternative product concepts, selecting one or several of the best concept ideas to be developed and tested further. The system-level design will develop the design product architecture, product composition, key components for initial design, geometric shape (internal and external) of the product.

The detailed design contains a specific description of the constituent components of the selected design, which then carried out in the process of making a prototype (low-fidelity or high-fidelity prototype). Testing and refinement conduct evaluation of product prototypes using methods that are tailored to the needs, which then make the improvements to the product design. The last stage is a stage that conducts periodic evaluations to identify deficiencies that still exist in the design of the resulting product.

3 Methodology

This research methodology aims to describe a collapsible motorcycle helmet design framework. The process begins with a literature study, followed by preliminary research to explore the methods of interviews, questionnaires, and secondary data search, the process of which is divided into the stages of choosing a helmet, using a helmet, storing a helmet, carrying a helmet, and disposal of helmets. Then the identification of user needs is carried out using a user-centered design using the interview method and field observation which then looks for ideas for designing product design concepts. Based on the design of the selected product design based on the trade-off considerations and contextual inquiry, a physical prototype was made using a 3D printer with filament made from TPA. Several tests were carried out for the prototype using the task scenario method, USE Questionnaire, and adaptation of the SNI standard test. Then an analysis related to the design of improvements for the collapsible motorcycle helmet product was carried out so that the design from the research could be developed, enriched, and applied.

4 Experiment

Experiments will contain each stage in developing and evaluating a collapsible motorcycle helmet mechanism for motorcycle users in Indonesia. Of the six stages of product design, this research was carried out until the fifth stage of testing and refining the design and high-fidelity prototype. The following are each stage of work from the research development and evaluation of collapsible motorcycle helmet mechanisms for motorcycle users in Indonesia.

4.1 Identification of User Needs

User identification process uses online and offline interviews and observations. The interview process was semistructured with 16 men and women with an age range of 19 to 40 years. The needs identified from interviews are 21 needs and four needs from observation, so a total of 25 needs were identified and grouped by making an affinity diagram to focus the design process. Nine groups of needs were found, then the relative importance of each group was calculated based on the frequency of respondents to that group during the interview process and from observations. The highest value bases first user needs is an ergonomic helmet is 29.5%, followed by ensuring safety while driving is 18%, then the need for a helmet that is easy to store and store is 15.5%, a helmet that can be reached in terms of price and spare parts is 11% then followed by a helmet that can save space is 8%. Then there is also the need for a helmet that is safe from theft with a weight of 5.5% then there is a weight of 5% for the need for an ecofriendly helmet which is followed by an aesthetic appearance and helmet design with a weight of 4%, and the last is the need for a helmet that is easy to clean that is equal to 3.5%. From the results of these needs, it becomes a guideline n the design process of a collapsible helmet design.

4.2 Product Key Target Specification

The product specification does not tell how to meet user needs, but it providing an unambiguous agreement regarding what it will attempt to achieve to satisfy user needs [22]. Product specification means the accurate description of what the product has to do. There are four stages carried out, first is preparing a list of measures of all the metric that used for reference and comparison competitive benchmarking product for the designing process, then setting ideal value as the designer would achieve and marginal target values which most common used metrics, and need-metric matrix that combine the list metrics and users needs.

The size list is all sizes that support the design of a collapsible motorcycle helmet. Collecting competitive benchmarking information is carried out by looking for several types of standard helmets and helmets that can be folded with the collection of information tailored to all needs from the size list. Determination of the target size used in the product design process is to determine the ideal value adjusted to the best value to be achieved by the designer and the marginal value based on literature data or commonly used and commercially feasible measures. From the nine groups of needs and the list of sizes formed, a need-metric matrix is made by marking the cells based on the relationship between the need group and the existing size.

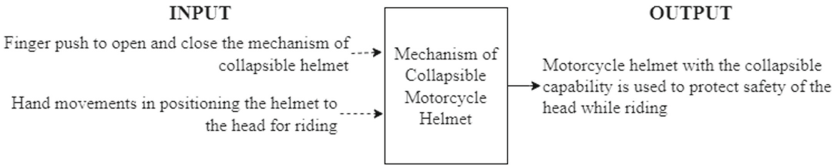

Fig. 1. Collapsible Motorcycle Helmet's Blackbox.

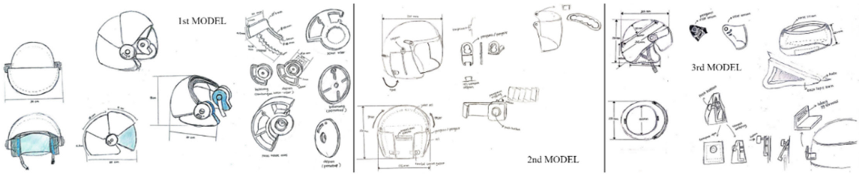

Fig. 2. Alternative Design for Collapsible Motorcycle Helmet.

4.3 Product Concept Generation

Started by making a black box to serve as problem clarification to facilitate the design process and product development of customer's group needs that have to be developed. In making a black box, consider and provide an overview of the processes that will occur in the helmet mechanism that will be formed. The input that will become a trigger on a collapsible helmet is a hand movement given by the user so that the helmet can function as it should. Then the output that will be received from the mechanism is a helmet with the advantage of a collapsible product that performs its function to maintain user safety. Fig. 1 is the black box for the collapsible motorcycle helmet product.

The process of designing a product concept design in the form of a sketch is carried out by six members each for one week. Eight alternative product design ideas were obtained by their respective unique models by conducting a benchmarking process with existing products' original designer ideas. Eight alternatives design were then filtered internally into three product idea models, which aim to focus on developing the detailed design of the mechanism of how the product works. The three models' result is screened by looking at the similarity of product ideas and the visibility of the development of the product mechanism are developed in detail by dividing the members involved into three development teams with design sketches that can be seen in Fig. 2.

The selection of the best and most appropriate product model among the three models is based on safety, volume reduction, and product manufacturing visibility that carried out using an external decision method with an expert online, and there is also a discussion between the expert and the members present. With the discussion results and consideration of its aspects, it is found that the order of priority, namely model 1, model 2, and model 3. The reason for choosing model 1 is because the security offered is higher than models 2 and 3 without sacrificing a lot of volume reduction, so that model 1 remains the optimal alternative for the current collapsible motorcycle helmet design and has the possibility of greater visibility in the design of the mechanism. From the considerations obtained, it is found that a helmet product with a collapsible concept and mechanism will have a protective strength that will be far less than a rigid helmet like the one that

Table 1. Tools and Materials

Tools		Materials			
1.	3D printing machine	1.	PLA filament	7.	Clear mica
2.	Grinding machine	2.	Sandpaper	8.	Spring
3.	Files	3.	Styrofoam	9.	Glue wax
4.	Scissor	4.	Foam	10.	Helmet buckle
5.	Cutter	5.	Smooth fabric	11.	Skewers
6.	Glue gun	6.	Merimes fabric		

Table 2. Tasks List

No.	List Interview Questions
1. 2. 3. 4. 5. 6.	Take the collapsible motorcycle helmet from the position of the helmet being folded on top table Unfold the collapsible motorcycle helmet when you want to drive Using the collapsible motorcycle helmet before being in the vehicle Using the collapsible motorcycle helmet while in the vehicle Removing the collapsible motorcycle helmet after use Fold back the collapsible motorcycle helmet which is then stored

already exists. This is because the available fault conditions or gaps provide room for weakness in any product. Thus, making collapsible motorcycle helmet products must involve experts who can be involved in the design process because proper considerations and calculations are needed to reduce collapsible weaknesses and strive for safety to be upheld. Efforts to design the selected model have considered several aspects that still need to be improved in the design details. Thus in this research consideration, model 1 can be continued to proceed to the stage of making physical prototypes.

4.4 Prototyping

The prototype model is carried out up to the high-fidelity prototype to see the design mechanism. Several things are needed to be prepared for the smooth process of making the prototype. There are six tools and 11 materials used during the process of making a collapsible motorcycle helmet. Table 1 shows the tools and materials used in the manufacture of prototyping.

Nine helmet components will be produced from these tools and materials, including the lower shell, middle shell, upper shell, visor, stopper, visor connection, visor bulkhead, upper shell shaft, and cover. The nine components are then arranged to start from the bottom shell and then affixed to the stopper installed on the helmet's right and left sides. Then proceed with attaching the middle shell, followed by the shell-visor connection component on each shaft. Next, the helmet visor is attached, followed by the visor bulkhead component and the upper shell shaft, the part that has serrations connected

Fig. 3. Prototype of Collapsible Motorcycle Helmet.

to the visor serrations, and the other side of the component that will connect with the upper shell. The next component is the installation of the upper shell on the shaft of the previous component then, all of the components are closed by a cover component which is then locked with large bolts and small bolts that also function as foolproof. Fig. 3 illustrates the finished result of a collapsible motorcycle helmet.

4.5 Testing the Product

Tests were carried out in two types of tests safety testing and usability testing. The safety testing process is carried out by taking a shock absorption test, system effectiveness test, and penetration test, adapted from the SNI 1811–2007 testing process. The shock absorption test is used to determine the helmet's resistance to blunt objects, the effectiveness test is used to see the resistance of the buckle position, and the penetration test is to see the helmet's resistance to sharp objects. In the shock absorption test results, it was found that the components were damaged, so the test was only carried out twice at the two points, on the top and left side of the helmet. The mechanism of the helmet does not hold out because of the influence of the product manufacturing process, especially the molding process. From the effectiveness of the retaining system, there was no movement of the buckle after the test was carried out by pulling five times. The helmet was not badly damaged for the penetration test, so it only damaged the top layer, not penetrating to the inside.

Usability testing was conducted for effectiveness, usefulness, and satisfaction criteria. That criteria can be tested by only one method, the USE Questionnaire because it evaluates the usefulness and satisfaction, also related to the effectiveness [23]. Testing the effectiveness criteria can be used by the list of tasks that evaluate and see the product performance according to the user's need statement [24]. In this study, testing the effectiveness is done by giving six tasks list to seven respondents as in Table 2. The criteria usefulness and satisfaction using the USE Questionnaire with a scale of 1 to 7.

The test results from the effectiveness criteria obtained a value of 88.10%, which is declared very good. The usefulness and satisfaction criteria test is carried out after the effectiveness test with the same respondents. The value of the results for the usefulness criterion is 5.66, and the satisfaction criterion is 6.24, which is declared good because it has exceeded the value of 5. Several things need to be improved from this product. There is a stopper, the size of the cover hole, and it combines the components of the visor bulkhead and top shell shaft that are initially separated. To provide additional reinforcement, there are changes in shape, type of filler pattern used, grade of density, and the manufacturing process for each component. Changes also occur in the visor component in the shape and material of the spring. The direct visor component uses acrylic material and emphasizes the jagged shape so that the visor component better describes the mechanism. The spring material uses stainless steel wire with a thickness of less than 1 mm so that the suppression mechanism on the stopper is better and does not have an additional effect on the stopper.

In addition, the test is also carried out to determine the interests of respondents and the target users of collapsible helmet products apart from testing for safety and usability. While testing, the product could be an alternative helmet for easy storage in certain locations and easy to carry during mobility. However, there is also feedback regarding the helmet's back neck shape design to be more ergonomic so that it is not too stiff at the neck because the design that has been formed is still very rigid. There is still a thickness that can provide a load on the neck.

5 Discussion

This study found that this collapsible motorcycle helmet design has a good market share because the randomly selected respondents responded well to the presence of the product design in concept, design, and prototype. The collapsible motorcycle helmet product line is one of the new products for the market, especially in Indonesia, because helmet products with similar mechanisms and purposes have not been widely developed. This research still focused on the folding mechanism and needs to pay more attention to helmet size and testing following SNI, also considering the safety aspects if compared with other research conducted in Indonesia [25], which developed the design of the Proteus model helmet design. In addition, it is still being determined whether the overall volume reduction from the helmet concept is offered, but if seen the mechanism this design concept might reduce the volume more than half from its original size, this will make convenient to the user. Other collapsible helmet products that have been commercialized are still used for other needs and activities and are found in other countries. Compared with the collapsible helmet design from India [26], the design still takes up quite an ample space while stored, even if the result has reduced 51% of the regular size. It is because the shape is still hemispherical, so it still will be difficult to store it on the motorcycle seat simultaneously compared to the research helmet design conducted.

The comparison helmet still does not fully meet the standards for a helmet for motorcycles, especially SNI. The results of the collapsible motorcycle helmet design found an excellent overall average score for the mechanism and functions based on usability testing was 88.1%. In contrast, the safety testing that adapted the SNI 1811–2007 standard still needed some improvements to improve the safety factor and the strength of each component to remain in the structure and construction. Collapsible motorcycle helmets also need some improvements, such as the need of minimal components for the minimal size, as the initial goal of the study to reduce the size to assist in the storage, the ease of mobility when carrying a motorcycle helmet, and reconsider about the design foam which is the key component for the safety [27]. However, in terms of the research carried out, the results of this collapsible motorcycle helmet design can be accepted and developed, especially for its long-term benefits in designing an increasingly minimalist product.

6 Conclusion

From the results of the research conducted, there are several conclusions obtained. There are nine groups of needs identified from 21 needs based on the results of interviews and four needs based on the results of observations. The final design of the collapsible motorcycle helmet is made up of four parts consisting of nine components and an additional buckle. The mechanism follows the pangolin animal. Re-improvement needs to be done to the circumference of the helmet's inner circle because the prototype process emphasizes costs to look more at the mechanism on the helmet axis. Improvements were made to the shape of the stopper components, covers, visor bulkheads, and changes to the spring and visor materials.

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