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ERGO - EVALUATION OF URBAN BUS DRIVER'S WORKSTATIONS IN SOUTH WEST NIGERIA

Salami O. Ismaila[1], ORCID: 0000-0002-9875-8594,
Samson A. Odunlami[2], ORCID: 0000-0002-4838-6542,
Sidikat I. Kuye[3], ORCID: 0000-0002-0286-1539,
Adekunle I. Musa[4*], ORCID: 0000-0002-4998-507X,
Adeniyi Olayanju[5], ORCID: 0000-0002-4771-1171

[1,3]Department of Mechanical Engineering, Federal University of Agriculture Abeokuta, Nigeria
[2]Department of Mechanical Engineering, Federal Polytechnic, Ilaro, Nigeria
[4]Department of Mechanical Engineering, Moshood Abiola Polytechnic,, Abeokuta, Nigeria
[5]Department of Agricultural and Bio-Resources Engineering, landmark University, Omu Aran. Nigeria
*Corresponding author: Adekunle I. Musa, *musa.adekunle@mapoly.edu.n*g

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Abstract. This study evaluated the ergonomic performance of drivers' workstations in southwest Nigeria. Fifty urban buses selected from ten brands were investigated by direct measurement. The buses were mini-A and midi-B. Vertical and horizontal distances of the seat reference point to the pedal and steering wheel, with the seat dimensions were considered. The anthropometric dimensions of 150 male bus drivers were taken from South-west Nigeria. The results revealed that the values for driver's seat height from the cabin floor, seat backrest height, seat shoulder level width and low back width were 44.00-50.00cm, 53.00-58.15cm, 40.00-50.00cm and - 40.15cm respectively as against 39.15-43.00cm, 38.75-49.49cm, 34.60-43.59cm and 45.73-53.25cm respectively in the urban bus workstations. It is concluded that the drivers' workstations in the urban buses were not ergonomically fit for the bus drivers since the anthropometric dimension of the Nigerian male bus drivers were not considered in the designing of the buses.

Keywords: *Anthropometric, Ergonomics, Workstation, Drivers', Urban, Buses, Nigeria.*

Introduction

The focus of the ergonomics approach is that the interaction between humans and other elements of a system and therefore the workstation so as to enhance efficiency, safety, and human well-being [1]. Several studies have confirmed that operators are readily available and more productive when their working environments are designed for his or her best performance [2, 3]. Where work tasks and equipment don't preclude ergonomic principles in their designs, workers are susceptible to be exposed to undue physical stress, strain, and overexertion, like an excessive amount of vibration, awkward working postures, forceful exertions, repetitive motion and work during a bid to correct and reduce hazards thereby improving worker's protection, it's very essential to acknowledge the ergonomic

risk factors within the workplace. Therefore, ergonomists first consider human needs, his abilities and limitations as priorities when designing and evaluating tasks, jobs, products, environments and systems.

Proper ergonomic design is therefore necessary to stop repetitive strain injuries, which may develop over time and may cause a long-term or permanent disability. Ergonomic designs also consider the entire work system. it's widely applied in the areas of aviation, other transport systems, sport, education, public facilities, home, recreational equipment and facilities within the workplaces respectively. Really, all aspects of human endeavor enjoy ergonomic designs [4]. Anthropometric data may be a collection of the size of the physical body and is beneficial for attire sizing, forensics, physical anthropometry and ergonomic design of the workplace [5]. Similarly, some authors defined anthropometric data as that utilized in ergonomics to specify the physical dimensions of workplace, equipment, furniture and clothing [6, 7].

Byran et al., [8] acknowledged that so as to hold out the varied given tasks; the driving force has got to operate the vehicle controls during a sedentary posture. Controls like hand-controls and pedals are often described in terms of human outputs so as to regulate the vehicle. The hands are widely used for steering controls and various lever controls like gear and hand-brake controls. The hands also are wont to manipulate other controls like joystick controls (found in tractors) and delicate switch controls. The feet are used mostly to supply outputs for longitudinal vehicle control like acceleration or brake pedals. The sedentary posture has been acknowledged throughout the professional literature as problematic, as a serious risk factor and a contributor within the development of musculoskeletal disorders [8].

Li and Haslegrave [9], suggested that posture needs special attention during the planning process, especially when amid other manual manipulations that involve the utilization of force. The extra operations often cause adopting inadequate, un- comforted or 'bad' body postures, resulting on high risk of musculoskeletal disorder or maybe physical injury. The anthropometric study suggests an evaluation of all physical elements inside the cabin. The evaluation checks the geometric location, dimension, angel, and position of each element, in reference to each other and in reference to the Seat point of reference (SRP). Additionally, the study evaluates the geometric location of all controls (foot and hand), and displays, inside the cabin, to best fit the operators' anthropometry. It also evaluates the controls for his or her location with the utilization of force [8].

The influence of various forces and vibrations transmitted to the physical body through the seat during the drive shows a particular importance because they inflict a state of tiredness, especially to the driving force that makes a further effort as compared to other occupants [10]. It was reported that within the design of mobile equipment, a balance driver's seat usually reduces the ill effect of vibration within the vertebral column of the operators [11]. He concluded that care must therefore be taken in designing tractors and particularly tractor seats, to scale back vibration and shock to a minimum also as ensure comfortable posture. Driving postures employed by bus drivers should also take into consideration musculoskeletal and biomechanical factors, and make sure that all driving tasks are conducted within a cushy reach range. The posture of the seated person depends on the planning of the seat itself, individual sitting habits and therefore the work to be performed. Seated person depends on the planning of the seat itself, individual sitting

habits and therefore the work to be performed. Seated postures are defined because the body position during which the load of the body is transferred to a supporting area.

The biomechanical considerations of seated postures include the spine, arms, and legs. The muscles at the rear of the thighs influence the relative position of the spine and pelvis, the situation and slope of the work area influence the position of the neck, shoulders, and upper extremities, when a private is during a seated posture. Tan et al., [12], reiterated that comfort is an attribute that today's drivers demand more and more; while seat is one among the important features of auto where the professional driver spends most of their time. Therefore, truck seat, which are in touch with truck occupants, play a crucial role in improving the comfort and work environment of a driver.

However, Tan et al., [12] in their research acknowledged that there's a huge majority of objective measures used for evaluating comfort and discomfort. From their literature search, they identified the target measurement methods for seat like pressure distribution, posture analysis, CAD (CAD), computer aided engineering (CAE), temperature, humidity, Oxygen saturation, vibration, Spinal Loading, electromyography (EMG), and adrenaline. Nigerian bus drivers always complain of undue stresses and extreme body pains during and after work. This, however, might be thanks to some preventable factors like the planning of the drivers' workstations which could not properly fit into the physical nature of the drivers; thereby forcing them to figure in awkward positions and conditions.

Ajayeoba and Adekoya [13], says that the optimum seat for one vehicle may not be the optimum seat for another vehicle and that most of the automotive seats, especially bus driver seats, were not designed according to the anthropometric data of Nigerians. Adekoya and Ajayeoba [14], noted that little work has been done in the area of functional design relationships which are significantly useful in the bus operator workstation. The objectives of this research work is to collect relevant design data from the drivers' compartments and seats of the selected urban buses and the anthropometric data of the Nigerian drivers of urban buses in South-Western Nigeria.

Methodology

Collection of anthropometric and workstation variables

In this study, 30 anthropometric variables of 150 professional male drivers, randomly selected from seven urban centers (Abeokuta, Ilaro, Sagamu, Ijebu-ode, Oshodi, Yaba, Ibadan and Oyo) in three states (Lagos, Ogun and Oyo states) in South -West Nigeria were collected.

Similarly, 50 urban buses in two categories were considered. Category 'A' comprises of 6 common brands of urban mini buses with various capacities (MITSUBISHI - 10 seaters and 14 seaters, TOYOTA- COASTER- 30 seaters, MAZDA – 10seaters, HONDA – ODDYSEY 10-seater and NISSAN – URVAN 14- seaters). Category 'B' consists of 4 common brands of midi buses (FOTON - 42 seaters, ASHOK - 42 seaters, TATA - 42 seaters and COMIL - 54 seaters). Measurement of the workstation parameters and the seat dimensions in all selected buses were done.

Measuring Instruments used are, Digital Stadiometer, PD 300M (DETECTO); Manufactured by Cardinal Scale Manufacturing Company, UK (figure 1), Digital Vernier Caliper - 600mm (figure 2) manufactured by Mitutoyo Corporation, Japan. A 3.5m Steel tape (figure 3); manufactured by Komelon, U.K was also used for this work and Bevel Protractor (figure 4). The Universal Bevel Protractor was manufactured by Mitutoyo Corporation, Japan.

Figure 1. Standiometer.

Figure 2. Digital Vernier caliper (600mm).

Figure 3. Steel Tape.

Figure 4. Universal bevel Protractor.

Measurement of the Driver's Seat Variables:

Preliminary search was conducted to identify the available brands of urban buses found to be commonly used in South-west Nigeria. These include: Toyota, Mazda, Mitsubishi, Nissan, and Honda. Observations together with direct linear and angular measurement were also carried out on the sampled drivers' seats.

The physical measurements of seat variables that were carried out on the sampled buses include: Seat height, Seat depth, Seat width, Headrest height, Headrest width, Backrest height, Backrest width (Lumber level), Backrest width (Thoracic level), Headrest angle, Backrest angle, and Armrest height/length (where available).

Table 1

Anthropometric Dimensions collection

Anthropometric parameters of urban bus drivers and their relevance

P. No.	PARAMETER (P)	RELEVANCE
P1	Stature	Cabinet Total Height
P2	Sitting Height	Seat Backrest Height
P3	Eye to Floor	Seatpan Height from Cabin Floor
P4	Shoulder width	Seat Backrest (shoulder level) Width
P5	Shoulder Height	Seat Backrest Height
P6	Shoulder to Elbow	Armrest placement Height
P7	Knee Height	Steering Wheel Height from floor
P8	Popliteal Height	Seat Height and Pedal placement
P9	Foot Length	Pedal placement from SRP

Continuation Table 1

P10	Foot Width	Pedal width
P11	Hand Length	Steering wheel rim thickness
P12	Hand Width	Armrest surface width
P13	Chest Width	Steering wheel diameter
P14	Elbow angle with Steering	Steering wheel Distance from SRP
P15	Elbow angle with gear	Gear-lever Distance from SRP
P16	Popliteal angle (leg on floor)	Placement of Pedal
P17	Foot angle (leg on pedal)	Placement of Pedal
P18	Back angle (Sitting)	Placement of Steering wheel
P19	Hip Width	Seatback/backrest width
P20	Stomach Depth	Steering wheel placement
P21	Knee Length	Seat distance from Steering rack
P22	Head Width	Headrest width
P23	Head Height	Headrest height
P24	Stomach to steering	Steering rack placement
P25	Popliteal Length	Seat Depth
P26	Elbow to wrist	Steering wheel placement/armrest
P27	Chest to steering wheel	Steering wheel placement
P28	Knee to dashboard	Placement of seat from dashboard
P29	Knee to steering rack	Placement of seat
P30	Arm length	Placement of Steering wheel

Statistical Data Analysis

Data collected were analyzed using Microsoft Excel Starter 2010 and SPSS 16 to obtain the mean, standard deviation, 5^{th}, 50^{th}, 75^{th} and 95^{th} percentile for this research work.

Results and Discussions

Data Obtained from Workstations

The Seat Reference Point (SRP) was used for the placement of the two controls. The following tables present the results of the statistical analysis of the data collected during the field work.

Table 2

Summary of data obtained from mini bus workstations (Category A)

S/N	VARIABLE	No.	STD. DEV	MEAN	5^{th} Percentile	50^{th} Percentile	75^{th} Percentile	95^{th} Percentile
1	Cabin Height	30	13.39278	142.1667	122	148	149.5	150.75
2	Cabin width	30	6.531973	92.66667	90	90	90	102
3	Cabin Length	30	2.316607	90.16667	87.25	90.5	91.75	92.75
4	Seat to Door dist.	30	3.444803	5.333333	3	4	5.5	10.5
5	Cabin floor to road	30	16.54086	59	36.5	61.5	67.5	77.25
6	Pedal to Seat	30	4.490731	42.83333	38.5	41.5	45.25	49
7	Steering to Floor	30	4.119061	66.83333	61	68.5	70	70
8	Dashboard-backrest	30	10.65364	77.5	62.5	79.5	81.5	88
9	Steering to backrest	30	3.577709	45	40.5	45.5	46.75	49.25
10	dashboard width	30	6.531973	92.66667	90	90	90	102
11	Dashboard height	30	7.339391	41.66667	32	42.5	44.5	50.25

Continuation Table 2

12	Steering wheel Dia	30	4.722288	40.5	38	38.5	39.75	47.5
13	Steering rim thickness	30	0.917424	3.583333	2.625	3.5	4	4.75
14	Pedal angle	30	2.581989	46.66667	45	45	48.75	50
15	Steering rack angle	30	2	64	61	65	65	65
16	Door width	30	9.287985	113.3333	101.25	116	120	122.25
17	Door height	30	5.776389	134.8333	127	135	139	140.75
18	Dashboard to Seat	30	8.140434	26.33333	14.5	29	30	31.5
19	Gear lever to Seat	30	5.329165	16	10	16.5	19.5	22.25
20	Bus total Height	30	30.06271	194.1667	162	190	197.5	235.25
21	Steering rack to Seat	30	13.60392	23.33333	9.5	21.5	24.25	42.25
23	SRP-STR(H)	30	5.785038	50.66667	42.5	51.5	54.5	55.75
24	SRP-STR(V)	30	2.44949	32	30	31	34.25	35
25	SRP-PDL(H)	30	3.32666	91.66667	87.25	93	93.75	94.75
26	SRP-PDL(V)	30	2.316607	27.16667	25	26.5	29.25	30

Table 3

Summary of data obtained from mini bus Drivers' Seats (category A)

S/N	VARIABLE	No.	STD. DEV	MEAN	5th Percentile	50th Percentile	75th Percentile	95th Percentile
1	Floor to Seat	30	6.08824	32.66667	25.5	33.5	34.75	40.25
2	Seat front width	30	1.966384	50.33333	48.5	50	50	53
3	Seat back width	30	2.75681	41	38	41	43.5	44
4	Seatpan depth	30	0.516398	49.66667	49	50	50	50
5	Backrest width (Lumbar)	30	2	49	47	49	50	51.5
6	Backrest width (thoracic)		2.258318	44.5	42.25	44	45.75	47.5
7	Backrest Height	30	3.141125	53.66667	50	54.5	55	57.25
8	Headrest width	30	4.086563	26.5	22	25.5	28.25	32
9	Headrest height	30	8.438009	23	16	22	22.75	35
10	Armrest Length	30		30	30	30	30	30
11	Armrest width	30		7	7	7	7	7
12	Armrest thickness	30		8	8	8	8	8

Table 4

Summary of data obtained from midi bus workstations (category B)

S/N	VARIABLE	No.	STD. DEV	MEAN (cm)	5th Percentile (cm)	50th Percentile (cm)	75th Percentile (cm)	95th Percentile (cm)
1	Cabin Height	20	5.737305	198.75	192.6	199.5	203.25	203.85
2	Cabin width	20	23.38803	104.5	80.25	105	120.25	128.05
3	Cabin Length	20	10.62623	122.75	109.85	127	128.5	129.7
4	Seat to Door distance	20	8.80814	17.25	10.15	15	21.5	27.5
5	Cabin Floor to Ground	20	8.01561	103.75	94.1	106.5	107.75	109.55
6	Pedal to Seat distance	20	7.325754	30.5	23.6	29.5	34	38.8
7	Steering to Floor	20	3.316625	72.5	70	71.5	74	76.4
8	Dashboard to backrest.	20	12.52664	81.75	69.6	82.5	92.25	92.85
9	Steering to Backrest dist.	20	6.531973	42	35.2	42	44	48.8
10	Steering Wheel Diameter	20	9.804081	54.7	49.49	50	54.85	66.49
11	Steering rim thickness	20	1.367175	3.525	2.475	3.1	3.85	5.17
12	Pedal Angle	20	7.465197	133.125	124.375	135	136.25	139.25
13	Steerg rack angle	20	2.954516	76.125	73.3	75.75	77.375	79.475
14	Door width	20	0.707107	79.5	79.05	79.5	79.75	79.95
15	Door height	20	12.72792	165	156.9	165	169.5	173.1
16	Dashboard to Seat distance	20	2.828427	28	24.6	29	30	30
17	Gear lever to Seat distance	20	10.78579	20.5	8.25	22	25.25	30.65
18	Total Height from ground	20	0	310	310	310	310	310
19	Steering rack to Seat dist.	20	14.84363	30.5	13.95	33.5	42.25	42.85
20	Pedal to seat distance	20	21	50.5	28.1	54	68	68

Continuation Table 4

21	SRP to Steering (Horiz.)	20	2.061553	54.75	52.45	55	55.5	56.7
22	SRP to Steering (Vertical)	20	2.217356	23.75	22.15	23	24	26.4
23	SRP to Pedal (Horizontal)	20	4.924429	88.25	82.35	90	90.5	91.7
24	SRP to Pedal (Vertical)	20	2.986079	42.75	40.3	42	43.25	46.25

Table 5

Summary of data obtained from midi bus Drivers' Seats (category B)

S/N	VARIABLE	No.	STDEV	MEAN (cm)	5th Percentile	50th Percentile	75th Percentile	95th Percentile
1	Floor to seat Height	20	2.061553	41.25	39.15	41.5	43	43
2	Seatpan thickness	20	2.362908	11.75	10	11	12.75	14.55
4	Seatpan back width	20	4.358899	41.5	38	40.5	44	46.4
5	Backrest Angle	20	7.371115	102.5	95.2	102	104.5	110.5
6	Backrest thickness	20	2.629956	10.25	8	10	12.25	12.85
7	Backrest width (lowback level)	20	3.855161	48.67	45.728	47.5	50.25	53.25
8	Backrest width (Shoulder level)	20	4.391001	39.4675	34.6	40	42.4675	43.5895
9	Headrest Angle	15	28.30783	127.3333	110.2	112	136	155.2
10	Headrest width	15	1.921909	27.78667	26.568	26.82	28.41	29.682
11	Headrest height(with stand)	15	1.732051	37	35.3	38	38	38
12	Headrest height(no stand)	15	2	22	20.2	22	23	23.8
16	Seat Depth	20	5	47.5	41.5	50	50	50
17	Backrest Height	20	5.057997	44.25	38.75	44.5	47	49.4
18	**SRP to Steering (Horizontal)**		2.061553	54.75	52.45	55	55.5	56.7
19	**SRP to Steering (Vertical)**		2.217356	23.75	22.15	23	24	26.4
20	**SRP to Pedal (Horizontal)**		4.924429	88.25	82.35	90	90.5	91.7
21	**SRP to Pedal (Vertical)**		2.986079	42.75	40.3	42	43.25	46.25

Table 6

Summary of the Anthropometric Dimensions of 150 Nigerian Male Urban Bus Drivers Length/Height (cm), Angles (degree)

	VARIABLE	No.	MEAN	STD.DEV.	5th Percentile	50th Percentile	75th Percentile	95th Percentile	MIN.	MAX.
P1	Stature	150	173.15	3.32473	168.8	173	175.5	179.1	166	180
P2	Sitting Height	150	83.175	4.51713	76.9	83	86.25	90	74	91
P3	Eye-Floor height	150	73.4	5.2315	60	77	81	83.15	50	88
P4	Shoulder Width	150	44.5	3.25458	40	44	46.2	50	39	51
P5	Shoulder Height	150	55.395	1.96898	53	55	56	58.15	53	62
P6	Shoulder-Elbow	150	34.6125	1.90642	31.475	35	36	37.05	31	38
P7	Knee Height	150	59.25	1.48497	56.95	59	60	61.05	55	62
P8	Elbow-Wrist	150	30.2875	1.34873	28	30	31	33	28	33
P9	Knee Length	150	60.7125	1.67901	57.95	61	62	63	57	63
P10	Popliteal Length	150	48.75	-1.4456	49.95	49	50	50	45	51
P11	Hip Breadth	150	37.0175	1.97975	34.7	37	38	40.145	32.4	41
P12	Tommy Depth	150	20.3325	3.06171	14.93	21	22.4	25	11.7	25
P13	Popliteal-Height	150	47.4625	1.21628	46	47.5	48	50	45.5	50
P14	Foot Length	150	26.5275	0.83297	25	26.4	27.1	28	25	28
P15	Foot Breadth	150	9.5175	0.73794	8.395	9.7	10	10525	8.2	11.2
P16	Hand Length	150	20.0575	0.70234	19	20	20.625	21	18.8	21
P17	Hand Breadth	150	9.745	0.57466	8.99	10	10	10.505	8.7	11
P18	Shoulder - Wrist	150	64.8	2.93258	60.475	65	67	70	60	70
P19	Head Breadth	150	14.975	0.73441	13.895	14.95	15.525	16	13.8	16.1
P20	Head Length	150	20.2075	0.98668	19	19.9	21	22	19	22
P21	Tommy - Steering	150	19.7	3.18812	15.95	19.5	22	24.1	15	26

Continuation Table 6

P22	Chest – Steering	150	32.2	2.94566	27	33	34	36	26	38
P23	Right knee - Dash Board	150	12.45	2.26399	9	12	15	16	9	16
P24	Left knee -Dash Board	150	12.95	2.34193	10	12	15	16.05	10	17
P25	Knee-Steering Rack	150	8.275	1.88431	5.5	8	10	11	5.5	11
P26	Elbow Angle, with Steering	150	144.188	3.88073	140	144.25	146	147.15	139.5	162
P27	Elbow Angle with Gear	150	165.3	3.37563	160	166	168	171	158	171
P28	Knee Angle foot on Floor	150	123.075	1.91669	120.95	123	123.25	126.025	120	130
P29	Ankle Angle foot on Pedal	150	95.675	4.74686	91	94	98	104.25	91	110
P30	Back angle Sitting	150	100.975	4.02229	96	101	102.25	111.05	96	112

Table 2 shows the summary of data obtained from mini bus workstation (category A), while Table 4 shows the summary of data obtained from midi bus workstation (category B),. In the tables, the 5th 50th, 75th and 95th percentiles of the horizontal and vertical distances of the steering wheel/pedal from the seat reference point (SRP) were stated.

The percentile value was in the range 42.50 - 55.75cm for the horizontal distance of the centre of steering wheel to the seat reference point for category 'A' buses. For category B, the range was 52.45 -56.70cm. Table 2 showed that the percentile value range of the vertical distance of the steering wheel from the SRP for buses in category A was given as 30 - 35cm while, for the midi buses in category B as it appeared in Table 4 was between 22.15 and 26.40cm. Table 2 also showed that the value range of the vertical distance of the pedal from the SRP for small buses (A) is 25 – 30cm; while Table 4 revealed that the range for midi buses (B) was 40.30 – 46.25cm Category A buses as in Table 2, the horizontal distance of the SRP to the pedal was within the range of 87.25 – 94.75cm while that of category B in Table 4 is 82.35 – 91.7cm. Tables 3 and Table 5 show the results obtained from the driver's seat data analysis for the two categories A and B of buses considered in this research work respectively. Table 3 revealed that 5th and 95th percentiles value range for the seat height from the cabin floor is 25.5 - 40.25cm for category A buses while Table 5 showed that 39.15 – 43cm for category B. Table 6 showed the results obtained for the popliteal height of range 46 – 50cm from the anthropometric data analysis of the drivers. Table 3 showed the value range of the seat pan depth for category A as 49 - 50cm while the range for category B in Table 5 is 41.5 – 50cm.

Meanwhile, Table 3 showed that give the back width range of 38 – 44 cm, while Table 5 depicts the back width range of 38 - 46.4cm showing slightly wider dimensions when compared to the drivers' hip width range of 34.70 - 40.15cm in table 9. However, the seatpan front width range is 48.5 – 53cm for category A and the range for category B is 47.15 - 49.7cm. The backrests have different width dimensions at the low back and shoulder levels. The shoulder level range for category A is 42.25 - 47.5cm and 34.6 - 43.6cm for B. Tables 3 and Table 5 again failed to accommodate 95th percentile of shoulder breadth (50cm) dimensions of the sampled drivers' population shown in Table 6. Table 3 and Table 5 showed the ranges for the lumber level are 47 - 51.5cm for category A and 45.73 - 53.25cm for category B. The backrest height is determined by the shoulder height sitting. However, the backrest height result for category A of (50 - 57.35cm) seems to

be lower to the anthropometric value range of the shoulder height (53 - 58.5cm) than that of category B (38.75 - 49.4cm), which is rather too short for the Nigerian driver to work with comfortably and efficiently.

Table 5 reveals that none of the midi buses in category B has an armrest; while table 3 of the category A buses gives only constant values for the armrest parameters. Headrest provides support for the head while driving. Table 3 gives the height value range of 16 - 35cm for category A buses while category B has (20.2 - 23.8cm) as in table 5. The headrest widths for the two categories in tables 3 and table 5 showed that Category A buses has the width range of 22 – 32cm, and those in category B have 26.6 - 29.7cm range. Meanwhile, the head widths of the drivers are within 13.89 and 16cm range according to Table 6 (P19) of the anthropometric dimension of 150 bus drivers'. It is to be noted that the backrest for one bus brand in that category B has no headrest.

Table 7

Comparisons of Drivers' Seats Structural Dimensions for Categories 'A' and 'B' and the Current Study Values

S/N	SEAT PARAMETER	CATEGORY A (cm)	CATEGORY B (cm)	Current study Value(cm)	Determinant
1	Floor to Seat height	25.5 -40.25	39.15 – 43	46 - 50	Popliteal height
2	Seatpan depth / length	49 - 50	41.5 – 50	49.95 – 50.00	Popliteal length
3	Seatpan (back) width	38 - 44	38 - 46.4	334.7-40.15	Hip width
5	Backrest width (low back level)	47 - 51.5	45.73 - 53.25	34.7-40.15	Hip width
6	Backrest width (shoulder level)	42.25 - 47.5	34.6 - 43.59	40 – 50	Shoulder width
7	Backrest height	50 - 57.25	38.75 - 49.4	53 -58.15	Shoulder height
8	Armrest length(Right Hand only)	30 (Honda only)	None	47 – 54	Elbow to wrist length
9	Armrest height(Right Hand only)	11 – 19	None	15.9-27,5	Shoulder to elbow
10	Armrest width(Right Hand only)	7 (Honda only)	None	8 – 12	Hand Width
11	Headrest height	16 – 35 (adjustable)	20.2 – 38	18.75 – 37	Shoulder to head
12	Headrest width	22 – 32	26.6 -29.7	13.89 – 16	Shoulder width

Note
Category A & B is a direct measurement
Current study is the anthropometric data obtained from the drivers'.

Relevant design dimensions of the driver's compartment and seats had been collected and analysed from 6 brands mini buses and 4 brands of midi buses operating in south western Nigeria. The data collected were summaries and recorded in Tables 8 – 12. The results obtained were compared with relevant researchers and useful inferences drawn.

Table 8

Comparison of drivers' anthropometric (Mean) dimensions of the current study and previous related study

	Anthropometric Data Mean (cm)	Current Study (cm)	Ajayeoba (2009) (cm)	Onuoha (2012) (cm)
1	Stature	173.15	173.30	163.4
2	Hand length	20.06		18.6
3	Hand breadth	9.75		8.2
4	Popliteal height	49.46	49/8	43.4
5	Buttock to Popliteal	48.75	48.9	48.2

Continuation Table 8

6	Shoulder breadth	44.50	42.8	43.1
7	Hip breadth	37.02	34.9	29.0
10	Elbow to wrist	30.29		29.8
12	Shoulder height	55.4	57.1	54.2
13	Shoulder to elbow	34.61	36.2	31.0
14	Sitting Height Erect	83.18		83.7
15	Knee length	60.71	58.1	58.3
16	Knee height	59.22		52.8
17	Eye to floor height	73.40		74.6
18	Elbow rest height	24.6		24.3
19	Back to knee	55.6		58.0
20	Foot length	26.53		24.9

Table 9

Comparison of relevant anthropometric variables of the current study and some other countries of the world

Anthropometric Variable	South-Western Nigeria (present study)		Germany**		Japan**		China**		Britain**		Russia**		Philippines**	
(cm)	Mean (cm)	S.D	Mean (cm)	S.D	Mean (cm)	S.D	Mean (cm)	S.D	Mean (cm)	S.D	Mean (cm)	S.D	Mean (cm)	S.D
Stature	173.15	3.3	171.5	6.6	168	5.5	170.5	5.9	174	7.0	173.6	6.1	186.7	N/A
Sitting Height erect	83.18	4.6	90.3	3.4	91	3.0	91.0	3.0	91	3.6	90.9	3.2	86.4	N/A
Sitting Eye Height	73.4	9.23	77.5	3.4	79	2.9	79.1	2.9	79.0	3.5	79.1	3.2	76.1	N/A
Sitting Shoulder Height	55.40	1.9	60.1	3.1	59.1	2.6	60.2	2.6	59.5	3.2	N/A	N/A	56.9	N/A
Sitting elbow Height	20.8	N/A	24.4	2.9	25.4	2.3	26.4	2.4	24.5	3.1	24.1	2.6	24.6	N/A
Thigh Clearance	N/A	N/A	15.1	1.5	15.6	1.2	N/A	N/A	16.0	1.5	14.6	1.6	15.5	N/A
Knee height	59.25	1.5	53.1	2.7	50.9	2.2	52.1	2.9	54.5	3.2	55.0	2.5	52.8	N/A
Popliteal height	47.46	1.2	45.2	2.6	40.2	1.9	41.1	1.9	44.0	2.9	45.0	2.2	47.5	N/A
Shoulder to elbow	34.61	1.9	N/A		33.7	1.8	33.8	1.9	36.5	2.0	N/A	N/A	32.00	N/A
Elbow to finger tips	50.33	N/A	46.5	2.0	44.8	1.8	42.7	2.7	47.5	2.1	45.3	N/A	46.2	N/A
Forward grips	87.94	N/A	76.3	3.7	N/A	N/A	71.0	3.6	78.0	3.4	60.1	3.6	N/A	N/A
knee Length	60.71	1.68	60.3	2.7	56.7	2.3	55.8	3.1	59.5	3.1	N/A	3.1	N/A	N/A
Popliteal Length	48.75	-1.4	48.6	2.5	N/A	N/A	N/A	N/A	49.5	3.2	45.0	N/A	47.2	N/A
Shoulder breadth	44.5	3.25	47.1	2.4	N/A	N/A	46.0	2.3	46.5	2.8	34.8	2.2	41.4	N/A
Hip width sitting	37.02	1.98	36.9	2.2	37.9	1.9	36.0	2..7	36.8	2.9	22.0	2.4	40.9	N/A
Foot length	26.52	N/A	26.4	1.3	25.1	1.1	N/A	N/A	26.8	1.4	28.0	1.2	25.7	N/A
Foot breadth	9.5	N/A	10.2	6..0	10.4	0.5	N/A	N/A	9.5	0.6	N/A	N/A	10.4	N/A
Hand length	20.07	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	18.8	N/A
Hand width	9.75	0.57	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10.9	N/A
Shoulder Height	55.40	1.97	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	56.9	N/A

*Source: **Onawumi and Lucas [15]*

Table 8 showed the comparison of the drivers' anthropometric dimension in the present study with other researchers. Table 9 shows the comparison of relevant anthropometric variables of adult male Urban Bus drivers in South Western Nigeria obtained in this study with the male adults in other countries such as Germany, Japan, China, Britain, Russia and Philippines. Tables 9, 10 and table 11 showed the comparison of the present study with [13], [15], [16].

From Tables 8, 9 and table 11, it can be deduced that the mean values obtained in this study compared favourably with the range of values procured earlier by Ajayeoba and Adekoya [13], [15] for most parameters. Table 8 revealed that the research of Onuoha *et al.*,[16] for the south - eastern Nigerian drivers were slightly different because they were obtained from another ethnic group and environment in the same country.

Table 10

Analysis of Seat Dimensions and Relevant Drivers' Anthropometric Dimensions in this Study

	Seat Dimensions				Drivers' Anthropometric Data		
Parameter	**BUS (A)**		**BUS (B)**		**Relevant Parameter**		
	Mean	SD	Mean	SD		**Mean**	**SD**
Seat height	32.67	6.09	41.3	2.06	**Popliteal height**	47.46	1.22
Seat length	49.62	0.52	47.5	5.0	**Buttock – popliteal**	48.75	1.45
Seat width	41.0	2.76	41.5	4.6	**Hip width**	37.02	1.98
Back rest height	53.67	3.14	44.3	5.05	**shoulder height**	55.40	1.97
Back rest width (lumbar level)	49.0	48.67	48.7	3.8	**Shoulder breadth**	44.50	3.25
Backrest width(thoracic level)	44.5	39.46	39.5	4.39	**Hip width**	37.02	1.98
Head rest height	23	8.4	22.0	2.0	**Shoulder height**	27.78	N/A
Head rest width	26.5	4.09	27.8	1.92	**Shoulder breadth**	44.56	3.25

Table 11

Comparison of Workstation Dimensions in this Study with Related Results by Ajayeoba and Adekoya, [13

S/N	**Workstation Parameter**	**Current (Study)**		**Ajayeoba and Adekoya, 2010 (Molue buses)***	
		Mini Bus (A) cm	**Large Bus (B) cm**	**Small Molue Bus (A) cm**	**Big Molue Bus (B) cm**
1	Pedal to seat	42.82	30.5	43.17	38.7
2	Dash board to back rest	77.5	81.75	72.1	74.8
3	Door width	113.33	79.5	52.3	54.8
4	Door height	134.83	165	130.7	188.7
5	Door step to Road	59	63.75	49.2	49.3
6	Steering wheel thickness	3.58	3.525	3.3	3.3
7	Steering wheel diameter	40.5	54.7	41.8	55.3

*Source: *Ajayeoba and Adekoya, [13].*

Table 12

Comparison of Seat Data in this study with those in a related work

		(URBAN BUS)		**(MOLUE)***	
	SEAT VARIABLE	**Current Study**		**Ajayeoba and Adekoya [13]**	
		Mini Bus (A)	**Large Bus (B)**	**Small Molue (A)**	**Big Molue (B)**
1	Seat height	32.67	41.25	34.5	41.8
2	Seat length	49.67	47.5	42.4	50.5
3	Seat width	41.00	41.5	42.1	46.5
4	Backrest width (shoulder)	49.00	48.67	41.7	50.0
5	Backrest height	53.67	44.25	43.9	50.8

*Source: *Ajayeoba and Adekoya [13].*

Similarly, table 9, could be inferred that generally there were notable differences in the mean values obtained in this present study and those from the six other countries of the world (Germany, Japan, China, Philippines, Russia and Britain). This corroborates with the findings of Hedge [17], that people from different ethnics groups have proportionally

different characteristics. This study also revealed that Japanese adult males have shorter mean (168 ± 5.5cm) stature than the south western Nigeria adult male (173.15 ± 3.3cm).. In addition, the Nigerian males have longer elbow to finger tip/ forward grip and higher popliteal height than their counter parts in Germany, Japan, China, Britain and Russia.

Table 9 showed the differences between stature and sitting height (erect) also suggest that adults in south western Nigerians had shorter lower limbs 983.18 ± 4.6cm) than their counterparts in the other countries. This confirms the findings of Hedge [17] that most Africans have shorter lower limbs than the Europeans. This will therefore have direct impacts on the placement of both the hand and leg control devices in the drivers' workstation as well as the dimension of the seat height.

However, the dimensions of the hip widths, foot length and foot breadth, and popliteal lengths of the south-western Nigerian adult males compared favourably with those of Germans, Japanese, Chinese, Philippines and British except for the Russians whose hip dimensions are smaller. This inferred that there will be a mismatch if the anthropometric data of the citizens of those countries were used to design equipment for southwest Nigerians. Table 10 revealed that there were considerable differences between the anthropometric dimensions of the Nigerian bus drivers and the seat dimensions in the two categories A and B of the selected buses. Meanwhile, Parcells *et.al*,.[18] suggested that a chair whose seat height is > 95% or < 88% of popliteal height is a mismatch for the user. They also suggested that if the seat length is > 95% or < 80% of the buttock – popliteal length and then the seat is a mismatch for the user.[19].

Therefore, table 10 showed that mismatches exist between the popliteal Height and seat height, buttock to popliteal length and seat length as well as between hip width and the seat width. For mini buses (A) – the mean height is 68.8% (< 88%) of the mean popliteal height. This implies that the seat was too low for the users hence, uncomfortable for him as he must bend while sitting on the seat to drive. This posture may result in low back pain and sprain of the thigh as well as driver hitting the knees against the steering wheel.

The mean seat length/depth was 101.8% (>95%) of the buttock to popliteal length. This is a mismatch for the user as the seat is longer than the popliteal length of the user. This makes his leg not to touch the floor or the driver has to shift forward so that his leg could touch the floor, and to do that he will lose contact with the back rest. This may have health implication which may be leg, back and shoulder pains. Also, there is a mismatch between the seat width and the hip width. The seat width was 110.8% (>95%) of the hip width. Similarly, for large buses in category B, the mean seat height was 86.8% (<88%) of the mean popliteal height having the same effects of being slightly low for the comfort of the Nigerian bus drivers. The side effects may include back pain, spraining ankle, hitting the steering wheel with the tight and the dashboard with the knees. The mean seat length/depth here was 97.4% (>95%) of the mean buttock to popliteal length. This is also a mismatch for the user as suggested by Parcells *et.al* [18]

In the same manner, the results from this study showed that the mean seat width of the driver seat was 41.00 cm for 37.02 cm mean hip width of the large bus drivers i.e. 97.43 (>95%) of the hip width implying a mismatch for the users and leading to back pain and discomfort when in use. Parcells *et.al*.,(1999) suggested that seat height should not be <88% or >95% of popliteal height, it then follows that the mean seat height for a mean popliteal height of 47.46cm should be between 41.76 and 45.09cm, rather than 25.50 to 40.25cm;

and 39.15 to 43.00cm ranges representing the 5th and 95th percentile ranges in mini buses (A) and large buses (B) respectively.

Similarly, for the seat depth/length, Parcells *et.al.,* [18] suggested that good seat depth should not be <80% or >95% of the buttock - popliteal length. Therefore, ergonomic driver's seat depth for a mean buttock - popliteal length of 48.75cm, should range between 39.00 and 46.71cm rather than 49 to 50cm and 41.5 to 50 cm representing the 5th and 95th percentile in the mini buses (A) and midi buses (B) respectively.

Ismaila *et.al*, [19] reported that the seat width should be equivalent to 99 percentile of the hip value plus 15%. With this, the ergonomic seat width range should be 41 to 47.15 cm and not 38 to 44cm and 38 to 46.4 cm representing the 5th and 95th percentile for the mini buses (A) and large buses (B) respectively. This study also noted a mismatch between the anthropometric data of the drivers and the dimensions of the backrest. Some of the seats have square or rectangle shape with short heights. While some assumed a shape of which the lower parts are wider than upper parts. This affects the comfort of the drivers, and may lead to neck and shoulder pains. This study hereby suggests that the ergonomic driver seat should have 95th percentile of the shoulder height for the backrest height, 95th percentile of the shoulder width for the dimension of the upper part; and the seat width dimension for the low back level. This puts the seat dimensions at 58.15cm height, upper shoulder level width of 50cm and the low back / hip level width of 47.15cm rather than the mean height, upper width, low back width of 53.66, 49, 41.5; and 44.25, 48.67, 39.47cm in that order for small bus (A) and luxury bus B respectively.

Table 11 and table 12 showed the comparison of the present study with the study of Ajayeoba and Adekoya [13]. The result showed that the pedal-seat of the mini and midi buses in the present study of 42.8cm and 30.5cm are far apart from 43.17cm and 38.7cm of the Ajayeoba and Adekoya [13]. The steering wheel thickness was 3.58cm and 3.53cm for mini and midi buses in the present study as against 3,3cm of the Ajayeoba and Adekoya [13]. Table 12 also revealed a drastic different in the seat height of 32.67cm and 41.25cm mini and midi buses of the present study as compared with 34.5cm and 41,8cm respectively/.

Conclusions

The results of the analysis so far conducted showed that there were mismatches between the drivers' anthropometric data and the design measurements of the present driver seats as well as the locations of both hand and foot controls in the drivers' workstations. With reference to the main objective of this study, it could therefore be concluded that the drivers' workstations in the urban buses used in South-West Nigeria were not ergonomically fit for the urban bus drivers in South-West Nigeria since the anthropometric data of the Nigerian male bus drivers were not put into consideration in the designing the buses. According to the objective, the designed data were collected from the drivers' compartments and seats of the selected buses for ergonomic analysis. It could also be concluded that this study had provided appropriate dimension for ergonomic drivers' seat in the urban buses for Nigerian drivers. Similarly, this study had adequately made provisions for ergonomic drivers' seats and appropriate placement of the steering wheels and pedals in the urban buses to be ergonomically suitable for the Nigerian drivers.

Having achieved this, the ergonomic placement of the steering wheel and the pedal, as well as the drivers' seat dimensions within the drivers' workstations to improve the efficiency

and availability of urban bus drivers within the scope, various numerical results obtained from this analysis are hereby recommended for direct use and also for further ergonomic studies. The anthropometric data are also recommended for other designs and production of safety and clothing materials such as hand glove, foot wear, goggle, and apron for the driver and related populations.

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