International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: http://doi.org/10.31695/IJASRE.2018.32921

Volume 4, Issue 10
October - 2018

Analysis and Design of Bus Chair for Economic Class Using Ergonomic Function Deployment (EFD) Method

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ABSTRACT

Bus is one of favorite transportation used in Indonesia. The comfort aspect of passenger seat of the economy class bus is still not a top priority in the bus transportation services. The design of economy class bus seats is still based on experimental results, so that the design does not match the body shape (anthropometry) of Indonesian people. Based on a survey conducted by the research team found that the design of the economy class bus seat is not comfortable for the posture of the people of Indonesia. In this research has been designed design of bus seat ergonomically using Ergonomic Function Deployment (EFD) method. By using Ergonomic Function Deployment (EFD) method, the design of ergonomic economy class bus passenger seat is obtained. The design of the ergonomic chair is given the following dimensions of the height of the backrest is 956 mm, the holder length of is 370 mm, the width of the holder is 457 mm, the length of the armrest is 267 mm, the height of armrest is 89 mm, seat height is 349 mm. The research result used in this research are in 5th, 50th, and 95th percentile data.

Key Word: *Anthropometry, Bus, Chairs, Ergonomics.*

1. INTRODUCTION

Transport has a very important role in people's lives today. Transportation has become a medium for moving goods or people from a place to the destination. The community's need for transportation is increasingly increasing along with the growth of population and the movement of the people in their daily activities. Humans in today's life cannot be separated from their needs with modern transportation. Starting from school, work, shopping, traveling for leisure, delivery of goods, distribution of raw materials and production goods, and various other activities. So transportation becomes one important aspect to support the economy. Therefore it is very necessary parties or agencies capable of providing public transport services to provide transportation services to communities who need it. Under these circumstances there will be mutual reciprocity between the two parties, i.e. between the transport service providers and the public using transportation services called "passengers" [1].

Public transport bus is one of the most favored transportation by the people that is alternative services that are in great demand by the users of transportation services. This is because the bus transportation services are relatively cheaper to travel long distances compared to other transportation services. Consumers are sure to expect transportation services to optimize services as they see fit. One of them is the convenience of the bus transportation services. Comfort is a state of feeling of a person who feels comfortable

DOI: 10.31695/IJASRE.2018.32921

based on the perceptions of each individual. While comfortable is a condition has been fulfilled basic human needs are individual due to several factors environmental conditions.

In designing ergonomic passenger seats it is necessary to design the seat dimensions to suit the anthropometry of passengers. Passenger seat design in accordance with passenger anthropometry can reduce the fatigue and discomfort of passengers while sitting for long time [2].

Comfort for the passenger of the vehicle is an essential factor, the discomfort will cause the impact of fatigue which can ultimately lead to imbalance of body condition. One reason is because the passenger seat used is not in accordance with the anthropometry of the wearer's body (not ergonomic). An ergonomic chair will provide comfort and a little fatigue for passengers, if the ergonomic factor and aspect applied in designing the passenger seat will certainly provide greater benefits [3].Ergonomics is the science, art, and application of technology to harmonize or balance between all facilities used both in activity and rest with the abilities and limitations of both physical and mental human beings so that the overall quality of life for the better life[4].

From the description, the researcher identifies the existing passenger bus seats to find out the suitability of the passenger bus dimension of the bus with the anthropometry of Indonesian people and can make the design of ergonomic bus passenger bus seats.

In this study was conducted to improve the design of the chair that has not been ergonomic. In the preliminary research that has been done by interview and observation, found some problems on the bus that is the physical bus facility is still not adequate, one of which is the design of the bus seat is less ergonomic resulting in pain in the neck, pain in the waist, pain in the knee [5].

The purpose of the research are:

i. Identify existing passenger bus seats so far to determine the suitability of passenger bus dimension with anthropometry of Indonesian people.

ii. Creating an ergonomic design of the economy bus passenger seat.

2. RESEARCH METHODOLOGY

This study is a case study of economy bus passenger seats on one of the bus companies. This research is conducted by direct observation on economic bus. This observation is done by measuring the physical dimensions of the existing passenger seat of the bus and passing the questionnaire sheet to the bus passengers to determine the seat portion to be modified according to the needs and desires of the customers/passengers of the bus. Anthropometric measurements of Indonesians were then undertaken to design an ergonomic bus passenger bus in line with the anthropometry of Indonesians. In this research the result of the observation will be analyzed using EFD method to facilitate during the process of designing and decision making.

Preparation of questionnaires related to the sitting position of respondents, respondents complaints and respondents' wishes to the design of passenger seat of the economy bus. This research questionnaire sheet contains some questions that are subjective to know the opinions of respondents to the existing passenger seat facilities in the economic bus and the desire of respondents to the design passenger seat of economic bus. The questionnaire sheet was distributed to 200 randomly selected respondents regardless of gender. Besides distributing questionnaires, anthropometric measurements of bus passengers were also carried out. Measurements anthropometry of 100 respondents of randomly selected Indonesians at the age of 17-70 years. Measurement activities conducted in several places, namely, Jember, Lumajang and Probolinggo.

The independent variable was determined by the researcher before doing the research. The independent variables in this research are anthropometry data criteria, criteria of questionnaire data as well as product design and development i.e. new design of economic bus passenger seat. The dependent variable depends on the independent variable so that the dependent variable in this research is the result of anthropometry data, the result of the questionnaire data and the new seat dimension.

3. RESULTS AND DISCUSSION

Based on the questionnaire results from economy class bus passengers, 78% of respondents found uncomfortable bus seats. Complaints felt by passengers include, neck pain 80%, back pain 70%, 77% waist pain, 60% stiff butt, 72% stiff arms, 70% sore elbow, 76% sore knee, 61% stiff leg. Based on the complaints data experienced by the bus passengers, it is necessary to redesign the bus seat by considering anthropometry of bus passengers. By using anthropometry data in this bus seat position, it is expected that the inconvenience experienced by bus passengers can be minimized or eliminated.

Results of anthropometry measurements from 100 respondents can be seen in Table 1 and Table 2. The normality test of the data is to know the empirical data obtained in the field whether appropriate or not in accordance with the normal distribution of the data. To know the normal distribution of a data can be done by using Kolmogorov-Smirnov test.

DOI: 10.31695/IJASRE.2018.32921

Table 1 Test of Data Normality and Uniformity For Anthropometric Data

No	Body Dimensions	N	$\bar{x}$ (cm)	Standard Deviation (s)	Z	Upper Control Limit (UCL)	Lower Control Limit (LCL)
1	Stature height	100	1657	67	1,2	1780	1489
2	Stature height in seated position	100	874	40	1,2	964	772
3	Shoulder Height In Seated Position	100	604	37	0,9	670	528
4	Elbow Height In Seated Position	100	206	49	2,7	282	200
5	Knee length	100	538	82	3,0	639	182
6	Popliteal Length	100	458	45	1,2	55,8	34,5
7	Knee Height	100	523	42	1,4	628	403
8	Popliteal Height	100	409	33	1,4	500	336
9	Width of Shoulders	100	446	56	1,2	584	320
10	Hip width	100	343	46	1,8	494	230
11	Chest Thickness	100	219	51	3,0	379	162
12	Thick Stomach	100	233	52	2,2	407	152
13	Upper Arm Length	100	406	63	0,6	502	300
14	Lower Arm Length	100	420	49	3,3	482	203
15	Head Length	100	188	21	2,9	283	141
16	Head Width	100	177	29	3,3	298	140
17	Elbow length	100	846	53	1,2	928	729
18	Weight	100	62.4 (kg)	9.3	1,2	800	510

The calculated data are described normally distributed if the value of Z is greater than or equal to 0.05. Table.1 shows that all data is normal because all have a value of $Z \geq 0.05$ using the Kolmogorov-Smirnov test. The uniformity test shows that all the average values are located between the Upper Control Limit (UCL) and the Lower Control Limit (LCL) so that all the data on the Table 1 can be declared to be uniform.

Table 2 Anthropometric Data

No	Body Dimensions High Body	N	$\bar{x}$ (mm)	Standard Deviation (s)	Percentile (cm)		
					5th	50th	95th
1	Stature height	100	1657	67	1510	1682	1765
2	Stature height in seated position	100	874	40	796	873	956
3	Shoulder Height In Seated Position	100	604	37	529	608	657
4	Elbow Height In Seated Position	100	206	49	89	208	282
5	Knee length	100	538	82	318	558	628
6	Popliteal Length	100	458	45	370	472	527
7	Knee Height	100	523	42	445	525	615
8	Popliteal Height	100	409	33	349	408	471
9	Width of Shoulders	100	446	56	341	450	542
10	Hip width	100	343	46	278	340	457
11	Chest Thickness	100	219	51	164	209	365
12	Thick Stomach	100	233	52	165	225	356

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13	Upper Arm Length	100	406	63	300	406	494
14	Lower Arm Length	100	420	49	304	422	476
15	Head Length	100	188	21	158	187	231
16	Head Width	100	177	29	140	171	264
17	Elbow length	100	846	53	741	856	923
18	Weight	100	62.4 (kg)	9.3	51.7	59.0	79.3

3.1 Result of Technical Specification With Consumer Desire

The results of percentile calculations of anthropometric data that have been taken will then be used to determine the design of the dimensions of the new economy class bus passenger seat. In this phase the product components, shapes and dimensions of each product component are defined. The design variables of ergonomically class bus passenger buses based on the anthropometric dimensions obtained are as follows [6]:

1. Seat Height

High chair = high popliteal data anthropometry. Data taken from the 5^{th} percentile anthropometric data is 349 mm. This is to cover a small population, because if the seat is too low then the leg will be elongated and forward position, but a tall person will be able to feel more comfortable when using a chair with a lower seat than a short body using a base that too high. So in the design of the new economy rail passenger seats using a 349 mm seat height including seat thickness.

2. Seat Depth

Seat depth = long popliteal 5^{th} percentile anthropometric data. Considering the consumer's desire for the addition of the base of the seat, the designer uses the 50^{th} percentile popliteal length data from the anthropometric data to determine the depth of the seat size in order to accommodate the largest number of wearers with the shortest popliteal spacing to the shortest but long popliteal length . If the seat depth is too long then the knee can be formed. So in the design of the new economy bus passenger seats using the 370 mm seat depth size does not include the addition of seat depth to support the back support.

3. Length of Seat

Chair length = width of anthropometric data of 95^{th} percentile diminished 5 cm (2.5 cm right and 2.5 cm left). Data of anthropometric data hip width with 95^{th} percentile of 457 mm minus 50 mm to 407 mm. Considering the consumer's desire to increase the base of the seat, the designer decides not to subtract the 95^{th} percentile data and round up the value to 400 mm for the design of the new passenger seat of the economic class of bus. It will not affect the seating condition of the passengers. With a 400 mm seat length, the 5^{th} percentile population may be included and the 95^{th} percentile may also be included.

4. Chair Backrest height

The seat backs used in the design of the economy class bus seats use a high level backrest, supporting the entire head and neck weight. The data used as the backstop design parameters is high data in the 95^{th} percentile sitting position of 956 mm. With the height of the chair's seat height, the 5^{th} percentile population may be included and the 95^{th} percentile may also be included. So in the design of the passenger seat of economy-class buses that use the new size of the seat height of 956 mm. In the design of this backrest, the new chair backs are given the addition of indentations that fit the curve of the human body in a sitting position. Making the curve to pay attention to the configuration of the backrest that should be able to support the profile of the spine, especially the lumbar area of the designer does not make it too fit to prevent consumers to change the position of his body. The lumbar height used by the designer to determine the size of the backrest that supports lumbar support using lumbar high dimensional data from [7], which is 200 mm.

5. Angle or Tilt Back Angle

The seating design has good contact with the backrest, the angle used is = 105^0 and 115^0 (reclining), the angle is viewed from the pedestal. The angle selection is based on seat angles for general use according to [7] which is 105^0 and the addition of angle determined by the designer is 115^0 where the angle is expected to provide additional convenience for consumers who travel far in a relatively long time.

6. The width of the chair backrest

Wide backrest of seat = width of shoulder side. The data were taken from anthropometric data with the 50th percentile of 450 mm. With the width of the seat backrest, the average population can be covered. For the width of the 5th percentile shoulder width, which is 341 mm, is used as a parameter of adding a curve to the back of the back to support the back in a sitting position. So in the design of the passenger seat of the new economic class bus using the seat backrest width of 450 mm.

7. Armrest Height

Armrest height = elbow height in sitting position. The anthropometric data used is the 5^{th} percentile of 89 mm in order to include the population with the lowest elbow height, because if the height of the elbow is too high it is used the small-sized chair user

DOI: 10.31695/IJASRE.2018.32921

should attempt to lift his body from the chair and put his shoulders around. This can lead to fatigue and discomfort of muscle activity used. So in the design of the new economy rail passenger seats using the size of the armrests height of 89 mm.

8. Armrest Length

Armrest Length. Based on [8] armrest length is 267 mm.

9. Leg Room

a. According to [7], the lateral legroom measures approximately 450 mm in order for the legs to get enough space for movement and passengers can reach the bag / pouch in front of it or to hold onto the seat in front of it without having to get up from the seat.

b. Vertical legroom

• Used size according to the height of the 95th percentile population knee that is 615 mm.

10. Seats / Seat Surface

Seat material used is similar to the seat material on the previous passenger seat that is the type of sponge foam (Polyurethane foam) wrapped in fabric from PVC (Polyvinyl chloride) but without spring and has a color of blue navy wrapping cloth. The material is designed with a size of 100 mm thickness [9]. The measure is viewed from the consumer's desire for a more padded seat.

3.2 Identification of Respondents Needs

The needs of respondents derived from aspects of ergonomics are effective, comfortable, safe, healthty, and efficient. In the Table 3 shows the needs of consumers regarding the economic bus passenger seat.

Table 3 Consumer Needs

No	Consumer Desire (A)	Consumer Needs for Ergonomic Seat (A1)
1.	The color of the chair provides a sense of psychological comfort	Blue navy in order to provide comfort for passengers
2.	Has a comfortable backrest	The height of the backrest corresponds to the height dimension when sitting with the 95th percentile anthropometric data
3.	Has a palm rest	Taken from the length of the forearm and elbow height when the person is sitting
4.	Seat pads and back pads use a soft material on the seat mat	Using Polyvinyl Cloride (PVC) sponge material
5.	Comfortable chair when in use	In accordance with the anthropometry of passengers

Technical specifications that describe the design of products to be designed in accordance with voice of customers is described on Table 4. Meanwhile consideration of the relation between the elements of the technical specifications in the technical specification section with each customer's needs on the customer's wishes is described on Table 5.

Table 4 Technical Specifications

Consumer Needs and Desires	Technical specifications
Chair Backrest	• Given a thicker sponge • Comfortable back corner • Appropriate body shape
Soft Materials On Base and Backrest	• Use a more soft sponge • Seats with PVC
Comfortable Chairs	• Match the body dimension • Secure and safe when used to sit
Supporting Facilities	• the color of the chair is blue navy
Has a palm rest	• In accordance with anthropometry of passengers

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Table 5 Relation of Consumer Technical Requirements

Correlation	Information	Grade
Strong relationship	Chair design in accordance with the anthropometry of passengers	9
Ordinary Relationship	The color of the chair is blue navy	3
Strong relationship	Soft and comfortable seat cushions and armrest	9
Strong relationship	Seat with wide seating space	9
Ordinary relationship	Chairs use armrests	9

Chair design designed in this study is considered good and can be said ergonomically, in this case seat design is in line with the anthropometry of economy bus passengers. And the desire of the chair with the armrest has been applied in the design of the new chair. Matrix of Technical Requirements. Section that contains the importance (ranking) of the technical requirements. The sequence of interests based on the number of relationships present in each of the technical specifications is shown in Table 6.

Table 6 Matrix of Technical Requirements

Consumer Needs and Desires	Technical specifications	Priority
Chair Backrest	• Used material from a more soft sponge • Direction of the right angle of chair • Support the body shape appropriately	1
Armrest	• The positition of the armrest corresponding to the anthropometry of the passenger	4
Soft Materials On Backrest and Chair	• Using sponges • Seat cushions and backrest using PVC	3
Seat with wide seating space	• Match the body dimension	2
Supporting Facilities	• The color of the chair is blue navy	5

The Table 3,4 and 5 above show that the process of making the House of Quality matrix table is in accordance with the research process undertaken, with the matrix results obtained that the economic bus passenger seat is in accordance with the anthropometry of economic bus passengers and is considered in accordance with the needs and desires of consumers.

4. CONCLUSION

Based on the analysis and the data obtained from the test results can be drawn the following conclusions:

1. Ergonomic chair of bus for economic class is with a height of 956 mm backrest, 370 mm holder length, 457 mm holder width, 267 mm arm rest length, 89 mm armrest height, seat height 349 mm. The percentiles used are 5^{th}, 50^{th}, and 95^{th}.
2. Seat material using a soft sponge (PVC) and the color of the chair covers is blue navy.

DOI: 10.31695/IJASRE.2018.32921

ACKNOWLEDGEMENTS

The research was supported by the Director General of Higher Education, Ministry of Research, Technology and Higher Education of the Republic of Indonesia.

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DOI: 10.31695/IJASRE.2018.32921