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Analysis of Train Passenger Seat Using Ergonomic Function Deployment Method

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***Abstract*—**Indonesian people use trains for their transportation, especially they use economy class train transportation because it is cheaper and has a more precise schedule than any other ground transportation. Nevertheless, the economy class passenger seat raises some inconvenience issues for passengers. This is due to the design of the chair on the economic class of trains that did not adjusted to the shape of anthropometry of Indonesian people. Thus, research needs to be conducted on the design of the seats in the economic class of trains. The purpose of this research is to make the design of economy class passenger seats ergonomic. This research method uses questionnaires and anthropometry measurements. The data obtained is processed using House of Quality of Ergonomic Function Development. From the results of analysis and data processing were obtained important changes from the original design. Ergonomic chair design according to the analysis is a stainless steel frame, seat height 390 mm, with a seat width for each passenger of 400 mm and a depth of 400 mm. Design of the backrest has a height of 840 mm, width of 430 mm and length of 300 mm that can move at the angle of 105-115 degrees. The width of the footrest is 42 mm and 400 mm length. The thickness of the seat cushion is 100 mm.

***Keywords*—**Chair, ergonomics, function development, train passenger.

I. Introduction

SOME Indonesians use rail transport by train as their favorite transportation. The advantage when using the train as transport in Indonesia is that it is more economical than using other forms of ground transportation. Law no. 13/1992 of the Republic of Indonesia on railways describes the advantages of the national railway transportation system as an economic, energy saving, safe and environmentally-friendly mass transportation. The national railway system is expected to be a supporter and driver of national development for the improvement of people's welfare so that every railway support facility is made to provide convenience and comfort for railway users.

The comfort factor of take the train is an essential factor for passengers because an uncomfortable train journey can cause excessive fatigue.

The passenger seat is one cause of discomfort, when the design is not in accordance with the anthropometry of the user's body (not ergonomic). Creating an ergonomic seating design will provide a sense of comfort and can reduce fatigue for those seated. If the principle of ergonomics is applied in designing a passenger seat, then it will also provide the same benefits that can provide comfort and can reduce fatigue for passengers who sit on it [1].

As one of the largest railway manufacturers in Indonesia, PT Industri Kereta Api (INKA) should pay attention to the quality of each product it produces, one of which is the ergonomically designed railway passenger seat. Most quality experts now agree that the quality of a good product is that it can meet the needs and desires of consumers [2]. Currently, economic class train seats have a rigid shape that is less supportive of passenger posture when sitting, lacking armrests, with a too narrow distance of only about 10 cm between the feet of passengers facing each other.

In designing a comfortable passenger seat, it is necessary to determine the seat size in accordance with the anthropometry of passengers. By making the size of the seat in accordance with the anthropometry of the seat users then the factors that cause discomfort and fatigue for passenger can be reduced so that passengers do not feel excessively tired when sitting in the chair for an extended time [3].

An ergonomic approach in the design of the passenger seat is a challenge for the chair designer, due to the difficulties of formulating the comfort values for sitting of passengers and because the attitude of sitting is grouped as a dynamic activity in the understanding of ergonomics.

In designing a comfortable passenger seat, it is necessary to determine the seat size in accordance with the anthropometry of passengers. The design and manufacture of passenger seating must be based on the anthropometry data of users, otherwise, the final product may cause discomfort for users [4].

The method used in ergonomic train passenger seat research is the Ergonomic Function Deployment (EFD). EFD is a method to facilitate designers during the design process, because the decision is "recorded" in the form of matrices to be examined and then modified [1].

Problem statements

1. There is no technical reference on the design dimensions of the ergonomic train seat, so it is necessary to draw the dimensions of the design of the economy class of train passenger seats.
2. For the convenience of train passengers, the anthropometric of passengers should be in accordance with the dimensions of the seat.

The objectives of the research are to identify the design dimensions of existing economic train passenger seats, to determine the suitability of the current economy class train

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seats in relation to the anthropometry of Indonesians using the EFD method.

This study examines the ergonomics of economy class train passengers of one of Indonesia's train manufacturers, namely INKA. A preliminary study was carried out by direct observation on the rail economy class named Logawa with the permission of PT INKA. This observation is carried out by measuring the physical dimensions of the train's existing economy class passenger seat. This was supported by a questionnaire conducted with train passengers to determine in their view, the part(s) of the seat to be modified in accordance with their needs and desires. An anthropometric measurement process of rail passengers was then carried out to obtain anthropometric data from rail passengers. The data are used as the basis for designing train passenger seats to match the anthropometry of Indonesians. The results of the questionnaire and anthropometry measurement were analyzed using EFD method to facilitate the design and decision-making process; furthermore, the process of planning modifications by using the software to produce design drawings for an ergonomic rail passenger seat design.

II. Research Methodology

The research stages are as follows:

1. This research was conducted by distributing questionnaires to 200 respondents of economic class train users. The purpose of this questionnaire is to know the desirability of economy class train users regarding the design of passenger seats for economy class passengers. The questionnaires distributed to respondents contained 12 questions with multiple-choice and yes or no model. The respondents were briefed on the purpose of the study and the questionnaire prior to answering. The respondents were allowed to answer more than one of the multiple choices provided. The form of the questionnaire sheet can be seen in Table I. The answers of the questionnaire with the highest percentage for each question are used by the researcher as a guide in the design process of the train passenger seat.

TABLE I
List of Questionnaires

No.	Questionnaires
1	From an economy class train passenger seat, which part do you consider uncomfortable? (You can choose more than one answer) a. Backrest b. Cushion c. Seat height position d. Not uncomfortable
2	When seated as an economy class train passenger, which part of body feels pain or stiff? (You can choose more than one answer) a. Neck b. Back/hips c. Legs d. No pain or stiff
3	Is the backrest position in this economy class train too erect? a. Yes b. No
4	Is the material for seat cushion and backrest pads too hard? a. Yes b. No
5	Does the seat that you sit on you feel narrow? a. Yes b. No
6	Is the chair that you are sitting too low? a. Yes b. No
7	Is the space of legs between the Passengers facing each other too narrow? a. Yes b. No
8	Are you comfortable with a sitting position facing each other? a. Yes b. No
9	Do you need a backrest for your hand? a. Yes b. No
10	Do you need a backrest for your feet? a. Yes b. No
11	Do you need a bag to place your personal belongings? a. Yes b. No
12	Of the various seat cover options below, which seat cover color do you prefer? a. Brown b. Blue c. Gray d. None of these colors

2. Anthropometric measurements were performed on 100 volunteers, the physical details of 50 men and 50 women, excluding measurements for pregnant women, the physically disabled, as well as people with extreme-sized bodies. The data of anthropometric measurement results were then processed by conducting the data uniformity test to calculate the percentile value for each dimension of the human body measured. In the data uniformity test, any data is outside the limit control, such that the data value exceeds the Upper Control Limit (UCL) or exceeds the Lower Control Limit (LCL), should be eliminated until it becomes uniform. This test is made to facilitate the designer in making decisions during the planning process and product design. According to [5], the process of processing anthropometric data refers to (1) and (2), as:

a. Test Uniformity of Data

- Average ($\bar{x}$)

$$\bar{x} = \frac{\Sigma x_i}{n} \quad (1)$$

where: x_i = amount of data, n = many observations

$$s = \sqrt{\frac{\Sigma (x_i - \bar{x})^2}{n-1}} \quad (2)$$

- Standard deviation of sample (s)

where: x_i = value of data, $\bar{x}$ = average data.

- With the trust level K = 2, then:

UCL (Upper Control Limit): $\bar{x} + Ks = \bar{x} + 2s$

LCL (Lower Control Limit): $\bar{x} - Ks = \bar{x} - 2s$

b. Calculation of Percentiles

$$X = \pm Z\ s$$

where: X = Value for the desired percentile, $\bar{x}$ = Average data value, Z = Constants for the desired percentile, For the 5th percentile, the value Z = -1,645, For the 50th percentile, the value of Z = 0, For the 95th percentile, the value of Z = 1.645, s = Standard deviation

c. EFD: It is the development of Quality Function Deployment (QFD), by adding the new relationship between consumer desire and ergonomic aspects of the product. This relationship will complement the House of Quality (HOQ) matrix form which is also translated into desirable aspects of ergonomics [6].

III. Result and Discussion

Descriptive statistics of the anthropometric data of Indonesian economic class train passengers are summarized in Table II, while the percentage of questionnaire results of the questionnaire are described in Table III. Table IV presents the consumer desires and needs for an ergonomic seat.

TABLE II
ANTHROPOMETRY OF INDONESIAN ECONOMIC CLASS TRAIN PASSENGERS

No.	Dimension	n	Average (cm)	Standard deviation (s)	Percentile		
					5th	50th	95th
1	Stature height	100	162.8	8.2	149.7	163.3	180.1
2.	Stature height in seated Position	100	80.6	2.4	77.7	81.2	84.0
3.	Shoulder Height In Seated Position	100	61.7	3.7	58.0	61.9	64.0
4.	Elbow Height In Seated Position	100	21.0	5.8	19.3	22.3	24.7
5.	Knee Height	100	50.6	2.9	46.1	50.3	54.8
6.	Thigh thickness	100	15.4	2.7	11.4	15.3	20.7
7.	Knee length	100	54.6	1.3	50.6	54.3	57.7
8.	Popliteal Length	100	40.7	2.0	36.4	40.9	44.3
9.	Popliteal Height	100	42.0	1.6	39.3	42.7	46.9
10.	Shoulder Width	100	43.6	1.3	40.2	43.1	47.5
11.	Upper Shoulder Width	100	36.5	2.2	31.6	36.2	41.2
12.	Hip width	100	35.0	2.1	32.3	36.2	39.8
13.	Chest Thickness	100	17.0	3.9	14.7	18.5	23.0
14.	Thick Stomach	100	19.6	3.0	16.3	20.2	24.0
15.	Upper Arm Length	100	35.1	2.1	30.6	35.0	37.4
16.	Lower Arm Length	100	41.07	3.8	39.2	41.4	45.0
17.	Elbow Length	100	86.7	1.9	82.9	86.0	90.5
18.	Foot Length	100	24.6	1.6	21.4	24.6	28.8
19.	Head length	100	17.2	2.0	15.3	17.1	20.9
20.	Head Width	100	16.0	2.3	14.8	16.0	20.6
21	Weight	100	58.6 (kg)	9.9	40.0 (kg)	59.0 (kg)	78.4 (kg)

TABLE III
THE RESULTS OF THE RECAP OF THE QUESTIONNAIRE (IN PERCENTAGE)

No	Score Percentage (%)			
	a	b	c	d
1	48	26	16	10
2	43	38	14	5
3	90	10		
4	93	7		
5	69	31		
6	40	60		
7	86	14		
8	17	83		
9	84	16		
10	62	38		
11	69	31		
12	10	27	57	6

The results of the analysis of the questionnaires that have been processed are presented in Table V, and show the highest percentage scores.

The results of the questionnaire that were developed in the EFD diagram resulted in the ergonomic design of the ergonomic train seats as follows:

1. Seat Height. Height of chair = height of popliteal of data anthropometry. The data taken from the 5th percentile anthropometric data of popliteal height, which is 39.3 cm.
2. Depth of seats. Seat depth = length of popliteal in 50th percentile of anthropometric data i.e. 36.4 cm, excluding the addition of seat depth to support the back rest.
3. Length of Seats. Seat length = width of anthropometric data of hip of 95th percentile diminished 5 cm (2.5 cm right and 2.5 cm left, respectively). Data of anthropometric for hip width with 95th percentile that is 39.8 cm. For ergonomic design for seat length is minus 5 cm. So the seat length becomes 34.8 cm. In considering sufficient space to meet consumers' needs for the seating,

the designer can round out the 34.8 cm long seat to 40.0 cm for the economy-class rail seat length. With design of a seat length of 40.0 cm, it can reach anthropometry of population from the 5th percentile to the 95th percentile.

4. Backrest height of seat. The backrest height of seat size that used as the backrest of seat design parameters is the height data of the person at the sitting position in the 95th percentile, which is 84.0 cm.
5. Seat angle or tilt. A good seat should have good contact with a backrest. The design of a good backrest has a slope of = 105° to 115° in the direction of passengers in the reclining position.
6. The width of the chair back. Design of the seat back is determined as the width of the backrest = shoulder width of anthropometry data at 50th percentile, which is 43.1 cm
7. Armrests Height. Armrest height = elbow height in sitting position. The anthropometric data used is the 5th percentile i.e. 19.3 cm.
8. Armrest Length. Based on [7] armrest length is 26.7 cm (10.5 inches).
9. Leg Room/Legroom. According to [4], ideal lateral legroom measures approximately 45.0 cm in order for the legs of the average person to get enough space for movement. Vertical legroom is used according to the height of the 95th percentile of anthropometry data of knee, which is 54.8 cm.

TABLE IV
CONSUMER DESIRES AND NEEDS FOR AN ERGONOMICAL CHAIR

Consumer Desires	Consumer Needs for an Ergonomic Chair
Backrest can support the back to head	The height of the chair seat is high in the 95th percentile sitting position, which is 84.0 cm
The width of the chair corresponds to the size of the hips	The seat length corresponds to the width of the 95th percentile anthropometric data of the hip, which is 39.8 cm
The depth of the seat corresponds to the length of the folds in the knee to the buttocks	The seat depth corresponds to the popliteal length of the 5th percentile anthropometric data, which is 36.4 cm
The height of the seat allows the legs not to bend or hang	The height of the chair corresponds to the popliteal height of the 5th percentile anthropometric data, which is 39.3 cm
The angle of the backrest is more tilted back	The angle of back of the backrest 105^0 to 115^0, backrest made reclining
Armrest can hold the hand while sitting	The height of the armrest is in accordance with the 5th percentile of elbow height in sitting position, which is 19.3 cm
The leg room is enough to move	Lateral leg room size 45.0 cm, and vertical leg room is 54.0 cm
Seat pockets can be reached by hand when sitting	Seat pockets place in front of the passenger at the back of the backrest
Footrest can be reached while sitting	Footrest is in front with a distance of 30.0 cm from the knee
Seats not positioned facing	The seats are not positioned not facing
The color of the seat provides a sense of psychological comfort	The color of seats is gray in order to provide comfort for passengers
Seat cushions can support buttocks when seated	Seat cushion made of polyvinyl foam sponge material of 10.0 cm thickness
Chairs can support the human body during sitting	The frames of the chair are made of stainless steel

TABLE V
PERCENTAGE OF ATTRIBUTES OF THE QUESTIONNAIRE

No.	Variable	Attribute	Percentage (%)
1	Part of the chair is not appropriate	Backrest	48
2.	Parts of the body that have complaints	Neck	43
3.	Back position is too straight	Yes	90
4.	The seat and backrest are too hard	Yes	93
5.	The seat space is too narrow	Yes	69
6.	Seat position is too low	No	60
7.	The distance between the all rows of seats is too narrow	Yes	86
8.	Comfortable with a sitting position facing other passengers	No	83
9.	Requires armrest	Yes	84
10.	Requires foot rest	Yes	62
11.	Requires seat pocket for personal items	Yes	69
12.	Cover color of chair	Gray	57

10. Footrest width. Foothold width = 0.2 times of foot length. The anthropometry data of foot length in the 5th percentile that is 21.4 cm. From the calculation, obtained the width of the footrest is 4.3 cm.
11. Seat cover. The material used for the seat upholstery is a type of sponge foam (Polyurethane foam) wrapped in gray-colored fabric made of PVC (Polyvinyl Chloride), without springs. The material is designed with a size of 10.0 cm thickness. The chair is equipped with a front-seat pocket.

IV. CONCLUSION

Based the calculation and analysis of the results obtained in the study of Indonesia's economy class passenger train seats, it was concluded that the recommended dimensions of the new economy class passenger train seat are: seat height 39.3 cm, seat depth 36.40 cm, seat width per passenger 40.0 cm, height of back rest 84.0 cm, angle of tilt back rest is 105° to 115°, width of backrest is 43.1 cm, height of armrest is 19.3 cm, length arm of armrest is 26.7 cm, width of foot rest is 4.3 cm, existence of front-seat pocket, thickness of seat 10.0 cm, The seat model is a framework of stainless steel with a sponge foam (polyurethane foam) on it and wrapped with a gray PVC (Polyvinyl Chloride) cloth, no springs, and the seats are all positioned facing forward, not each other.

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