Ergonomic Design of Electric Car Cockpit

H. Soewardi and J. A. A. N. Nindiyanti

***Abstract*—Comfortable cockpit is an important component in a car specially provided for driver while driving. This facility may provide space for freely move to maneuver and control the car. However many drivers complain about some problems on part of the body such as neck, upper and lower back, waist, buttock, thighs, and knees. Thus it is crucial to develop new cockpit. Objective of this study is to design the ergonomic cockpit for electrical car satisfying user. Independent axiomatic design is a method to determine design parameter of the cockpit by mapping from costumer attributes and functional requirements. Anthropometric data of driver is used to support the design. Statistical analysis is conducted to test the hypothesis. On the basis of the study, it is revealed that the proposed electric car design corresponds to user requirement at 5% significance level.**

***Index Terms*—Comfortable cockpit, axiomatic design, electric car, ergonomic.**

I. Introduction

Currently, transportation is of a heightening necessity. This is due to the increasing need to move from one place to another. One of favorable mode of transportation is car. There are two types of car currently used by people namely electric car and fuel car. Nevertheless the fuel car is the most selected vehicle by rhe society. However, fuel car have shortcomings, among others are, unstable of gasoline price and environmental problem caused by fuel car. Therefore there began to develop an electric car.

Electric car is vehicle that has electric propulsion power. Electric car began to occur because it has advatages of electric car, among others are having quite sound [1], resulting in lower emission [2], and lower energy consumption [3]. There are several parts on the electric car one of which is car cockpit.

Car cockpit is a scapace where the driver interacts drictly with the car. Comfortable car cockpit is a facility that supports good interaction between the driver and the car. As mentioned in [4] comfortable car cockpit can improve driver's performance and it also can affect car performance. Car space for the user is one of comfortable car parameter [5]. Therefore it is necessary to pay attention on the ergonomic car dimension. Unsuitable ergonomic dimension increases injury probability in a car accident [6]. So, it is necessary to design electric car cockpit dimension based on user anthropometric dimension. Car interior is also important component to be considered. Currently car manufacturer make their design based on user wishes [7]. This statement affirms that car interior is also an important component to deal with because car interior influences driver's mental workload that can cause human error [8].

There have been many researches done previously discussed car cockpit. However, none of them discussed electric car cockpit based on Indonesian dimension and the aesthetic of electric car interior. Dynamics anthropometry is also considered to make adjustable car's seat. This study focuses on electric car cockpit and the aesthetic of the car interior. Car cockpit dimension is determined based on Indonesian anthropometric data.

The objective of this study is to design the ergonomuc cockpit for electric car satisfying user.

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II. Research and Method

A. Survey

Survey is divided into two states namely preliminary and final survey. Preliminary survey was done to identify customer's aspiration survey by distributiong questionnaires to 50 respondents who are actively driving. Final survey was conducted to test the hypothesis for verifying the proposed design to customer requirements.

B. Apparatus

Some equipments were used in this study as written in the followings :

1) SPSS software version 23 was used to statistical analysis.
2) Autodesk inventor professional 2016 software was used to design the virtual prototype.
3) Questionnaire divided in two types. They are questionnaire to identify customer voice and the next questionnaire is to validate the product.
4) Anthropomrtry was used to measure the human's body dimension.

C. Develop the Parameter Design of Electric Car Cockpit

Axiomatic design is a method to provide design with logical and rational thought process [9]. In [10] mention the application of axiomatic design is to design of product, production system, and software design.

There are four domains in axiomatic design method shown in Fig. 1 [9].

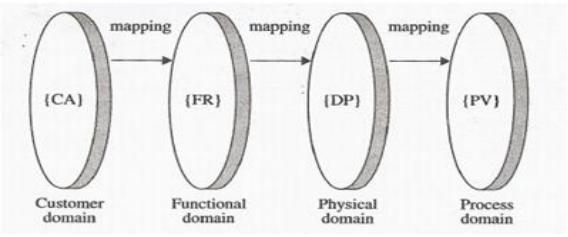

Fig. 1. Domain in axiomatic design.

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Customer domain is a domain containing need from user's point of view. Functional domain is a domain containing all function to be achieved from a design of the product. Physical domain is a domain that is manifestation of FR. Process domain is a domain that discussed how the design is produced [9], [11]. Mapping process is conducted to determine the next domain that satisfying the previous domain. This process involves the hierarchy and zigzagging process between domains [12].

D. Statistical Analysis

Nonparametric statistical analysis is done by using marginal homogenetity method. It is to test the hypothesis of design. The hypothesis (Ho) is the proposed design attributes to conform the customer requirements. While cronbatch's alpha was conducted to test reliability of attributes and validity of attributes is tested with corellation bivate pearson.

III. Result and Discusion

A. Result of Survey

On the basis of survey, result, it was revealed that the attriutes of cockpit design which customers require were an attractive design of cockpit, comfortable seat, ease to reach steer, spacious cockpit, ease to access electronic devices, and ease of information. Ergonomic design of cockpit, both physically and psychologically, is important to increase comfort in driving. thus the attributes should be fulfilled because the design will affect user's safety during driving. attractive design of cockpit can improve satisfactory of user [13]. And comfortable seat may increase comfortable in sitting and reduce pain in the body [14]. Third attribute is ease of reaching the steer. Steer is a control to drive which interacting with the driver directly so that it will be able to improve performance. While spacious cockpit must be suitable to user in order to accomodate an easiness of body movement [15]. As for easy to access the electronic devices is important for driver getting entertainment by listening music or radio. Thus it is significant to design referring to anthropometric of driver [16], [17]. The last attribute is informative. The cockpit should contain indicator display and provide required information clearly for driver to avoid decission making.

B. Result of Mapping Process

1) Design parameter for satisfying CA1: Attractive design of cockpit

Fig. 2 presents the herarchy structure of mapping process from FR1: providing grant happiness to DP1: ergonomic design which satisfy attractive cockpit design.

Based on Fig. 2, design parameter of gear lever is a sphere form (DP 1.5.1.2) with dimension is 15,55 cm (DP 1.5.1.1). This design has a comfortable in gripping (FR 1.5.1.1) so as easy to be operated (FR 1.5.1.2). Therefore, the design of gear lever can avoid pain on hand (FR 1.5.1). As for diameter of handle steer has a similar dimension with gear lever. It is 15,55 cm (DP 1.5.2.1) and certainly reducing pain on palm (FR 1.5.2) such that the design may minimize uncomfortable in driving (FR 1.5).Thereafter dashboard complexion of car is wood pattern (DP 1.1.1) so traditional impression could be appeared (FR 1.1.1). Colour of the wood pattern is brown and dashboard colour is black (DP 1.1.2). The colour applied intends to provide simple impression (FR 1.1.2). Accordingly the dashboard of car could serve classic impression (FR 1.1). Then plafond colour of the car is brown (DP 1.2.1). This colour is used to create clement impression (FR 1.2.1). Consequently it could increase comfortable sense of the driver (FR 1.2). Afterwards as a background of setting button black colour is used (DP 1.3.1). Background colour is meant to reveal symbol (FR 1.3.1). Futhermore setting of button size should be able to prevent finger pain (FR 1.3.2). The size is 1,52 cm for its length and 1,43 cm for its width (DP 1.3.2). Therefore, comfortable feeling while using driving control is appeared (FR 1.3). Last is nead impression of the car (DP 1.4.1) as shown from black colour (DP 1.4.1) of car seat so that elegant impression (FR 1.4) could be satisfying.

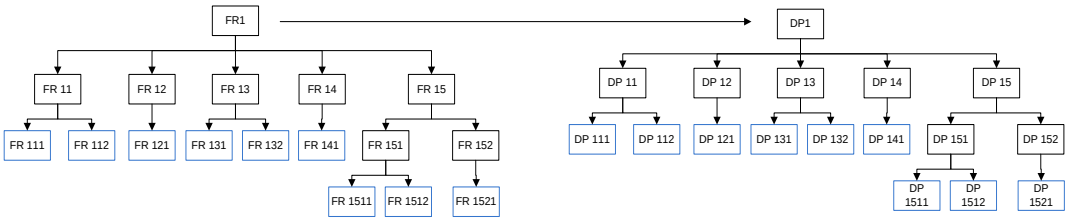

Fig. 2. Hierarchical structure of Customer Attribute 1.

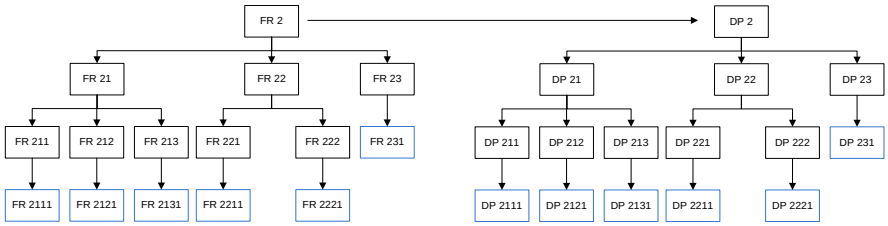

Fig. 3. Hierarchical structure of Customer Attribute 2.

2) Design parameter for satisfying CA2: Comfortable seat

Hierarchy structure of mapping process is shown at Fig. 3 from FR2: reduce pain to DP2: ergonomic seat design in order to satisfy comfortable seat attribute.

Referring from figure 3, design parameter for cushion of the car are 51,07 cm for depth and 45,29 cm for wide (DP

2.1.1.1). This dimension is determined to provide space for the biggest user (FR 2.1.1.1). Therefore buttock side pressure could be reduce (FR 2.1.1) furthermore reach of feet for smallest user (FR 2.1.2.1) is fulfilled by 44,74 cm (DP 2.1.2.1). This dimension also prevents pressure of driver at knees (FR 2.1.2). Thickness of the cushion foam is 4,9 cm [18] (DP 2.1.3.1). Thickness aims to improve support for the heaviest user (FR 2.1.3.1) so as the cushion provide support for upper body weight (FR 2.1.3). Afterwards 64,72 cm height and 51,61 cm wide are a backrest size (DP 2.2.1.1) so that the biggest user could be accommodated (FR 2.2.1.1) and it is sure that spine pressure could be reduced (FR 2.2.1). Besides there are headrest sizes. Headrest height is 28,42 cm and headrest width is 21,72 cm (DP 2.2.2.1) this to provide appropriate dimension for the biggest user (FR 2.2.2.1) accordingly neck pressure could be reduced (FR 2.2.2). As for seat coating material synthetic skin (DP 2.3.1) was chosen. It is because synthetic skin surface is cold (FR 2.3.1) so that seat temperature may be reduced (FR 2.3).

3) Design parameter for satisfying CA3: Easy to reach of steer

Ease to reach of steer is fulfilled by mapping process from FR3 : reachable steer to DP3 : ergonomic steer. The hierarchy structure of mapping process is shown in Fig. 4.

Based on Fig. 4, the design parameter of button in the car are on driver right side for rearview mirror, door lock, window control are and on the left side of driver there are hazard light and temperature control (DP 3.3.1.1). This button position is determined to provide ease to find position (FR 3.3.1.1). Hence, it could prevent searching (FR 3.3.1). Afterwards to minimize upper arm pain (FR 3.3.2.1) gear lever is placed on the left side of seat (DP 3.3.2.1). This is intended to provide arm comfortable position (FR 3.3.2). Those steer position is placed to prevent user confusion (FR 3.3). Then gear lever distance is 41,77 cm (DP 3.1.1) to provide suitable distance for smallest user (FR 3.1.1) and dashboard distance is 68,96 cm (DP 3.1.2) so it can prevent upper arm pain (FR 3.1.2). Objective steer distance is determined to minimize uncomfortable reach (FR 3.1). Finally, adjustable seat distance is 81,72 cm (DP 3.2.1) and 111,85 cm (DP 3.2.2) therefore it can provide comfortable reach of the smallest user (FR 3.2.1) and the biggest user (FR 3.2.2) so as to minimize calf pain (FR 3.2).

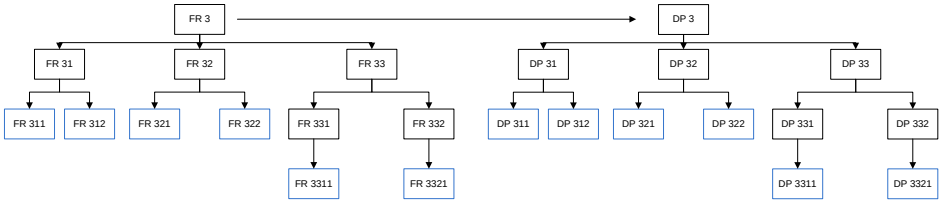

Fig. 4. Hierarchical structure of Custumer Attribute 3.

4) Design parameter for satisfying CA4: Spacious cockpit

Mapping process is started from FR4: suitable space of cockpit to user to DP4: ergonomic cockpit. Objective of mapping process is to satisfy spacious cockpit. The hierarchy structure of mapping process shown in Fig. 5.

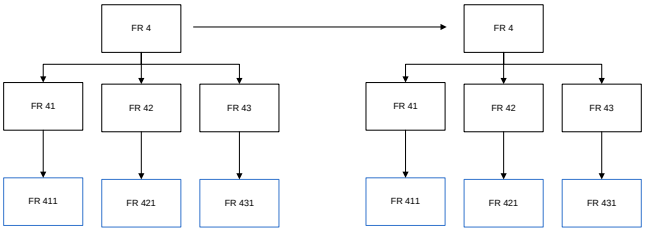

Fig. 5. Hierarchical structure of Customer Attribute 4.

Based on Fig. 5 represent above design parameter for dashboard is 65,6 cm (DP 4.1.1) to provide feet room for the biggest user (FR 4.1.1) so knees collide can be prevented (FR 4.1). Then, convenient room for the biggest user (FR 4.2.1) is fulfilled by handle bar distance from backrest is 51,07 cm (DP 4.2.1) to prevent pressure of stomach (FR 4.2). Last, plafond height is 100,64 cm (DP 4.3.1) in order to give suitable room for the tallest user (FR 4.3.1) to prevent them from bow posture (FR 4.3).

5) Design parameter for satisfying CA 5: Easy to access electronic devices

Fig. 6 is a hierarchy structure of mapping process which intends to fulfill easy to access electronic devices. The hierarchy structure started from FR5: increase visible support to DP5: electronic devices position.

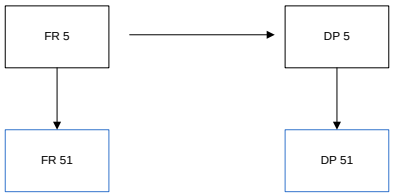

Fig. 6. Hierarchical structure of custumer attribute 5.

Refferring from Fig. 6 design parameter for electronic devices in the car is on the left side of driver (DP 5.1). It is to provide visible position (FR 5.1).

6) Design Parameter for satisfying CA 6: Easeof information

Fig. 7 presents the hierarchy structure of mapping process from FR6: informative car indicator to DP6: Indicator display. Thus it satisfies ease of information

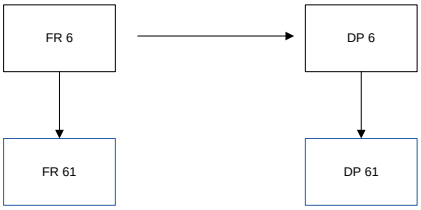

Fig. 7. Hierarchical structure of custumer attribute 6.

Based on Fig. 7 design parameter of car indicator are digital for odometer display and digital for fuel indicator display (DP 6.1) is determined to prevent misunderstanding information (FR6.1) of the car.

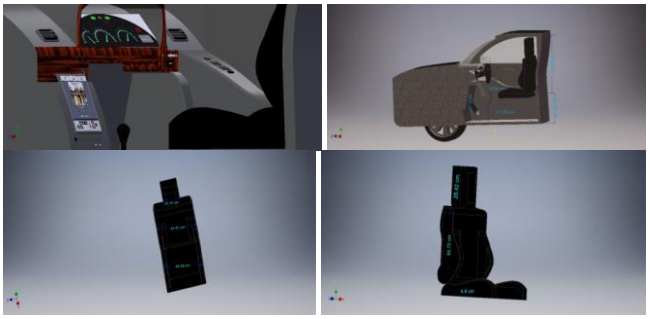

Fig. 8. Design of electric car cockpit.

Fig. 8 is ilustration of the attributes of electric car cockpit design which costumers require.

C. Result of Validation

Marginal homogeneity test was conducted to test the hypothesis. The hypothesis (Ho) is the proposed design attributes conform the custumer requirements.

TABLE I: TEST OF HOMOGENEITY RESULT

Attribute	Sig.
Attractive design of cockpit	0.311
Comfortable seat	0.124
Ease to reach of steer	0.339
Spacious cockpit	0.078
Ease of access to electric devices	0.218
Ease of information	0.572

Table I shows that attributes of the proposed cockpit design of the electric car is correspond with user requirement at 5% of significance level. It means the proposed design can satisfy what the user looks for.

IV. CONCLUSION

Conclusion of this study are shown below:

1) Attributes that user require from electric car cockpit are an attractive design of cockpit, comfortable seat, ease to reach of steer, spacious cockpit, ease of to access for electronic devices, and ease of information.
2) Design parameter for attractive design of cockpit are black colour and wood pattern for dashboard, brown colour for plafond, black colour for setting button, sphere shape for gear lever, and 15,55 cm for circumference of handle bar and gear lever. For comfortable seat, the design parameter are 51,07 cm for depth of cushion , 45,29 cm for wide of cushion, 44,74 cm for cushion height, thickness of cushion is 4,9 cm, 64,72 cm for backrest height, 51,61 cm for backrest width, 28,42 cm for headrst height, 21,72 cm for headrest width, and synthetic skin for material of seat coating. Design parameter of easy to reach of steer are 41, 77 cm for gear lever distance, 68,96 cm for dashboard distance, adjustable of seat distance at 81,72 cm and 111,85 level, right side for position of rearview mirror, right side for door lock, right side for window control, left side for hazard light, left side for temperature, and left side for gear lever position. For spacious cockpit the design parameter are 65,6 cm for dashboard height, 51,07 for handle bar distance, and 100,64 cm for plafond height. Design parameter of ease for access of electronic devices is electronic devices position on the left side of driver. Design parameter of informative is digital for odometer and fuel indicator display.
3) The developed cockpit design of the electric car is valid to satisfy costumer attributes at 5% of significant level.

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