ERGONOMIC DESIGN OF A COMMUTER BUS CABIN

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This work aims to redesign Mazda commuter bus cabin which is popular in motor parks of Oshodi/Isolo, Apapa and Kosofe Local Government Areas of Lagos State, to accommodate varying body sizes of commuters sing ergonomic principles to enhance comfortability of commuters throughout the period of travel. Four hundred and fifty (450) commuters with ages ranging from 19 years to 72 years from the three (3) local government areas were considered. Eight (8) anthropometric measurements were taken. Also, dimensions of locally fabricated seats in fifty (50) Mazda buses were measured. In addition, Mazda bus cabin layouts were measured. Data were obtained using Subjective (commuters' assessment of seat comfort via questionnaire) and Objective (measurement of seat dimensions) evaluation. The means, standard deviations, fifth, fiftieth and ninety-fifth percentiles were calculated. More so, the data obtained from commuters' body dimensions were compared with relevant seat dimensions using t-test analysis. The result showed some degree of mismatch in body dimension of commuters and seat design attributes when compared which eminently calls for redesign. This emphatically indicates that the commuters' body dimensions and seat dimensions are at variant giving a clear indication that the anthropometric dimensions of commuters were not employed in the design and manufacture of the seats in the Mazda bus cabins in theses parks. These variance results in various musculoskeletal disorder and discomfort, and hence the need for a redesign. Two conceptual design is proposed in this study. The redesigned seat dimensions shows improvement in the cabin seat and will enhance commuters comfort as several issues resulting in musculoskeletal have been addressed.

INTRODUCTION

Mobility is part of the characteristics of living things and important in human life for both economic and social activities, it is a to find people using commercial means of transportation as opposed to the private vehicles because of low income earning (Schwaller, 1993, Hilling, 1996 and Fricker, 2004). In line with this, a chunk number of the public greatly depend on fairly used imported buses (Ismaila *et al*, 2010) whose seats are locally fabricated without proper design concepts and consideration of the commuters. These improper locally fabricated seat results in discomfort among difficulties face by the commuters,, thus it is essential to take into consideration the human comfort as a major factor in the design of seat (Eliane, 2004)

Though sitting may be considered as a comfortable compared to standing or walking but the combined effect of sedentary lifestyle and activities that requires sitting may give rise to some health challenges if uncomfortable for a prolonged period of time (Pedro et al., 2005, www.answerergonomicchair.htm). Considering the duration of travel, the bus cabin seat which accommodates the commuter is regarded as an important entity (Deros *et al*., 2010). Furthermore, the bus cabin the interiors of which the seat is the major component is the major point of interest. Thus an improvement in the seat of the bus cabin is highly essential (carol *et al.*, 2002).

Ajayeoba *et al*. (2012) use the body anthropometric dimension to study suitability of the passenger seats in the *molue* buses used in Lagos and in line with ergonomic concepts proposed adjustments in the seat depth, seat/backrest length, seat height and seating clearance. Mohd (2010) also conducted RULA analysis using ergonomics to improve the bus driver seat for enhanced performance, improved health and safety as well as reduction of injury through adjustable seat that optimally adjusts to the user's physical dimensions to ensure adequate mobility while sitting to cover the range of motion possible.

Thus for enhanced productivity, reduction of discomfort, safety, ease of accessibility and adjustment taking into consideration the ages, weight, gender, physical dimension and disability of commuters (Okunribido, 2000, Oguntona and Kuku, 2000, Igboanugo et al., 2002, Ayodeji *et al.*, 2008, Byung and Kyung, 1990) two conceptual design for the Mazda bus cabin is thus presented in this work.

Key words: commuters' comfortability, redesign, ergonomic, muscoskeletal, bus cabin

MATERIALS AND METHODS

Questionnaires were administered to obtain data on commuter cabin used and postural discomfort experienced in the course of the journey. Both structural and functional anthropometric data were obtained from each respondent also both in sitting and standing positions. All the samples of commuters taken were conducted at Kosofe Local Government Area, Oshodi/Isolo Local Government Area and Apapa Local Government Area of Lagos State. A samples consisting of 450 commuters between the ages of 19 years to 72 years without any form of observable physical deformity were used and fifty (50) randomly selected locally fabricated seats in the commuter Mazda bus cabin. These samples were collected over a period of forty-two weeks.

The commuters' anthropometric data taking are Popliteal Height (PH), Buttock to Popliteal length (BPL), Hip breadth (HB), Sitting to Shoulder Height (SSH), and Shoulder Breadth (SB), while the dimensions of the locally fabricated seat of the Mazda bus obtained are the seat height (SH), seat width (SW), seat depth (SD), backrest height (BH), backrest width (BW), gap between seats (GS), head rest (HR), roof to seat pan (RS) and seat to floor (SF). The samples of the 450 commuters from which the anthropometric data was obtained to cut across the population distribution of the three parks considered (See Table 1). Figure 1 shows the various body or anthropometric dimension and figures 2 to 5 shows Mazda bus cabin from the three parks.

The data obtained were grouped into subjective and objective analysis. The subjective analysis entails the use of commuters view in assessing the comfortability of the Mazda bus use and examined How Wide (TW), Narrow (TN), Short (TS) or High (TH), and How Adequate (A) or Inadequate (I) the seat and cabin features. The objective analysis entails the anthropometric dimensions of the commuters and bus cabin dimensions. From the questionnaires administered commuters from all three local government areas complained about how short and narrow their back rest cushion, unavailability of head rest, how uncomfortable the seat are, which evidently would lead to developing musculoskeletal problems if used over a long period of time. This complaints provides information on the areas to be improved on in the redesign, so the anthropometric data of the commuters and the measurements of the bus cabin was taken to address these needs.

The mean, standard deviation, fifth, fiftieth, and ninety fifth percentiles for each group of data were obtained after which t-test analysis was conducted.

The mean of the anthropometric data obtained from the commuters and the dimensions taking from the Mazda bus was computed to determine the average for each group of data. The mean is given as

$$\bar{X} = \frac{\sum x_i}{N} \qquad 1$$

Where x_i is the set of values of height or shoulder to shoulder length or femur length or tibia length or popliteal height, and N is the Total number data. The standard deviation of the data is given as

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{X})^2} \quad 2$$

The t-test was used to compare the means of the commuter's anthropometric data to relevant bus cabin dimension to determine whether the means of the seat dimensions and the means of the related anthropometric dimensions are in correlation or their will be need for redesign. Popliteal height (PH) was compared to the seat height (SH), while the Buttock to popliteal length (BPL) was compared to the Seat depth (SD). Also the Sitting to shoulder height (SSH) was compared to the backrest height (BH), while the Hip Breadth (HB) was compared to the Seat Width. The Shoulder Breadth (SB) was also compared to the Backrest width.

The t-test is given by equation (3)

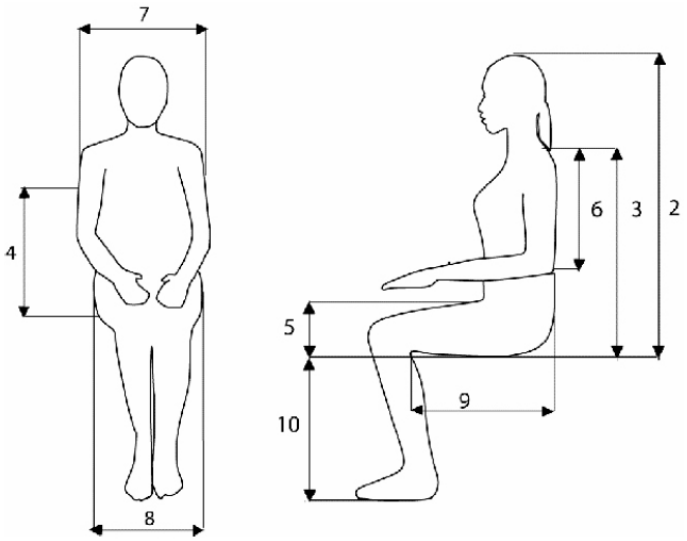
$$\frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{\sigma_1 + \sigma_2}{N(N-1)}}} \quad \text{(Pal and Sarker, 2006)} \quad (3)$$

t= t-statistics, N_2 = sample 2 size (Number of randomly selected buses), N_1 = sample 1 size (Number of respondents), $\bar{X}_1$= mean of sample 1, $\bar{X}_2$= mean of sample 2, σ_1 = standard deviation of sample 1, σ_2 = standard deviation of sample 2

RESULTS AND DISCUSSIONS

RESULTS

The summary of the mean and standard deviation of the ages, weight, anthropometric data of the respondents and the dimensions of the Mazda buses obtained from the three parks used in this study are documented in Tables 1, 2 and 3 respectively. Tables 2 and 3 also shows the fifth, fiftieth, and ninety fifth percentiles anthropometric data of the respondents and the dimensions of the Mazda buses obtained.



2. Sitting height (SH)
3. Seat to shoulder height (SSH)
4. Lowest point scapula to sitting
5. Thigh clearance height
6. Shoulder to elbow length
7. Shoulder breadth (SB)
8. Hip breadth on the seat (HB)
9. Buttocks to Popliteal Length (BPL)
10. Back knee height / Popliteal Height (PH)

Figure 1: Measured Anthropometric dimensions

	KOSOFE		OSHODI		APAPA	
	Weight (kg)	**Age (years)**	**Weight (kg)**	**Age (years)**	**Weight (kg)**	**Age (years)**
Minimum	59	19	52	20	52	19
Maximum	107	72	105	69	112	57
Mean	81.66	35.273	79,77	34.9729	80.82	34.45
Standard Deviation	12.2883	10.3313	13.843	9.5418	13.4763	8.584

Table 1: Commuters Data from Kosofe, Oshodi and Apapa

Figure 2: A Mazda commuter bus

Figure 3: Seat in a Mazda commuter bus cabin at kosofe

Figure 4: Seat in a Mazda commuter bus cabin at oshodi

Figure 5: Seat in a Mazda commuter bus cabin at Apapa.

	OSHODI					KOSOFE					APAPA				
	μ	**σ**	**5th %**	**50th %**	**95th %**	**μ**	**σ**	**5th %**	**50th %**	**95th %**	**μ**	**σ**	**5th %**	**50th %**	**95th %**
SH	**42.26**	**2.22**	**39**	**43**	**45.55**	**40.32**	**3.69**	**36**	**40**	**47**	41.08	3.57	36	40	47

SD	**39.24**	**1.73**	**37**	**40**	**42.2**	**38,18**	**2.23**	**35**	**38**	**41**	38.76	2.39	35	39	44
SW	**43.38**	**7.24**	**35**	**42**	**54**	**48.24**	**5.62**	**40.35**	**48**	**56**	38.9	4.06	35	47	56
BH	**46.36**	**2.61**	**40.35**	**47**	**50**	**45.12**	**5.85**	**36.45**	**46**	**54**	46.58	6.65	36	47	53
BW	**40.4**	**3.11**	**34.45**	**40**	**45**	**38.7**	**4.53**	**32.45**	**38.55**	**48**	45.3	5.61	32.45	39	45
GS	**8.86**	**6.06**	**0**	**8**	**20.55**	**7.68**	**5.93**	**0**	**7**	**21.55**	8.16	6.93	0	7	21.55

Table 2: Dimension of fabricated Mazda bus seat at Oshodi, Kosofe and Apapa

	OSHODI					**KOSOFE**					**APAPA**				
	μ	**σ**	**5th %**	**50th %**	**95th %**	**μ**	**σ**	**5th %**	**50th %**	**95th %**	**μ**	**σ**	**5th %**	**50th %**	**95th %**
PH	46.72	7.91	39	46	58	45.86	7.218	39	45	58	45.29	7.071	39	44	57
BPL	44.69	8.53	36	42	59	43.54	7.760	36	42	57	43.49	7.778	36	42	57
SSH	49.32	12.26	31	45	71	47.27	11.398	33.35	44	68	46.98	11.28	33	43	68
HB	47.58	7.57	37	47	60	41.23	4.53	32.45	38.5	48	41.19	4.13	36	41	49.1
SB	41.9	4.51	36	43	52	50.12	7.88	37.45	50	60	48.47	7.5	37	49	60

Table 3: Anthropometrics Dimension of Commuters at Oshodi, Kosofe and Apapa

Anthropometric Dimensions			**Seat Dimensions**			**T test value**
	μ	**σ**		**μ**	**σ**	
PH	46.72	7.91	SH	42.26	2.22	27.71
BPL	44.69	8.53	SD	39.24	1.73	40.29
SSH	49.32	12.26	BH	46.36	2.64	8.03
SB	41.9	4.51	BW	40.4	3.11	3.94
HB	47.59	7.57	SW	43.38	7.24	14.76

Table 4: **T-test Analysis of Seat Dimensions and Commuters Anthropometric Dimensions for Oshodi Park**

Anthropometric Dimensions			**Seat Dimensions**			**T test value**
	μ	**σ**		**μ**	**σ**	
PH	45.86	7.21	SH	40.32	3.69	39.04
BPL	43.54	7.76	SD	38.18	2.23	12.83
SSH	46.27	11.39	BH	45.12	5.83	3.713

SB	41.23	4.35	BW	38.7	4.53	8.73
HB	50.12	48.24	SW	48.24	5.62	3.454

Table 5: **T-test Analysis of Seat Dimensions and Commuters Anthropometric Dimensions for Kosofe Park**

Anthropometric Dimensions			**Seat Dimensions**			**T test value**
	μ	**σ**		**μ**	**σ**	
PH	45.29	7.07	SH	41.08	3.57	23.13
BPL	43.49	7.77	SD	38.76	2.39	10.99
SSH	46.98	11.27	BH	46.58	6.65	0.121
SB	48.45	7.53	BW	38.7	4.06	3.106
HB	41.18	4.1	SW	45.3	5.61	19.59

Table 6: **T-test Analysis of Seat Dimensions and Commuters Anthropometric Dimensions for Apapa Park**

DISCUSSION

From the subjective analysis conducted, the commuters had some observable displeasure during the period of their journey such as the inability of complete relaxation of the lumber region of the backbone caused by narrow backrest frame and cushion, unavailability of head rest and inadequate leg room and inadequate seat pan which possibly leads to musculoskeletal disorder after a prolonged journey.

The t test analysis of the Commuters Anthropometric Data and the dimensions of the fabricated Mazda bus cabin seat from the three locations showed that a significant difference exists between the means of ‘popliteal height (PH) and seat height, Buttock to popliteal length (BPL) and Seat depth, Sitting to Shoulder height (SSH) and Backrest Height, Shoulder breadth (SB) and Backrest width, Hip breadth (HB) and Seat width, therefore a mismatch between the dimension used by the manufacture of the seat and the anthropometric dimension of the commuter. This mismatch highlights area where discomfort such as musculoskeletal related disorder is experienced by the commuters that use the seats which means that commuters anthropometry was not employed in the fabrication of this locally manufactured bus cabin Seats. Therefore this calls for a redesign of these Seats to accommodate varying sizes of the users and utilize the available space for the adjustment of Seats used by commuters, create clearance for leg movement and to determine the number of rows of seats the space will accommodate in the redesigning of Bus cabin seats.
To redesign the Mazda bus seat dimensions which will be common to all the three park in this study, the overall dimensions of the bus cabin across the three park is considered (See Table for the average dimensions of the Mazda bus cabin across the three park). The mean value of the seat dimensions that will be suitable for the varying size of commuters to enhance ride comfort was obtained from the various mean of the seat dimensions across the three park and use as the new seat

dimension for the redesign. The redesigned seat dimension was then compared with the initial dimension across the three parks, after which the standard deviation and the t-test analysis was estimated to check for variation or conformity in the new bus cabin seat design with the commuters' anthropometric data.

COMMUTERS ANTHROPOMETRIC DATA							REDESIGNED SEAT DIMENSIONS			T – TEST VALUE			REDESIGNED SEAT T-TEST RANGE
	OSHODI		KOSOFE		APAPA								
	μ	σ	μ	σ	μ	σ		μ	σ	OSHODI	KOSOFE	APAPA	
PH	46.72	7.91	45.86	7.218	45.29	7.071	SH	45.95	3.16	27.71	39.04	23.13	0.01 – 0.8
BPL	44.69	8.53	43.54	7.760	43.49	7.778	SD	43.90	2.12	40.29	12.83	10.99	0.1 – 0.8
SSH	49.32	12.26	47.27	11.398	46.98	11.28	BH	46.02	5.04	8.03	3.713	0.121	0.699 – 3.093
SB	47.58	7.57	41.23	4.53	41.19	4.13	BW	41.44	4.42	3.94	8.73	3.106	0.06 – 0.368
HB	41.9	4.51	50.12	7.88	48.47	7.5	SW	46.58	5.64	14.76	3.454	19.59	0.836 – 3.947

Table 7: T-test Analysis of the Redesigned Seat Dimensions and Commuters Anthropometric Dimensions for the three Parks

From figure 7 it is clear that the new seat dimensions fall well within the range of the commuters anthropometric data across the population in the three parks. Moreover, the reduction in the t-test value in the redesigned seat across the three park gives a clear indication of the improvement in the new design. The new design also shows a close correlation with data from Scott, 2006.

From the analysis above in comparison with the bus cabin dimension (see Table 8), two conceptual design of the seats are possible. Concept 1 is a design of four seats with three commuters per seat taking into consideration the SD with the BPL and BW with SB. The second concept is a design of four seat with four commuters per seat. Figures – shows the redesigned seat cabin and seat dimensions.

Bus Cabin Dimension	Mean	SD
Width	147.4	3.209
Length	320	0
Height	138.2	1.483
Roof to seat pan	102	9.137
Seat to floor	46.4	4.722

Table 8: Dimensions of Bus Cabin

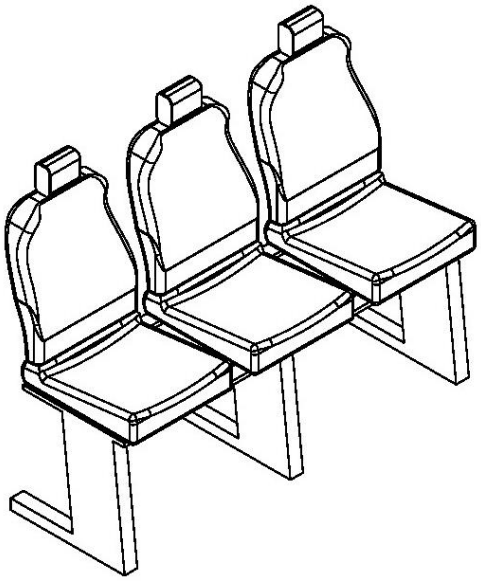


Figure 1: Concept 1 of the new bus cabin

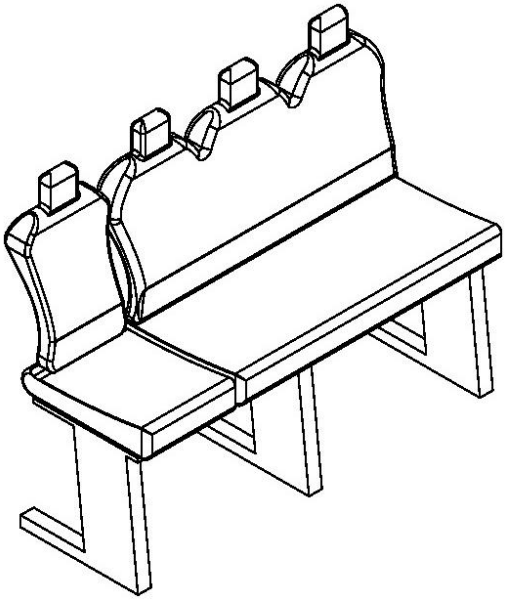


Figure 1: Concept 2 of the new bus cabin

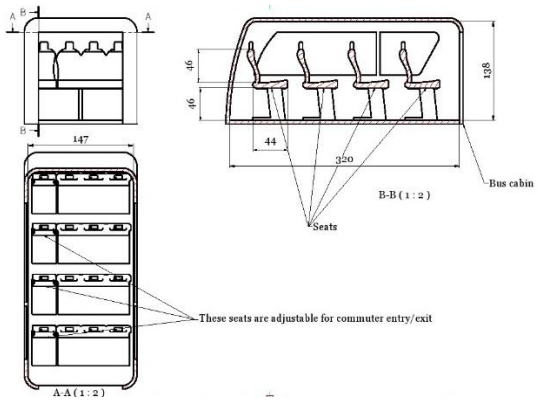


Figure Orthographic view of the bus cabin and new seat design

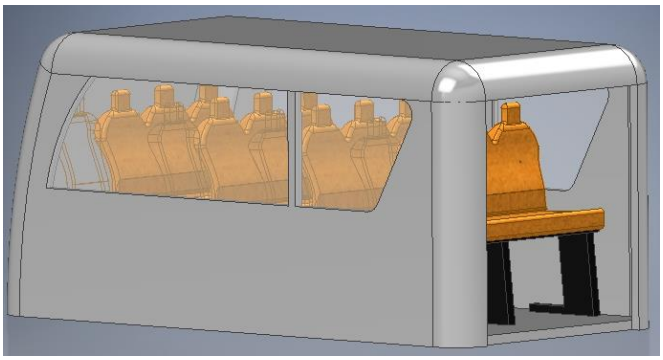


Figure 3D model of the bus cabin and the new seat design

CONCLUSION

However, in considering the fact that most of the Mazda buses used as commercial transportation are most from the Apapa, Oshodi, and Kosofe axis of Lagos to Ibadan are imported as fairly used buses and are redesigned to suit the needs of Nigerians. The seats which are locally manufactured do not meet the ergonomic design as obtained from the analysis. This in effect impairs negatively on the commuter that used the bus cabin as obtained via the subjective analysis of the questionnaire. Two conceptual design was proposed based on the commuters' anthropometric data and the bus cabin seat dimension obtained on a broad band population across the three parks. The redesigned seat dimensions show improvement in the cabin seat and will enhance commuters comfort as several issues resulting in musculoskeletal have been addressed.

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