

Ergonomic Passengers Analysis of Locally Modify Buses

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Abstract: *In India , privately changed midi transports are occupied with giving open transportation administration to intercity significant distance travelers. One of the serious issues in the privately made midi-transports is, the thought given by the rubberneck manufacturers for the travelers' ergonomics, security and solaces exceptionally less. Also, the nonappearance of all around expressed code of training for transport body structure and endorsement to control the business made the things to go in the incorrect manner. This investigation covers an examination from the ergonomic perspective, wherein differing angles and factors identified with the solace and protections of the clients. Among the primary perspectives assessed are the passage and exit of the transport, the straightforwardness to show up at the seats, the seats measurement, and dispersion of the seats. Every one of these viewpoints is identified with human body estimations, confirming its adjustment to the number of inhabitants in clients. Moreover, the dimensional information of the assorted units were contrasted and the qualities and parameters determined in the norm. At last a few proposals show up on the moves to be made in configuration terms that unquestionably will add to improve the security and the solace of the intercity travelers to get least degrees of solace without dumping the worries of wellbeing and security. This exploration is directed utilizing a few techniques or blended methodology, which incorporate perception, agenda, surveys and meetings with various gatherings of travelers, transport authorities, vehicle vendors, eavesdropper developers and professionals.*

Key words: *Midi-buses, Passengers ergonomics changes, Safety.*

I. Introduction

Transport represents one of the most important human activities worldwide. It is an indispensable component of the economy and plays a major role in spatial relations between locations [1]. The purpose of transportation is to overcome space, which is shaped by a variety of human and physical constraints such as distance, time, administrative divisions and topography.

In Ethiopia there are three modal systems of transport that exist (road, air and rail). However, studies conducted in Ethiopia in showed that about 99.31 percent of the total passengers used road transport for their mobility, 0.65 percent used airline and 0.04 percent used railway transport. [2]

Bus is one of the main alternatives of mass public transportation in Ethiopia as it is cheaper and has better coverage area than any other modes of public transportation.

Our society's increasing requirements for mobility with simultaneously growing environment is crucial for the manufacturers of light and heavy passenger vehicles and the body builders to become accustomed to the ecologically motivated requirement, which becomes more and more important with comprising on basic minimum requirements of safety and comfort. The problem areas and the whole exercise were aimed towards standardizing the essential aspects involved in the construction of the bus body considering the minimum requirements of safety and comfort for passenger.

Ergonomics is defined as the study of the design of a workplace, equipment, machine, tool, product, environment, and system which takes into consideration human being's physical, physiological, biomechanical, and psychological capabilities and optimizes the effectiveness and productivity of work systems while assuring the safety, health, and wellbeing of the workers (Fernandez and Marley, 1998). In general, the goal of ergonomics is to fit the task to the individual, not the individual to the task. [3][4]

Its fundamental aim is that all human-made tools, devices, equipment, machines, and environment should advance, directly and indirectly, the safety, well-being, and performance of human beings. This includes anthropometry, an applied discipline which is one of the cores of ergonomics. It commands ergonomic analysis which intends to design things to "fit" the human body, and therefore achieve its ultimate goal of generating "optimal" conditions which are so well adapted to human characteristics, capabilities, and desires, that physical, mental, and social well-being is achieved (Duffy, 2010). [4][5][6]

Ergonomics is applied in various industrial areas which includes transportation. It is evident that some of the vital artifacts of our daily lives are used to assist human activity and mobility. Design of cars, trains, ships, boats, planes, etc. is exhibited to enable the users an efficient, effective, and safe transportation.[4][5][6]

It is possible to carry a great number of passengers in public transport units, but in attention to the users comfort and safety, it is necessary to limit the number of passengers in such way that provide the minimum

comfort that the users deserve. The population of users varies in terms of age, size, weight and mobility, making necessary to consider this factors during the design phase. Extreme cases are represented by the population of bigger size, individuals with physical limitations or disabilities, and specially population segments of elderly and children, who are naturally more susceptible to accidents. [5]

The passengers' bus transport units are classified in units of Micro Bus, Mini Bus, Midi Bus and Standard Bus (Indian Automotive Research Association 2008, Delhi, India). With the objective of the present work, the interest will be concentrated in the units of intercity transport midi bus, specifically with seat capacity 25 which is modified locally by bus body builders.[13]

Midi-buses, similar to minibuses, are convenient for smaller groups of passengers. The difference is that midi-buses offer larger seating capacity, ranging from 24 to 35 seats, along with larger luggage compartments, thus making them more suitable for longer journeys. (<http://buscharter.org/bus-types/midibus>)

Therefore, this study, intends to fill the gap in the area of the passengers ergonomics comfort and safety by evaluating main aspects in the midi buses interior design and then propose the right standard to be used by the bus body building industry or by the transport authority.

1.1. Ergonomics of Bus Passengers

The design of transport means has progressed considerably in the last one decades, mainly in the area of the comfort and security of the passengers. In European countries, USA and many other countries there are standards and regulations in order to prevent accidents and to assure the minimum conditions of comfort and safety of users. Users differ in terms of age, stature, weight and mobility, therefore these factors must be considered in order to satisfy the users' requirements. The aspects to be evaluated can be determined by the corporal dimensions of the population of users and by their mobility. The extreme cases are represented by those people of greater body size, individuals with physical limitations and especially the senior and young segments of population that by nature are most prone to accidents.

The basic aspects being considered are:

- Entry and Exit stairways of the bus
- Ease of movement in the bus
- Access to the seats
- Space available in the seat for the user
- Form of the seats and rakes of seat, and the back rest
- Distribution of the seats

In the following work the author would like to highlight the basic ergonomic faults some of the buses and try to provide some solutions to the problems faced by several users. In addition, some dimensional parameters and characteristics of the transport units are considered in trying to guarantee the comfort and security of the passengers. It is not in the scope of this work to discuss each one of these dimensions and characteristics, but attention will be paid to those representing certain interest from the ergonomic point of view.

II. Experimental Setup

2.1. Methodology, Sampling and Findings

One hundred (100) intercity midi-buses engaged in public transportation service are randomly selected for this study. The most important dimensions from these buses measured and recorded. These actual values are compared with a given minimum standard according to Flores et al (1981), Mitchell (1988), Petzäll (1993) and Levis (1978). The variables taken for sample measurements are listed as:

- Inner height of the bus (A)
- Inner Width (B)
- Gangway (C)
- Width of the single seats (D)
- Height of back rest (E)
- Seat cushion height (F)
- Gap between seats (G)
- Inner length (H)
- Width of the twin seats (I)
- Depth of the seat cushion (K)
- Separation between the seat back rest and the contiguous chair (L)
- Inclination of back rest (M)
- Height from the road to the first step of the entrance or exit stairs (N)

- Height of the stairs of the access or exit stairs (O)
- Track of the stairs of the entrance or exit stairs (P)
- Width of the entrance or exit door (Q)

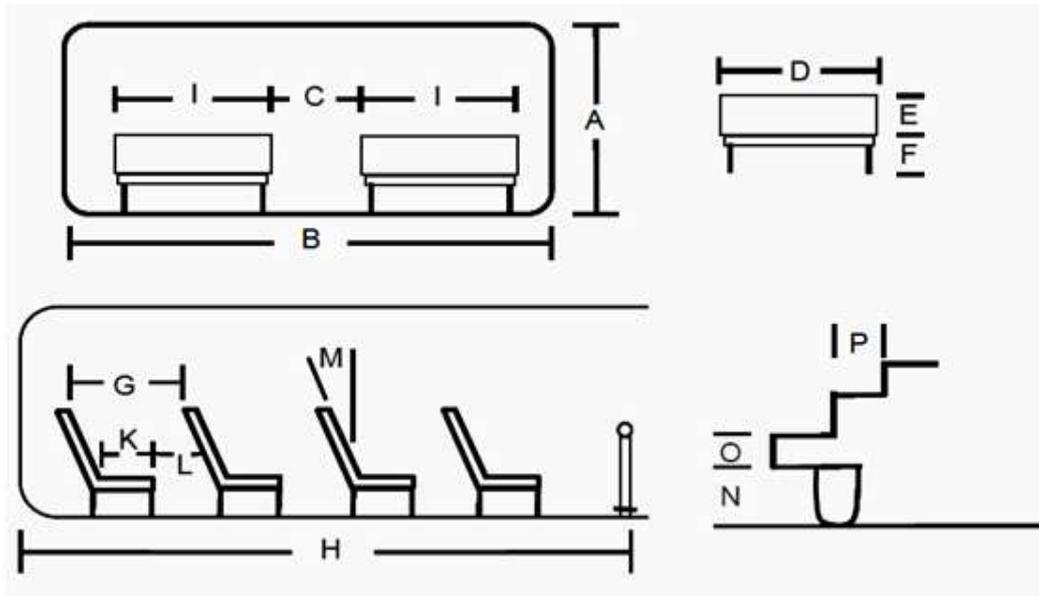


Figure 1 Dimensional variable considered in this study

III. Theoretical Analysis

3.1. Anthropometry

Factors which affect anthropometric measurements include gender, ethnicity, growth and development, secular trend, ageing, social class, and occupation, as well as clothing and personal equipment. Anthropometric surveys detailing various measurements have been conducted for various populations. (Pheasant, 2005). Currently, the most referenced source book is an international text for the International Labor Office (Jurgens et al., 1990). This text has compiled a comprehensive anthropometric database. The workforce is different in different parts of the world and diversified; therefore, it is important to design the workplace based on the anthropometry of the users. [7] Each person's anthropometric measurement is compared to values observed in the general population and expressed as percentiles.

In the modern world it is impossible to design in terms of average dimensions. It is for that reason that anthropometry plays a capital role in the world of design. [8] In terms of public transport, it is necessary to define the spaces of circulation, access and exit doors, as well as the dimensions of the seats considering the more corpulent people. On the other hand, the dimensions of the smaller people are used to define the height of the seats, height of the superior handles, height of the steps of the access and exit stairs, and finally the height of the last step of these stairs in relation to the road level.[9] It must be added that public transport is also used by elderly population and people with physical disability, which forces to make certain considerations to facilitate the access, the security and the comfort of these segments of the population during the use of the public transport.[10]

A detailed observation shows a great dispersion of the data values of the considered variables. The main reason, to which this dispersion of the data can be attributed, is the lack of control by the corresponding authorities as far as construction and distribution of the seats, space distribution and circulation of the users inside the units of public transport; giving freedom of action to the owners. There is no control on satisfying the minimum requirements of design according to security standards and the comfort of the users. Dimensions of buses were compared with the anthropometric data available of the population.

One hundred midi buses which are engaged in public intercity transport service are randomly selected for this study. The seat capacity of the bus is 25 passengers plus one driver and all the seats facing the front of the bus. Minimum and maximum values were taken by direct measurement from the buses and each one of the dimensional variables compared with the standard (minimum, maximum or recommended values).

3.2. Entrance and Exit Doors

Passengers through the access and exit doors, therefore it is required that its dimensions satisfy the 95 percentile of the population. Table 1 shows the results of the comparison of this dimension with the established value in standard. The minimum value registered obviously does not satisfy the requirements established in the standard, therefore users are forced to assume awkward postures and inconvenience to risk when getting on to and exiting of the transport units.

Table 1 Dimensions of the entry and exit doors.

	x - max	x - min	Average	Standard deviation	Standard minimum
Dimensions of the access & exit doors width, cm	70.0	65.0	67.33	1.7	70.0

The awkward positions (figure 2), reduces the space available so that the user can enter or exit the bus in a comfortable and secure way. This risk factor increases when the passengers carry on object in their hands which prevents them from holding appropriately to avoid falling.



Figure 2 passenger’s difficulty when descending from the bus

3.3. Entrance and Exit Stairs and Handrails

Steps at the bus entrance and exit are repeatedly cited as a barrier to people who have disabilities, but are still able to walk and climb steps, though with difficulty. Descending steps is more difficult than climbing steps and well-designed handrails makes both tasks easier. More than 90 percent of buses are not using the handrails to assist aged and disabled passengers.

The non-standardized measurements of the steps, particularly very high steps, increase difficulty during the entry to the bus, especially for the people of short stature, aged people and children. In addition, at the moment of exit, the risks of falling are even greater due to the instable posture in which the users find themselves. The handrails should be on each side of each entrance or exit stream, and they should be matched in shape, height and position to assist the entering and exiting passengers. Comparison of the dimensions of steps Table 2 shows examples in which steps height are too large and furthermore the passengers are forced to deliver an extra effort to raise themselves to the transport unit.

Table 2 Dimensions of step heights and comparison with the standard

	x - max	x - min	Average	Standard deviation	Standard max
Dimensions of step height, cm	40	30	35.6	2.88	15-20(*)

(*) Flores et al (1981)

The comparison of the dimension of the track obtained in the sampling of the units of public transport and the values recommended in the related list (table 3). In relation to the track of the steps of access and exit stairs, dimensions should prevent the accidents that can be caused due to the very small room in the steps to place the feet at the time of descending.

Table 3 Dimensions of the track and comparison

	x - max	x - min	Average	Standard deviation	Recommended minimum
Dimensions of track, cm	25	20	22.4	1.83	25-30(*)

(*) Petzall (1993) and DPTAC (1988)

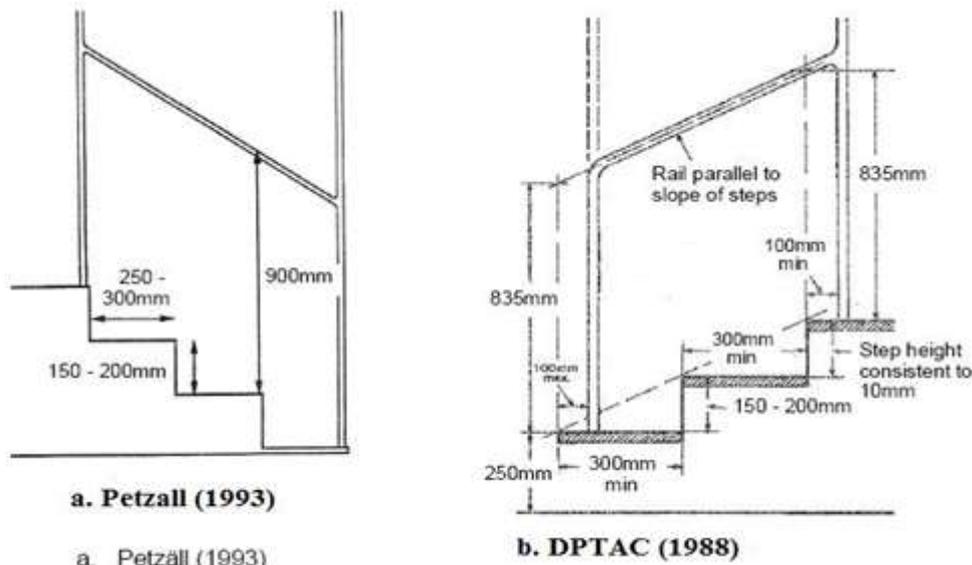


Figure 3(a and b) Recommended geometrics for bus entrances and exits

Regarding physical access, one of the most common complaints about buses are the high steps and the distance between the vehicle and the kerb (ECMT, 1989; Petzall, 1993). The Petzall study determined that uniform steps were needed, as they require fewer and smaller trunk movements. It is also preferable for the bottom step to be in-line with the pavement, as it reduces leg movement and starting line of steps for visually impaired people.

Once again it is observed that the average values of the track of the steps not satisfying the recommended values. Nevertheless, the detected minimum values create a high risk of accident at the moment of descending from the units. Finally it is necessary to consider the height of the last step of the entry and exit stairs from the road, which generally is a dimension greater than the height of the other steps. This represents a greater falling risk when exiting, as well as great discomfort at the moment for accessing figure 4.

Table 4 Height from the road to the last step of the access and exit stairs

	x - max	x - min	Average	Standard deviation	Standard max
Dimensions of the road to the last step, cm	54.5	45	50.77	2.57	38 cm *

*Petzall (1993) and DPTAC (1988)



Figure 4 Too small size of step track (Left) and **Figure 5** (right) the last step represent a greater risk of accident when descending.

3.4. Gangways Dimension

Table 5 presents the values obtained values show that the movement of the users within the unit is uncomfortable, forcing in most cases to lateral displacements. It is possible to observe that the passengers are forced to invade the corridor of the unit, which reduces even more the available space for movement inside the unit as shown in figure 6

Table 5 Dimensions of the circulation corridors

	x – max	x – min	Average	Standard deviation	Standard min
Dimensions of the aisle ,cm	30	25	29	6.13	35(*)

*The Pennsylvania Code, School Bus Body Standards



Figure 6 Discomfort to move within the bus

3.5. Seats Dimensions

To assess the seats; it is important to consider the segments of population like taller and bigger sized people, for example when evaluating the legroom available for the passenger inn the seated position; and for others, the sector of smaller population, for example for the height of the seatts. Table 6 presents the data corresponding to the height of th e seats and their comparison with the values recommended according to ergonomic criteria. The average dimensions are not very elevated in coomparison with the values recommended in relation to the b ack-knee height of the population of users, however, a great deviation of the data and maximum values, which are very far from satisfying the conditions of comfort of the users, are observed.

Table 6 Height of the seats and comparison with the standard

	x - max	x - min	Average	Standard deviation	Standard
Seat height, cm	46.0	40.0	43	2.16	40-46(*)

*Recommendations for seat dimension Levis (1978)

Table 7 presents space for legroom data and the comparisons. It is possible to observe that average values do not fulfill the minimum requirements of comfort to accommodate the legs in the available space, as shown in figures 7. Furthermore, minimum dimensions found during this work are small that do not allow an adult user to fit in the seat. The main problem that appears when this dimension is very small is, the contact between the knee and the rigid surface of back rest of front seat, which causes pain and discomfort to the passenger.

Finally, in the case of abrupt braking or vibrations produced by the irregularities of the road, the knee is subject to continuous blows. Sometimes the space available for the legs is so small; that the passenger cannot place his legs in there causing greater discomfort, as much for the seated passenger as for those passing through the corridor, as it is shown in figure 7.

Table 7 Space available to accommodate the legs

	x - max	x - min	Average	Standard deviation	Standard Min
Space for the legs, cm	30.0	28.46	26.55	1.36	30.0



Figure 7 Insufficient spaces to accommodate the legs, and allows the passenger to place his/her legs in the gangway.

As far as the comfort requirements are concerned; the width of the seats are very critical. Obviously the seats are designed to accommodate single person, therefore the analysis will be done based on the space available for each passenger. Table 8 presents the summary of these data and their comparison with the corresponding corporal dimensions. It is simple to observe that the standard values of seat dimension are not fulfilling the requirements of comfort related to necessary room for the users. Thus, lack of enough space users must travel tight to others occupy their individual space, causing physical and psychological annoyance. In addition, the passenger who seats near the corridor interrupts the movements of passengers and constantly struck by the passengers in transit.

Table 8 Seats width comparison with related corporal dimensions.

	x - max	x - min	Average	Standard deviation	Standard Min
Seats width, cm	40	30	34.53	4.43	40

The values of back rest and seat inclination angles recommended is indicated in tables 9 and 10. The obtained values for the specified angles are less than the recommended values, resulting in passengers' dissatisfaction, lack of comfort and security for the passengers, since the angles do not prevent the sliding

forward in the case of abrupt braking. Also, the inclination of back rests forces the passenger to travel in a very unnatural position, causing tiredness and pain.

Table 9 Inclination of the horizontal surface of the seats

	x – max	x – min	Standard	Recommended values° (*)
Inclination of seat cushion, degrees	4°	-4°	-	14°-24°

(*) Grand jean 1991

Table 10 Inclination of back rest of the seats

	x – max	x – min	Standard	Recommended values in [degrees] (*)
Inclination of back rest of the seats, degrees	94°	90°	-	110° - 130°

(*) Grandjean 1991

3.6. Questionnaire Analysis

87 people were asked to give their feedback about the locally modified buses ergonomics, safety and comfort. 80% of the respondents witnessed that, the buses are not built by considering the standard required for passenger’s safety and comfort. In addition, the field survey and observation, the bus interior construction is found to be very poor (figure8). The interior structures should be built to reduce the secondary impacts during frontal collusion and vehicle roll over to minimize the risk life.



Figure 8 Unsafe structures in bus interior may hurt passengers or cause secondary impacts

The seats are not comfortable generate more heat (72.5%), the twin seats are not enough to accommodate two passenger (87%), no enough space for legroom (81%) and on the seat there are hazardous materials like bolts and sharp things (85%) are not properly finished or removed from the seat surfaces and not well trimmed. If these parts are not removed, these things will hurt the passengers’ body and may tear their dresses.

The seat cushions are not comfortable (60%) and the covers used also are not of standard ones used (65%), the cushions should be energy absorbing cushion made of foam material e.g. PUR polymer and flexible surface layer e.g. of PVC or ABS film.

The material used to cover the walls and roof ceiling is mild steel sheet, according to the feedback of the respondents (63%). As recommended, the space between the exterior and interior perforated roof panels shall be completely covered with 1.5 inch thick layer of fiberglass or mineral wool insulation.

IV. Conclusion

- Since the goal of ergonomics is to reduce stress and eliminate injuries and disorder associated with the overuse of muscles, bad posture. Thus, the bus body designers and builders for long distance intercity passenger services must integrate the user, the bus and the bus interior at least considering the minimum standard aspects of ergonomics such as safety, comfort, ease of use, productivity and aesthetics for the passengers.
- As observed from the study some of the major society groups like aged, children, disabled, and people with limited mobility are not satisfied in this public transportation sector. To avoid these problems there must be Code of practice for bus body design and approval which comprehends all segments of the population to be used equally without partiality.
- With the procedure in place, it is all the more essential to introduce a scheme of accreditation of bus body builders so that the implementation could be fair and uniform in all the bus body building industries.
- The handrails should be on each side of each entrance or exit stream, and they should be matched in shape, height and position to assist the entering and exiting passengers.
- Insulation materials are used to maintain comfort conditions by minimizing noise and heat infiltration to the occupant compartment and thereby provide a comfortable ride.

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