CONTRIBUTION OF LOCALLY DESIGNED AND FABRICATED VEHICLE-SEATS TO ACCIDENT INJURIES

By

Edem Denis Kwame Dzebre, BSc. (Hons)

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DECLARATION

I hereby declare that this submission is my own work towards the Master of Science in Mechanical Engineering and that, to the best of my knowledge, it contains no material which has been accepted for the award of any other degree of the university or any other university, except where due acknowledgement has been made in the text.

Edem Denis Kwame Dzebre ……….……..…......... ....……………

(PG 4846010) Signature Date

Certified by:

Dr. Joshua Ampofo ……….……..…....... …...……………

(1st Supervisor) Signature Date

Department of Mechanical Engineering

KNUST.

Dr. Raphael Kumah-Ametepey ……..…................... …...……………

(2nd Supervisor) Signature Date

Accident and Emergency Directorate

KATH.

Dr. Samuel Mensah Sackey ……….……..…......... …...……………

(Head of Department) Signature Date

Department of Mechanical Engineering

KNUST.

ABSTRACT

Buses and minibuses account for a large number of reported Road Traffic Accidents in Ghana. Most of these vehicles are used goods transport vans, modified for passenger transportation purposes. One of such modifications is the provision of seats. These seats are designed and fabricated locally by artisans, but not according to any known accepted safety standards. This among other reasons has resulted in a hypothesis among medical personnel that, the design of these seats are also responsible for some of the injuries sustained in accidents.

This research sought to support this hypothesis with the results of a computer simulation. The simulation results were compared with data obtained from a Mini Survey, which was conducted between November 2011 and January 2012, at the Accident and Emergency Centre of the Komfo Anokye Teaching Hospital, Kumasi, Ghana.

Findings include injuries that are mostly sustained by occupants of accident vehicles fitted with the seats in question, as well as design features of the seats, which are most likely to cause these injuries. Based on these findings, recommendations on safer design features for the seats and future researches were made. Some information on the seats in question, which was unavailable in literature as at the time of conducting the research, was also reported.

DEDICATION

To my family and all Road Traffic Accident victims.

AKNOWLEDGEMENT

I will like to express my sincerest gratitude to my Supervisors, Dr. Ampofo of the Department of Mechanical Engineering, KNUST, and Dr. Kumah-Ametepey of the Accident and Emergency (A&E) Centre, Komfo Anokye Teaching Hospital (KATH), for their invaluable patience, encouragement, ideas and guidance.

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LIST OF ACRONYMS

Acronym	**Meaning**
RTAs	Road Traffic Accidents
HTIs	Hard Tissue Injuries
STIs	Soft Tissue Injuries
KATH	Komfo Anokye Teaching Hospital
A&E Centre	Accident and Emergency Centre
NRSC	National Road Safety Commission
DVLA	Drivers And Vehicle Licensing Authority
MTTU	Motor Traffic And Transport Unit
KNUST	Kwame Nkrumah University of Science and Technology
NGO	Non-Governmental Organisation

CHAPTER 1: INTRODUCTION

1.1 Motivation

Over the years, Ghana has been experiencing an increase in the occurrence of Road Traffic Accidents (RTAs). This has largely been attributed to the increased number of motor vehicles on its roads, coupled with population growth in the face of economic development [1]. RTAs are a major cause of death worldwide, killing an estimated 1.3 million people every year, and leaving an estimated 20 to 50 million people injured [5]. According to media reports, Ghana's accidents rates are very high as compared to other developing countries, with an estimated 11,400 RTAs resulting in 1,800 fatalities and 14,000 injuries annually [2, 6].

The causes of road accidents in Ghana vary. Excessive speeding is reputed to be a major cause, accounting for about 60% of all reported crashes in 2010 [3]. Other causes include driving under the influence of alcohol, bad driving practices, bad vehicle maintenance practices, bad roads and road sign placements among others.

Over the years, Government and other stakeholders have been making efforts to address the country's accident problem. Notable is the establishment of National Road Safety Commission (NRSC) which has been running road safety campaigns since 2001 [7]. Others include the Motor Traffic and Transport Unit (MTTU), a division of the Ghana Police Service, which has the mandate of enforcing safe driving practices on the roads. It is worth noting that, most of these are road safety programmes are aimed at reducing the risks of accidents occurring. It seems little or no attention is given to programmes which aim at protecting occupants of vehicles in the event of a RTA.

Buses and minibuses are among the commonest forms of transport for many people in Ghana. In 2005, they accounted for over 35% of all reported road crashes in the country [4]. Most of these vehicles are imported into the country as used goods transport vans without seats for public passenger transportation. Local artisans fabricate seats to be fitted into these vehicles so that they can be used for passenger transportation purposes. Unfortunately, it seems little consideration is given to passenger safety during the design and fabrication of these seats.

1.2 Justification

There is a well-known hypothesis at the Accident and Emergency (A&E) Centre of the Komfo Anokye Teaching Hospital (KATH), Kumasi, that, some of the injuries sustained by RTA victims may be due to the nature of seats found in the vehicles involved. This seems to be the case especially when the accident vehicles have been fitted with seats fabricated by local artisans.

Seats and contact surfaces are very important in any passenger transport vehicle. Not only are they supposed to provide some level of comfort to passengers, but are also designed to help reduce the physical effects of accidents on vehicle occupants. Vehicle seats designed and fabricated locally however do not seem to serve these purposes. In addition, the Drivers and Vehicle Licencing Authority (DVLA) which inspects and issues Road Worthiness Certificates to vehicles, seems to lack specific criteria for evaluating these locally fabricated seats. Vehicle inspections are, therefore, largely limited to road worthiness checks. It is disturbing to note that, some of the most widely used passenger transport vehicles within the country, notably the 12 and 15 Seat buses as well as the Mercedes Benz 207 and Sprinter buses, are mostly fitted with these locally fabricated seats. However, no known research has established if the designs of these seats are safe for passenger transportation purposes.

The research sought to determine through computer simulations and collected data, if the design of locally fabricated vehicle-seats could compromise passenger safety in the event of an accident, and to make further research recommendations based on this and other findings.

1.3 Objective(s)

The main objective of the research was to determine if some of the injuries sustained by occupants of RTA vehicles can be attributed to locally designed vehicle-seats found in these vehicles.

Specific objectives include:

- Document local vehicle-seat designs found within the Kumasi metropolis.
- Establish the parts of occupant victims' bodies that predominantly sustain injuries in RTAs.
- Determine parts of the body that are prone to injuries from locally fabricated vehicle seats.

1.4 Methodology

- Information about local vehicle-seat designs was obtained through measurements and interviews with some artisans at the Kumasi Suame Magazine and Tech. Junction areas, all suburbs of Kumasi.
- The predominant parts of victims' bodies that sustain injuries in RTAs were obtained from data collected through Mini-Survey that was conducted at the A&E Centre of KATH, over a three month period.

- Parts of the body that are prone to injuries from these seats were obtained through a kinematic analysis that was carried out using Working Model 2D Software. This also helped determine parts of the seats that are most likely to contribute to injuries in the event of an RTA.

1.5 Scope of Work and Delimitations

The scope of this research was limited to the carrying out of a computer simulation to identify accident injuries that can be attributed to the design of locally fabricated vehicle-seats. The simulation results were compared with the results from a Mini-Survey conducted at the A&E Centre of KATH.

1.5 Thesis Organisation

The thesis is organised into five chapters. The first chapter gives an overview of the project with an introduction, justification, a list of the thesis objective(s), methodology, scope of work and delimitations and thesis organisation.

The second chapter gives a literature overview of RTAs, the types of injuries that can be sustained in RTAs, existing research that has been done in the field of vehicle occupant safety and known research designs used in RTA researches.

The description of the research design and the methods which were employed in the research, among other things are discussed in Chapter three.

Chapter four covers the results of the research as well as discussions of these results. The thesis ends with a fifth chapter which draws conclusions on the research and makes policy and further research recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1 Road Traffic Accidents (RTAs)

RTAs, also known by such names as Motor Vehicle Accidents, Auto Accidents and Car Crashes, can be described as situations where one or more vehicles are involved in a crash. It may involve stationary and moving vehicles, or moving vehicles only. Most fatal accidents occur on highways and involve vehicles travelling at high speeds. Common causes of RTAs include bad driving conditions such as poor visibility as well as bad roads and bad driving practices among other things.

Worldwide, RTAs are a major source of concern for all road users since they mainly result in damage to property, injuries and fatalities. RTAs are reputed to constitute about 40% of all accident types in developed countries and about 80% in some developing countries. Furthermore, RTAs are among the leading causes of death in the developing world [8].

RTAs can be grouped into three main categories namely collisions, rollovers and run-off-the-road accidents. Rollovers occur when a vehicle somersaults landing on its back, side or back on its wheels. Common causes of this type of accident include the loss of control at high speeds, especially in curves, a tyre bursting while the vehicle is moving at a high speed or a vehicle plunging down a steep embankment, somersaulting in the process. It can be a very deadly, especially for the occupants of the vehicle involved. Rollovers usually involve only one vehicle; the accident vehicle.

Run-off-road accidents, also known as road or lane departure accidents are single vehicle accidents that occur when a vehicle drifts, is maneuvered off or leaves the road before crashing. A large percentage of run-offs result in rollovers making them quite dangerous to occupants of the vehicles involved [48].

Collisions can be described as situations in which a vehicle crashes into another vehicle, pedestrian, animal, or any other stationary or moving obstruction in its path of travel. Collisions may involve one or more vehicles. Taking one of the vehicles involved in a crash as the vehicle of interest, collisions can be further classified as head on or front, rear, and side collisions.

Head on collisions are RTAs in which the front of a vehicle of interest crashes into the front of another vehicle, or a building or tree. It is one of the commonest types of RTAs and can have very serious consequences. Head on collisions can involve vehicles travelling in opposite directions in the same lane.

Rear-end collisions occur when another vehicle crashes into the rear of the vehicle of interest, or the vehicle of interest crashes into something while reversing. They commonly occur at night and in other poor visibility conditions, when one vehicle suddenly stops and the one behind fails to stop. It a common form of RTA on dual lanes where tailgate is common.

Side impacts occur when a vehicle of interest is impacted on its side either by an object as a result of uncontrollable skidding on the part of the vehicle, or by another vehicle, often at intersections.

2.2 RTA Injuries

RTAs normally result in damage to property, fatalities and injuries. An estimated 20 to 50 million people are left with RTA injuries worldwide every year [5]. Available records from the NRSC indicate that the country recorded over 7000 injury related RTAs in 2007, leaving over 14,000 victims with varying degrees of injuries [9].

In a collision, an unrestrained occupant of a vehicle continues to move as the vehicle comes to an abrupt stop. This forward motion is arrested as the patient connects with parts of the stationary vehicle, resulting in injuries, which can be anything from small cuts to the body, to skull and spinal cord injuries. In front collisions, typical injuries include fracture/dislocation of the ankles, knee, pelvis and the femur. Injuries to the head, cervical spine and torso may also occur. Injuries from rear impacts are mostly neck injuries [10]. RTA injuries can be classified as Soft Tissue Injuries and Fractures and Dislocations, also known as Hard Tissue Injuries.

Soft Tissue Injuries

A Soft Tissue Injury (STI) can be described as damage to muscles as well as ligaments and tendons which hold bones together. STIs can occur from overuse of a particular part of the body or a direct or indirect trauma to muscles, ligaments, and joint capsules. Usually, direct trauma refers to an injury occurring from blunt force or a sudden overload. Soft tissue injuries can result in pain, swelling, and often bruising [11, 12].

Hard Tissue Injuries (Fractures and Dislocations)

Fractures or bone fractures as they are also known can be described as a disruption in the continuity in a bone structure [13], which may either be traumatic or pathologic. A traumatic fracture which is typical of accident victims occurs when external forces being imposed on a bone are more than what the bone can withstand. This damages the bone structure which results in a fracture. Fractures may also occur as a result of medical conditions which weaken the bone structure, in which case they are referred to as pathologic fractures. Some of these medical conditions include Osteoporosis, some cancers, tumors and Osteogenesis Imperfecta (also known as brittle bone disease), a genetic disorder [47].

Fractures can also be open or closed. Fractures are termed closed when the broken bone fragments do not penetrate the skin. With open fractures on the other hand, the fractured bone is exposed to the environment, either as a result of the bone fragments piercing the skin, or the impact object cutting the skin deep enough to create an open wound that exposes the bone. Open fractures are mostly sustained in traumatic and crushing injuries, which are consistent with RTAs. Open fractures are generally considered more dangerous than closed fractures since they run the risk of infections [14, 15, 16, 17, 18].

Dislocations are joint injuries that occur as a result of the separation of two bones at a joint. Dislocations are normally as a result of a sudden impact force to a joint. This puts a lot of force on ligaments, (soft fibrous tissues that connect bones and cartilage), allowing the ends of two connected bones to separate. Figure 2.1 shows the various joints in the body. These joints are potential areas of dislocations in an accident [19].

2.3 Occupant Safety Research

In view of the numerous RTA related deaths and injuries which have proven to be very costly worldwide, efforts have been made and are still being made to reduce the occurrence of these deaths and injuries. There have been suggestions that the RTA problem should be approached as an epidemiological problem with the aim of controlling hosts (victims), agents (vehicles) and environmental factors (driving conditions) [8]. Epidemiology can be defined as the study of the distribution and determinants of disease frequency in human populations and the application of this study to control health problems [20].

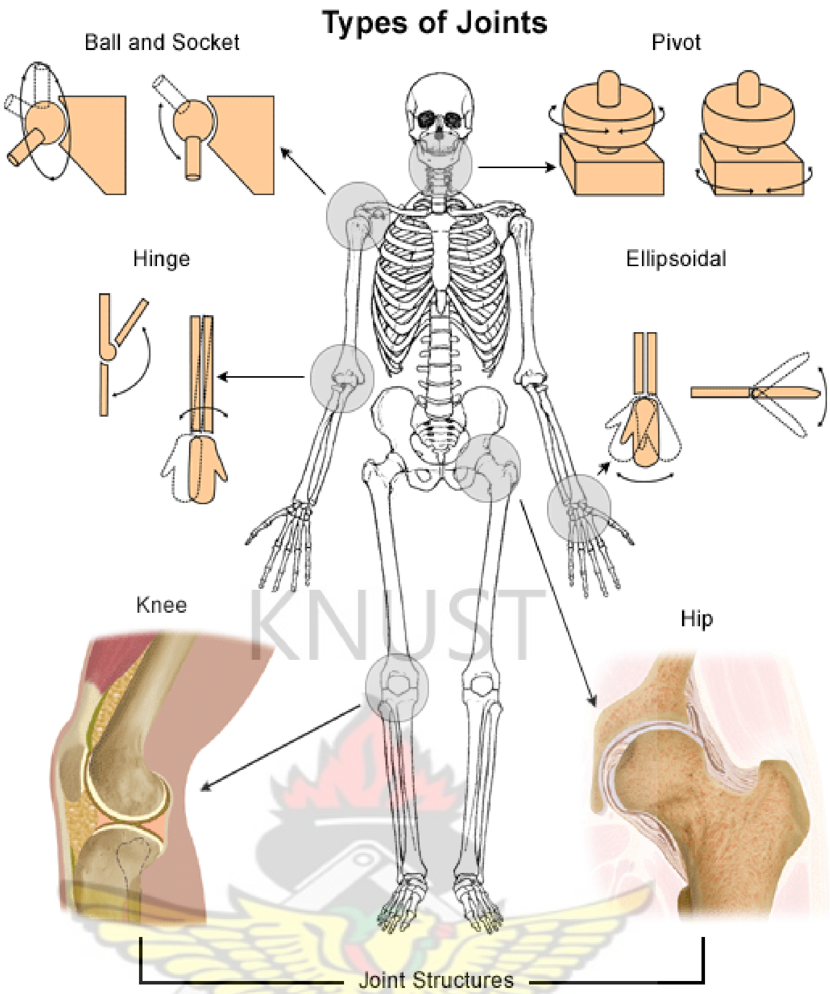

Figure 2. 1: Joints and Potential Dislocation Points on the Human Body [19].

Some of the efforts aimed at controlling the three factors above have been in the areas of Road and Occupant Safety. Road safety primarily focuses on reducing the risk of an accident occurring with the aim of preventing it from occurring altogether. This approach seems the most widely used in the developing world, where the RTA problem is more rampant and severe [21]. Road safety improvement measures have included the provision of better and safer roads with the right road markings, traffic lights and guard rails where they are required, just to mention a few. Enforcement of good driving practices is also a step in this direction.

The RTA issue has also been addressed through the improvement of vehicle safety.

One very important field in this area is vehicle crash worthiness. The Crash worthiness of a vehicle may be defined as the vehicle's ability to protect its occupants in the event of a crash [22]. Efforts to improve the crashworthiness of road vehicles have proven to be very successful over the years. Initial efforts have resulted in the development of protective systems such as seat belts and airbags, which have been proven to considerably reduce the risks of injuries in RTAs [23]. Restraints reduce the risk of impacts between body parts and the vehicle interior, reducing the risk of injuries. It is to this end that seat belts were developed to keep occupants in their seats during accidents. Airbags offer better protection in the event of the seatbelt providing insufficient or no restrain for the occupant.

The problem of occupant injuries is also being addressed through vehicle seat designs. The seats, like other components in the vehicle, are very important. This is because passengers spend most, if not all of the duration of their journeys sitting in them. And in the event of an accident, an occupant would be most likely seated. Vehicle seats are supposed to serve two primary purposes: occupant comfort and occupant safety. Researches aimed at satisfying these two requirements have been done. A notable research on occupant comfort came out with various recommendations for vehicle seat design. These included fit parameters (dimensions), feel parameters (cushion patterns, backrest patterns among others) as well as support parameters [24]. Anti-submarining safety pans and lap-belts have also been developed to safeguard against submarining (the tendency of a passenger to slide under the dashboard or seats in front of him during a front impact).

Researches have also been conducted on some of the already existing occupant protection systems, seatbelts for instance. This was in response to the realisation that some RTA abdominal and chest injuries are caused by the excessive loading of the seatbelts during accidents [25, 26]. The outcomes of these have been the development of the Pre-Tensioner and Force Limiter for vehicles. The Pre-Tensioner tightens the seat belt at the onset of a crash, whiles the Force Limiter prevents it from tightening beyond a certain limit by allowing more slack in the belt when necessary.

Researches into occupant safety are still on-going. Academic and research institutions, automobile and aircraft design and manufacturing companies as well as individuals are conducting researches that focus on such areas as injury mechanism, occupant response to impacts, the human body tolerance to impact forces experienced during accidents, rear seat occupant safety, child occupant protection technologies and assessments of existing occupant protection technologies [27, 28].

2.4 Research Design

A research can be defined as a study undertaken within a framework of a set of approaches using procedures, methods and techniques that have been tested for their validity and reliability [28]. A very important part of every research is the approach adopted in conducting the research, also known as the Research Design. Among other things, the research design determines the kind of information or data that will be required and to some extent, the data collection methods that should be used in getting this data.

Varied designs are employed in RTA researches. A common approach is to make a general inference about accidents using results from the analyses of accident data collected through surveys. A survey is basically a research tool that seeks to gather required data from a certain number of participants deemed to be representative of a whole population and use the data gathered to draw inferences about that population. A very important part of a survey is the determination of a sample size; the number of participants to be involved in the survey. This is done using statistical calculations.

A survey may be a full survey (which is most popular) or a Mini-survey. Mini-surveys are conducted on small scales and concentrate on recording few variables, using a small sample size. One of its most important characteristics is the small sample sizes required, which are normally between 25 and 70 [29]. Mini-surveys are used over full surveys when there is a lack of enough information about the population to be able to determine an appropriate sample size and inadequate resources among other reasons [29].

Early researches into occupant safety adopted an experimental approach. Sled tests were performed with dummies to get an understanding of occupant behaviour during accidents. Results from these experiments were then used to validate or invalidate proposed hypotheses. This approach obviously, is time consuming, expensive and is prone to inconsistent results, the failure of the dummies to correctly mimic real human behaviour, among others. With the advent of the computer, mathematical models of RTA scenarios have been developed. The first softwares of this nature included the MVMA2D and the CAL3D model also known as the Crash Victim Simulator [23]. At the moment, the most popular accident simulation software seems to be MADYMO®. Evaluations of computer simulations of RTAs have been done by various researches and results have proven to be satisfactorily accurate. Computer simulation is therefore a very popular research tool in occupant safety research and accident investigations, because it is less time consuming and less expensive.

2.5 RTA Research in Ghana.

RTA research in Ghana has not advanced as in the developed countries. It seems most of these researches are conducted by the NRSC and a few NGOs and individuals, and primarily focus on trying to establish the accident situation within the country through the conducting of surveys. Others focus on determining the causes of accidents. There are few, if any researches on occupant safety.

CHAPTER 3: METHODOLOGY

3.1 Research Design

The research was designed to support the hypothesis that, locally fabricated vehicle-seat designs are responsible for some of the injuries sustained by occupants of RTA vehicles. Results from a computer simulation and a mini-survey were used in the research. The computer simulation helped determine parts of the human body that are prone to injuries from the locally fabricated vehicle seats, while the mini-survey helped determine the actual parts of the body that normally sustain injuries in RTAs involving vehicles with these seats.

3.2 Sources of Information

Available information was reviewed to get a familiarisation of the various RTA types and injuries, and relevant researches that have been done on vehicle occupant safety. Sources of information included articles and books from the KNUST Main and Engineering libraries, as well as the internet.

Information about locally fabricated vehicle-seat designs was obtained through measurements and examinations of seats found in some public transport vehicles within the Kumasi metropolis. Interactions with some hesitant local artisans, who fabricate these seats, also yielded some information. Information sought from these interactions primarily included;

- The various kinds of locally fabricated vehicle-seat designs used in public transport vehicles.
- Dimensions of various kinds of seats
- Materials and fabrication methods used in the fabrication of these seats and the basis for selecting these materials and methods.

3.3 Research Tools and Methods

Mini-Survey

A Mini-Survey was conducted at the A&E Centre, KATH, to determine the predominant injury points of occupants of RTA vehicles. The mini-survey was most appropriate for this research, primarily because of a lack of enough information, to determine an appropriate sample size for a full survey [29]. Besides, access to accident victims at the hospital was somewhat limited. As a result, conducting a full survey would have been very difficult given the limited time and resources among the other limitations that were realised.

The survey was designed to gather information which included the height and locations of injury occurrences of victims, the type of vehicle the victims were in when the accident occurred and the type of accident the vehicle was involved in. The survey was conducted between November 2011 and January 2012, through the administration of a questionnaire on patients in some of the wards at the centre. A copy of the questionnaire and a summary of the gathered data can found in the Appendix. Data was taken from 31 participants who were limited to victims of the 12 and 15 Seat as well as the Mercedes Benz 207, Sprinter and 30 plus Seat capacity buses, since these are the vehicles that predominantly use these seats. STATA Data Analysis and Statistical Software was used to analyse the recorded data. Results of the analysis are available in the Chapter 4.

Computer Simulation

The potential injury places for occupants of vehicles involved in RTAs were determined through a computer simulation using Working Model 2D. It is primarily used for motion simulation and permits the modelling of objects as simple 2-

dimensional figures to which various constraints agreeing with real world conditions can be applied. Upon simulating, the objects move in response to the conditions that have been specified.

The simulation was basically a kinematic analysis of the human occupants in in relation to the seats in a vehicle when it is involved in a RTA. The aim was to determine how the body behaves as a result of its posture (which is largely determined by the seat), before an impact, and the areas of the body that contact the seats during and after the impact. Since it was a kinematic analysis, the magnitudes of the speeds of the vehicles involved in the impacts, as well as their masses were not considered [32]. The dummies were modelled as rigid bodies and it was also assumed that the seats remain attached to the vehicle floor and are not damaged during or after the accident.

The simulation required the modelling of a vehicle with seats occupied by human beings. Vehicle dimensions were approximated from vehicle brochures. The seats and the spacing in between them in vehicles were modelled with the dimensions obtained from the interactions with seat fabricators at Suame Magazine, as well as measurements of randomly selected seats in some public transport vehicles at Tek Junction and Kejetia Lorry Park, in Kumasi. The human occupant modelling required the dimensions of some parts of the human body, such as the length of the forearms, arms, torso, thighs, legs, neck and head.

To determine these, the 5th percentile of the heights of the survey participants was determined. This eliminated the heights that were not typical of the other heights taken. An average of the heights that fell above this value was taken. The required dimensions were calculated using the relative human body length proportions provided in literature.

The 5th percentile was determined using the Nearest Rank Method [33, 34]. The method requires the set of values whose percentile is to be determined to be arraigned in an ascending order. The position,

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Locally Fabricated Vehicle-Seat Designs

Locally Fabricated Seats are mostly of the bench type, designed to accommodate more than one occupant. They lack some basic features such as seatbelts, anti-submarining pans and headrests. A seat basically comprises a metal frame fabricated from mostly galvanised steel pipes, to which plywood of about 2 cm thickness is attached to complete the base and backrests. The base and backrests are padded with foam and then covered with synthetic leather. Frames for the Mercedes Benz 207 and Sprinter bus seats sometimes have a more elaborate backrest framework with what seems like an attempt to make a separate backrest for each individual intended to occupy the seat, as can be seen in Figure 4.2. They are also generally higher off the ground in contrast to the 12 and 15 Seat bus seats, which have a wide backrest for all occupants of a seat and are lower off the ground. The seats for the Mercedes Benz 207 and Sprinter buses also have longer backrests as compared to their 12 and 15 Seat bus counterparts. Figures 4.1 and 4.2 show seat frames intended for 12 and 15 Seat and Mercedes Benz 207 and Sprinter buses respectively. The white dotted arrows indicate the rear connecting member of the base, which is normally not padded.

The seats come in two varieties depending in how access is gained to the seats at the rear of the vehicle. Sometimes, a smaller seat is found in the middle or at the left end of all but the seat for the last row of passengers. These seats' backrests can be folded down and the folded backrest and base, creating a walk-way that permits easy embarking and disembarking of passengers. Other times these foldable seats are eliminated, and a walk-way created almost in the middle of the bus for easy embarking or disembarking from the vehicle. This second variety of seats (without foldable middle or left-end seats) are mainly used in 12 and 15 Seat buses and are as shown in Figure 4.4.

Figure 4. 1: Frame for the 12 and 15 Seat Bus Middle Seat

Figure 4. 2: Frame for the Mercedes Benz 207 and Sprinter Bus Rear Seat

Figure 4. 3: 15-Seat Bus Seats with Temporal Walk-way at One Side

Figure 4. 4: Seats Permanent walk-way in a 15-Seat Bus

With the exception of mainly 12 and 15 Seat buses, the use of foldable seats reduces the number of passengers a vehicle normally carries. It is believed this is the main reason why the foldable seats are only normally used in vehicles that ply long routes.

Table 4.1 gives the overall dimensions of these seats. Figure 4.5 shows the various dimensions. The spacing between the rows of seats, (measured between two backrests) averaged 60 cm in a lot of cases.

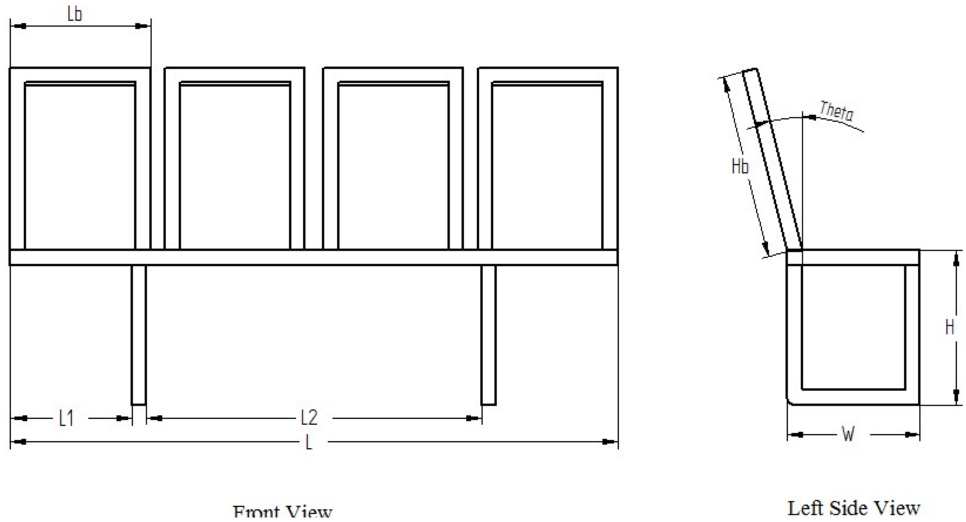

Figure 4. 5: Seat Dimension Locations

Table 4. 1: Approximate Seat Frame Dimensions (Dimensions generally vary from artisan to artisan and vehicle to vehicle)

Vehicle	Seat type	L	L1	L2	Lb	W	H	Hb	Theta*
207/ Sprinter	Back Seat	163	36	83	39	36	45	59	14^o
	Other Seats	158	36	78	39	36	45	59	14^o
12/15	Back Seat	127	25	94	127	36	40	50	14^o
	Middle double seats	82	0	55	82	36	40	50	14^o
	Middle single seats	38	0	38	38	36	40	50	14^o
	Seat behind driver	110	20	82	110	36	40	50	14^o

*** With the exception of Theta (in degrees), all other dimensions are in cm.**

It must be noted that most of these dimensions do not conform to what are specified in some accepted standards. The United Nations Economic Commission for Europe (UNECE), for instance specifies spacing in between seats as a minimum of 68 cm, and researches have recommended that, it is increased to at least 73 cm [49]. It also specifies the backrest inclination angle to be about 20^o [50]. The Australian Department of Transport and Regional Services also recommends the length of a seat backrest for adults be at least 70 cm [51].

4.2 Analysis of Collected Data

An analysis of the collected data is presented in the form of bar charts generated with the STATA Data Analysis Software.

The predominant RTA type among victims was Front Impacts with more victims coming from 207 and Sprinter buses as indicated in Figures 4.6 and 4.7.

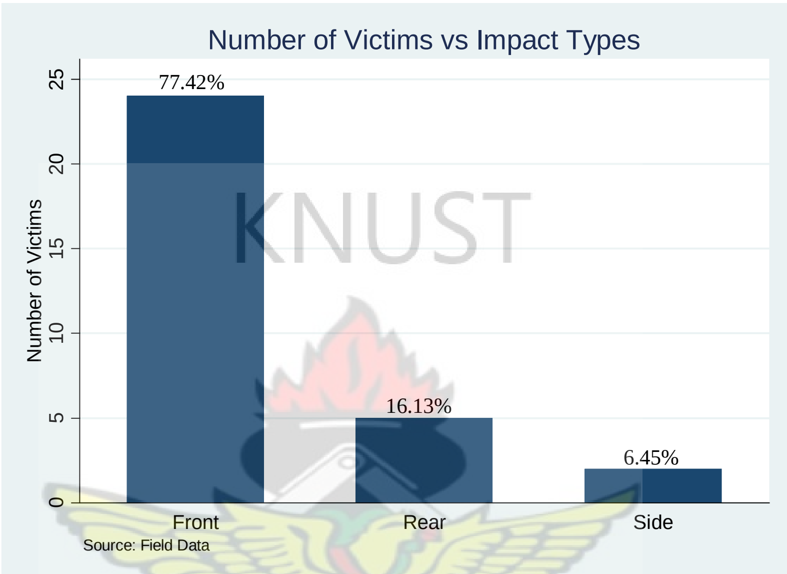

Figure 4. 6: Accident Victims Distribution (with respect to Impact Type)

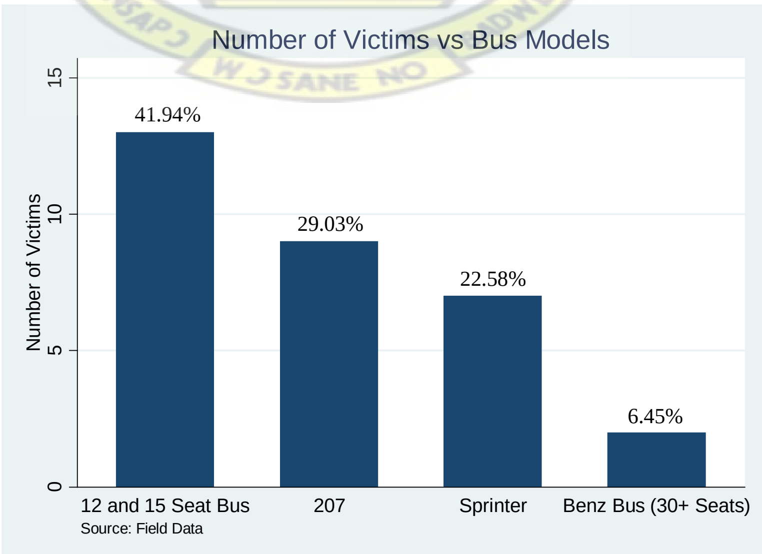

Figure 4. 7: Accident Victims Distribution (with respect to Minibus Model)

Eighty-four (84) injury occurrences were recorded out of which thirty-three (33) were HTIs. A high number of these injuries, both STIs and HTIs, were sustained in the leg, with a majority of these injuries being sustained in Front Impacts as illustrated in the charts in Figures 4.8 through to 4.11. Other areas of interest in which injuries were sustained included the pelvis.

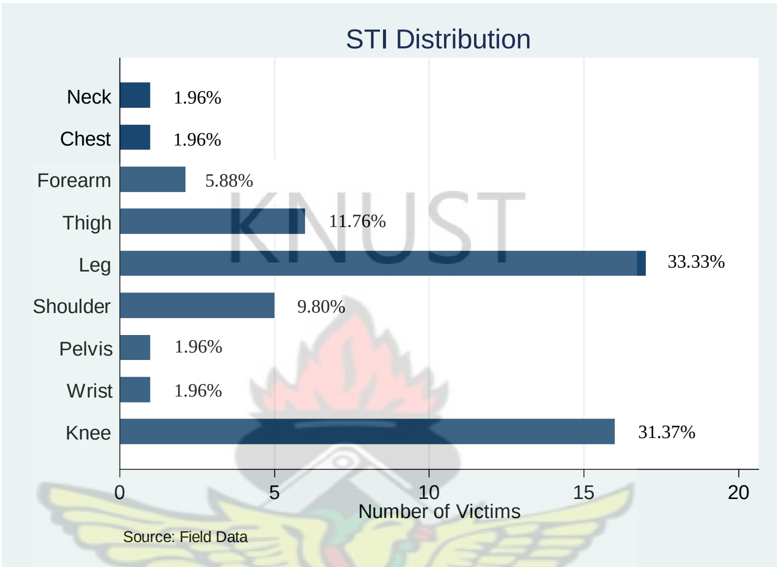

Figure 4. 8: STI Distribution

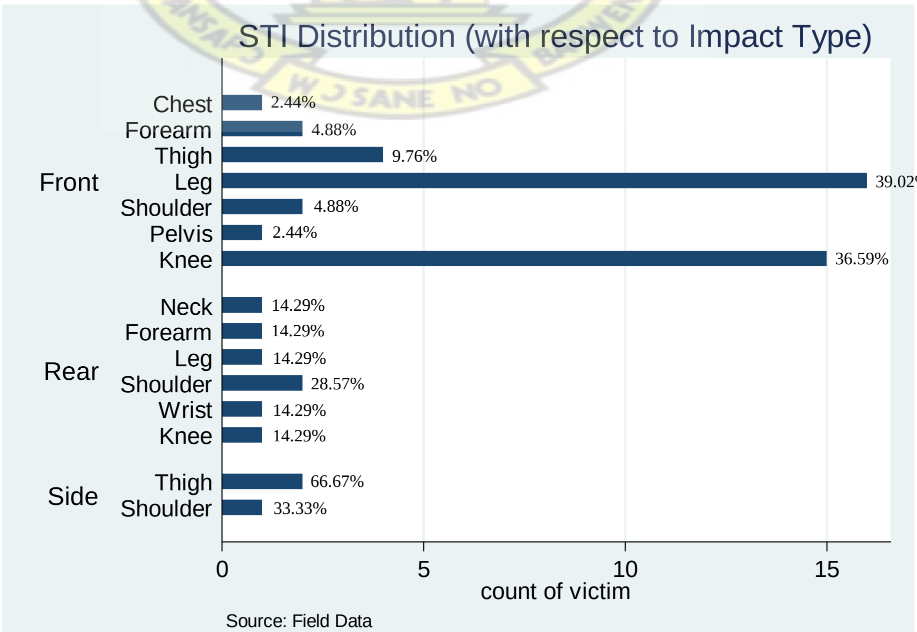

Figure 4. 9: STI Distribution (with respect to Impact Type)

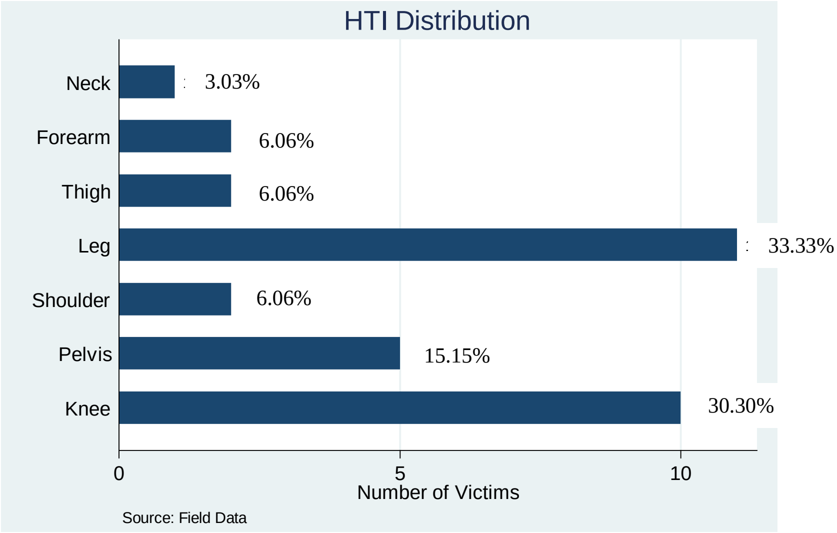

Figure 4. 10: HTI Distribution

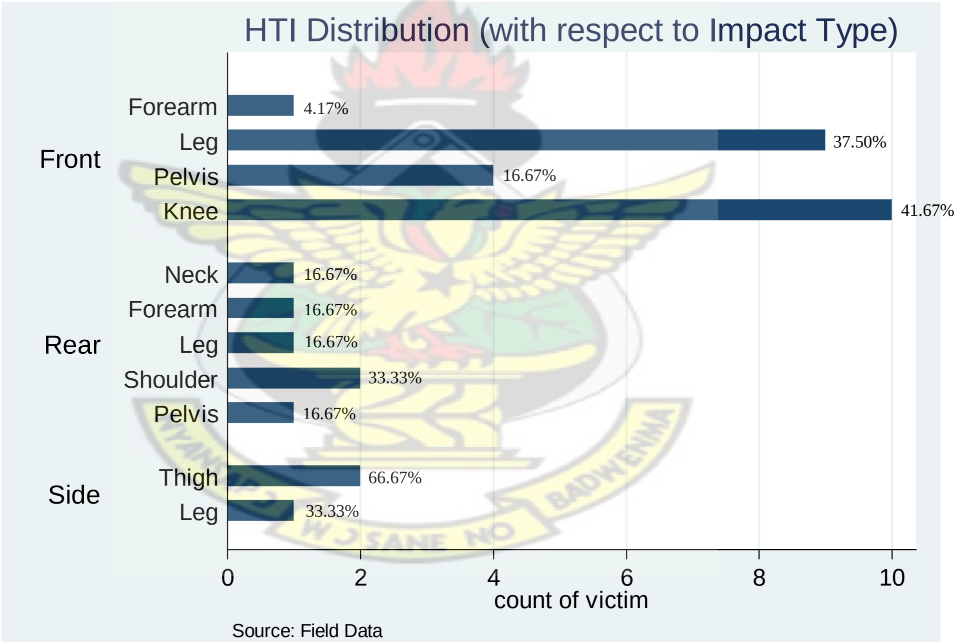

Figure 4. 11: HTI Distribution (with respect to Impact Type)

4.3 Average Height Calculations

Arranged recorded heights (all heights are in cm):

124, 148, 150, 150, 152, 152, 155, 156, 156, 157, 157, 158, 159, 160, 160, 160, 162, 164, 165, 166, 167, 169, 170, 173, 174, 174, 176, 176.

From equation (3.1), the position of the height corresponding to the 5th percentile, is

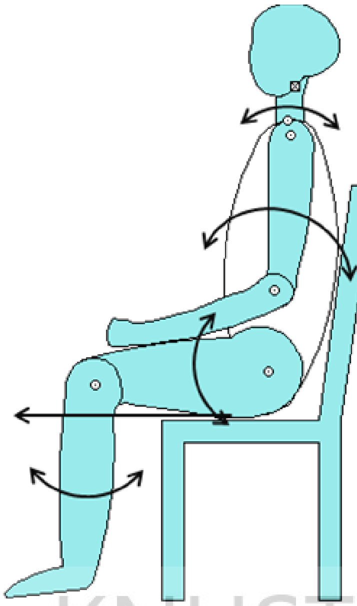

Figure 4. 12: Possible Motions Experienced by Occupant in Front End collisions

Front Impact Simulation

The Front Impact was considered in 4 stages. The first stage is as shown in Figure 4.13, indicating the sitting posture of occupants of a vehicle before impact.

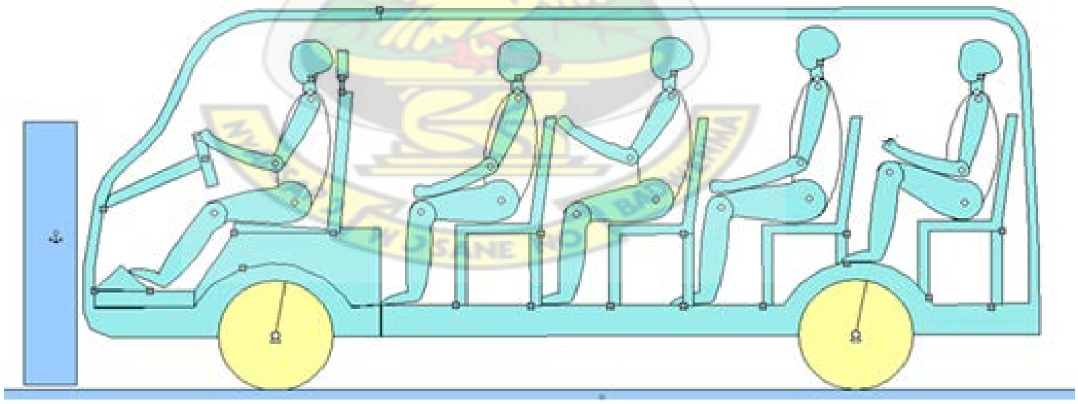

Figure 4. 13: Before Impact

The second stage is when the vehicle itself impacts the obstruction in its path. As shown in Figure 4.14. It is realised the passengers of the vehicle start sliding forward as a result of their inertia when the vehicle starts slowing down before the impact.

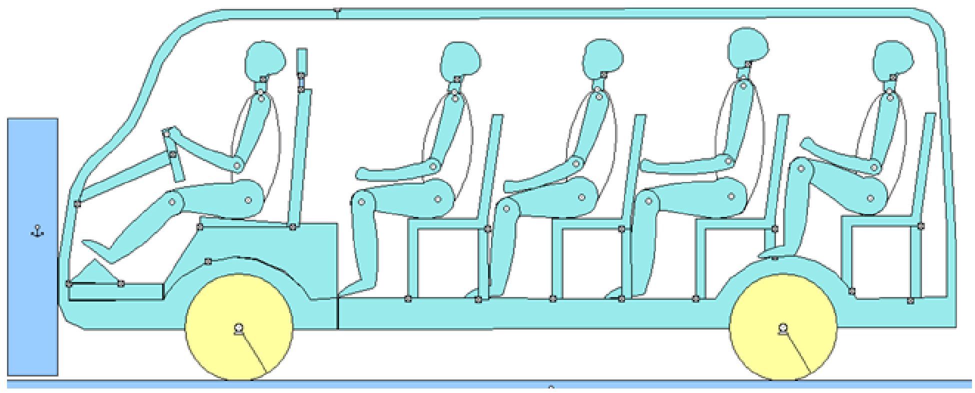

Figure 4. 14: Vehicle Impact

The third stage is when the occupants experience the impact, hitting the seats and other contact surfaces in front of them. This is indicated in Figure 4.15. Note the arrows indicating the areas of impact between the legs of occupants and the seats. Occupants' legs normally impact the lower rear connecting member of the seat (indicated by white broken arrows in Figures 4.1 and 4.2), which is normally unpadded.

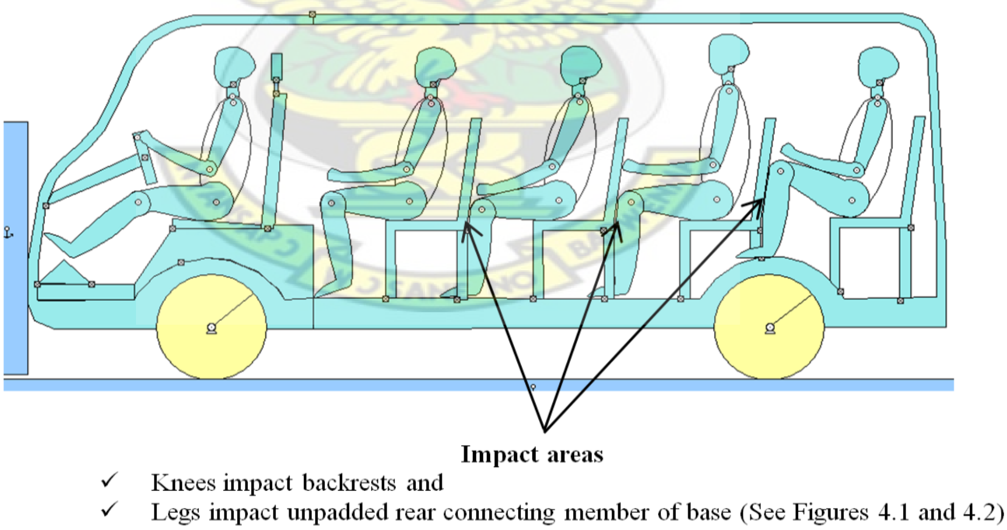

Figure 4. 15: Occupant Impact

The force of this impact halts the forward movement of the lower part of occupants' body, whiles the upper part of the body continues moving forward, resulting in a secondary impact between the body and the top of the backrest in front as shown in

Figure 4.16. Depending on the height of the victim, this second impact may involve the chest, neck or head regions resulting in injuries in these areas.

The passengers immediately behind the driver may sustain the most serious injuries since they normally impact part of the vehicle frame itself underneath which the engine is placed (for some 12 and 15 Seat Buses).

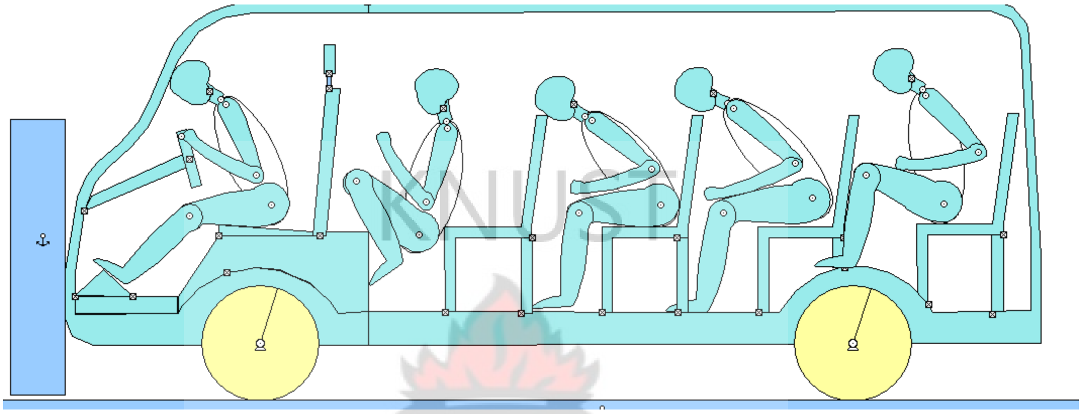

Figure 4. 16: Secondary Occupant Impact

Rear impacts

Figure 4.17 shows occupants' positions before a rear impact occurs.

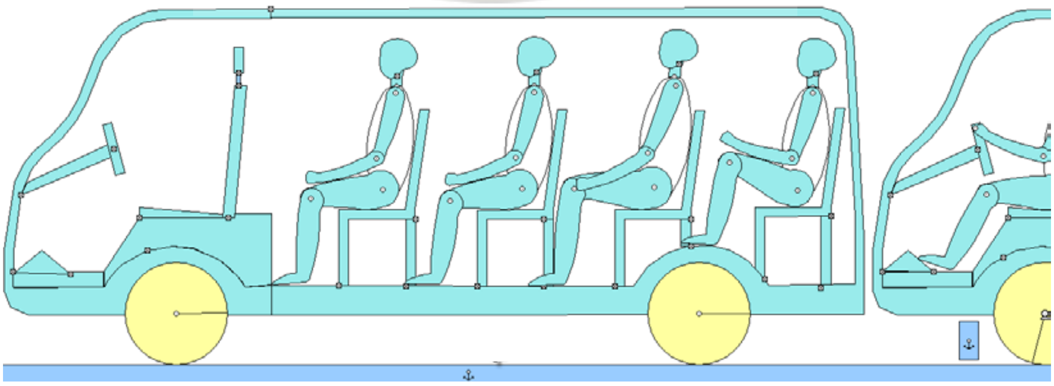

Figure 4. 17: Before Rear Impact

The sudden jerk experienced in rear impacts results in the upper and lower parts of the body being propelled forward, with the exception of the head and neck which end up appearing to be thrown backwards as shown in Figure 4.18.

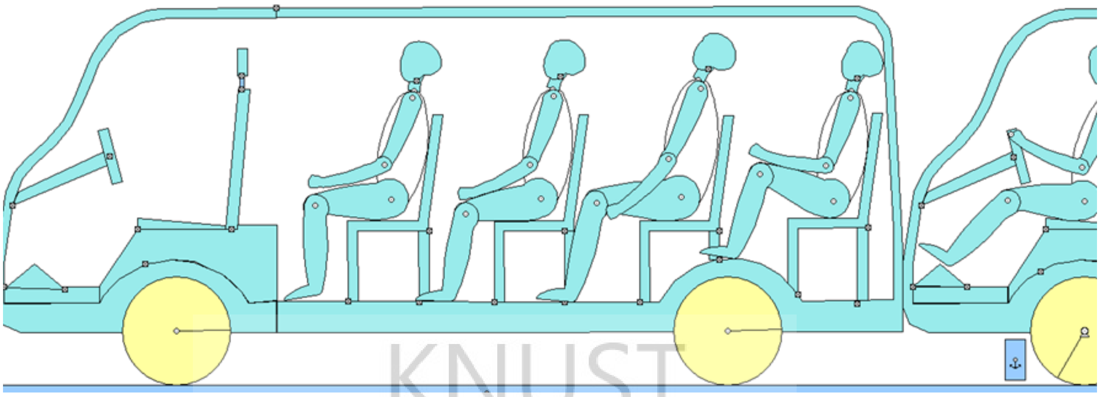

Figure 4. 18: Vehicle Impact

The forward motion of the body continues till the knees and legs hit the seats in front as shown in Figure 4.19 since there are no restrains to arrest this motion.

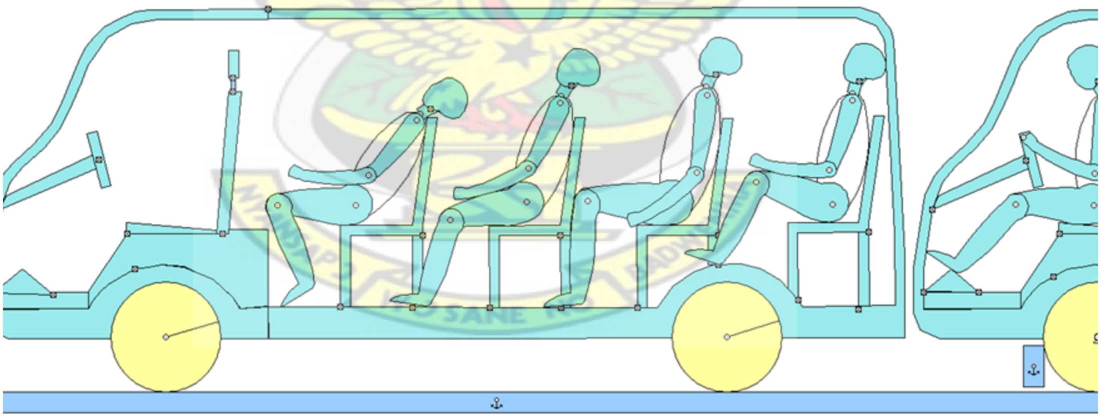

Figure 4. 19: After Vehicle Impact

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The basic aim of the study was to relate some of the Road Traffic Accidents injuries to locally fabricated vehicle-seat designs using results from a computer simulation and a survey conducted at the A&E Center of KATH.

It was realised from the simulation that, during Front Impacts, occupants of vehicles with locally fabricated seats are most likely to impact the rear connecting member of the seat base in front of them. This connecting member unfortunately, has no padding. As such occupants of these seats are likely to suffer from knee dislocations and leg fractures. Also, the transmission of the impact forces directly through the occupants' thighs (due to the posture of victims as a result of the height of the seat bases from the ground) can result in femoral fractures and pelvis dislocations. These were supported by the analysed data as presented in Figures 4.9 and 4.11, which indicated that majority of front impact STIs and HTIs, were recorded in the legs and knees with some injuries also being recorded in the pelvis.

Rear impacts, it was realised will most likely result in neck injuries. Even though the knee and legs also experience some impact, these are not likely to result in any serious injuries since the forces of impact will be small. The small number of victims recorded for rear impacts made it difficult to verify this finding.

So, from the findings it was realised that some accident injuries, especially knee and leg injuries (which were predominant), can be attributed to the design of these seats. As such, it can be concluded the locally fabricated vehicle-seat designs do compromise occupant safety in accidents, supporting the hypothesis of the Medical Practitioners at the hospital.

5.2 Recommendations

Based on the findings, the following are recommended:

- Criteria for the evaluation of vehicle seats, as well as occupant safety in general, should be developed and enforced by the DVLA and the MTTU of the Ghana Police Service.
- There is also the need for the design of the seats to be examined with emphasis on the rears of the seats, as well as their heights from the ground. The member of the seat base frame should be repositioned forward. A recommended design is shown in the Appendix.

  The sides of the recommended frame design could be fabricated from one long pipe that can be bent to the desired shape. This would permit shifting of the rear connecting member of the base forward without compromising the strength of the frame. In addition, the seats should be made shorter by a reduction in height of the base from the ground. This would change the seating posture of occupants, elevating their knees. The elevated knees will help in dissipating the impact forces that should be transmitted through the thighs to the pelvis. A simulation supporting this is in the Appendix, where it is realised the occupants' legs appear to be thrown upwards soon after occupant impact.

  Instead of using wood for completing the backrests, plastics should be considered since they can be flexible and help dampen the impact force, thereby reducing its effect on the knees and pelvis.

  Padding for the seats should be improved with the use of thicker and firmer foams, and the seat coverings should be made from a material that can offer a better resistance to the sliding motion of occupants, as compared to what the leather coverings used offer.

Safety features such as seatbelts, backrests and anti-submarining pans should also be incorporated in the design of these seats.

- The spacing between the seats is something that also requires scrutiny. As was stated earlier, the current seat spacing is below what is specified in some known accepted standards and these are even in the process of being revised upwards. A larger leg room as a result of increased seat spacing can affect sitting posture reducing the likelihood of hip injuries which are considered more life threatening as compared to leg and femoral fractures. Also the increased spacing increases the distance the body has to move through before impacting the next seat, reducing the likelihood of injuries in low speed impacts. A simulation supporting this is in the Appendix, where, as at the time of the vehicle impacting, the occupants are not close to impacting the seats themselves unlike the case of simulations with closely spaced seats where occupant occurs soon after vehicle impact. The seat spacing therefore needs to be optimised.
- Further studies should be carried out to ascertain the effects of these seats on passengers in side impacts, and the prevalence of the accident injuries due to seat designs in the country. These researches should be wider in scope and make use of accident simulation softwares, such as MADYMO or CRASH, or better still, accident dummies, for more accurate results. Also there is the need for more injury data to be collected and analysed to ascertain the injury trend observed in this study.

- An evaluation of the seats also needs to be carried out to determine if they meet internationally accepted safety standards.

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APPENDIX

Questionnaire

DATA SHEET

Date: ………………………..   Height of Victim: ……………………..

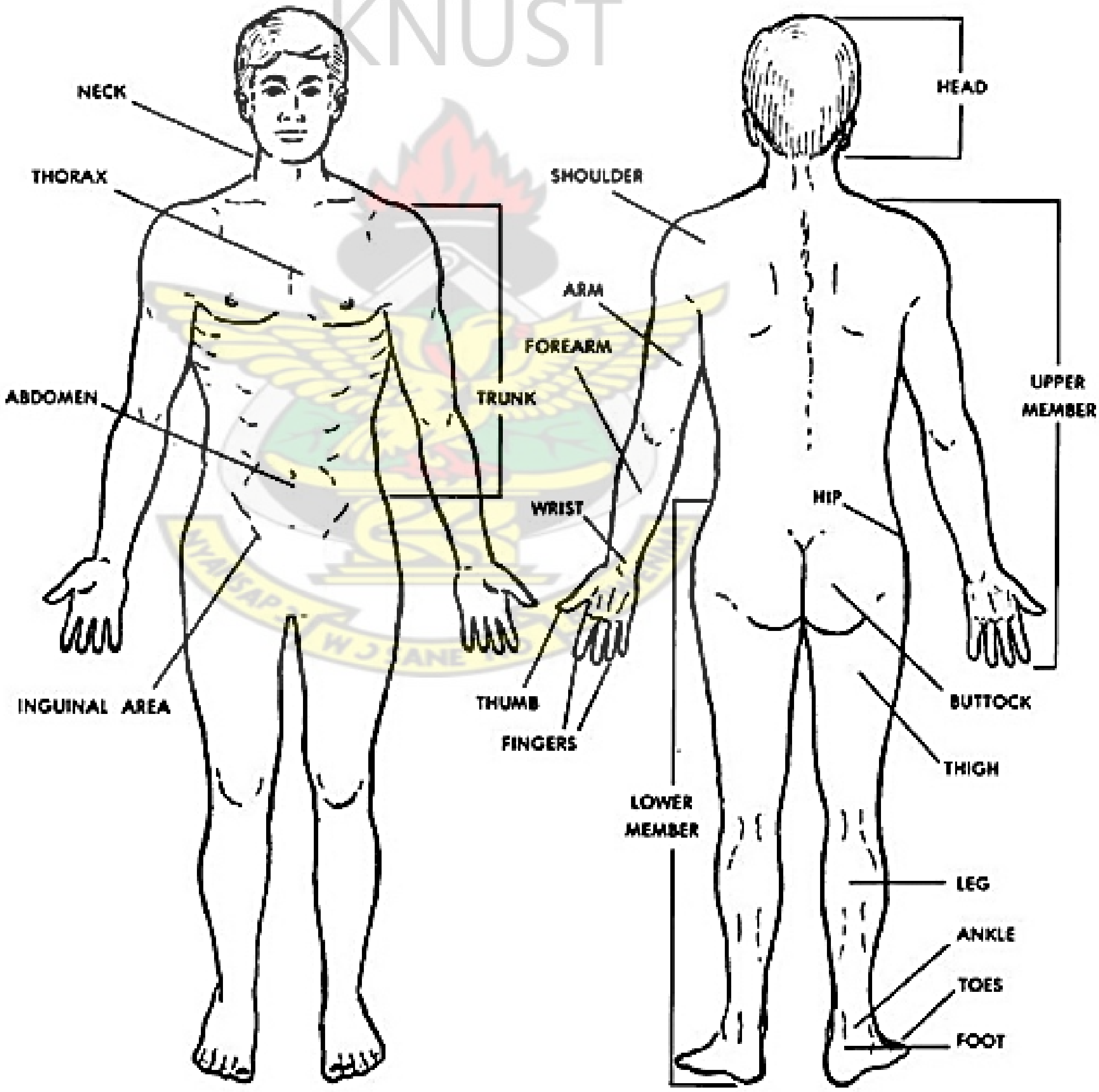
Vehicle Type: [15 or 12 Seater bus] [207] [Sprinter] [Benz Bus] [Other]   (Pls cross appropriate one)

Type of accident: [Head on Impact] [Side Impact] [Rear Impact] [Other]   (Pls cross appropriate one)

Position in vehicle at time of accident: [Front row of seats] [Other]   (Pls cross appropriate one)

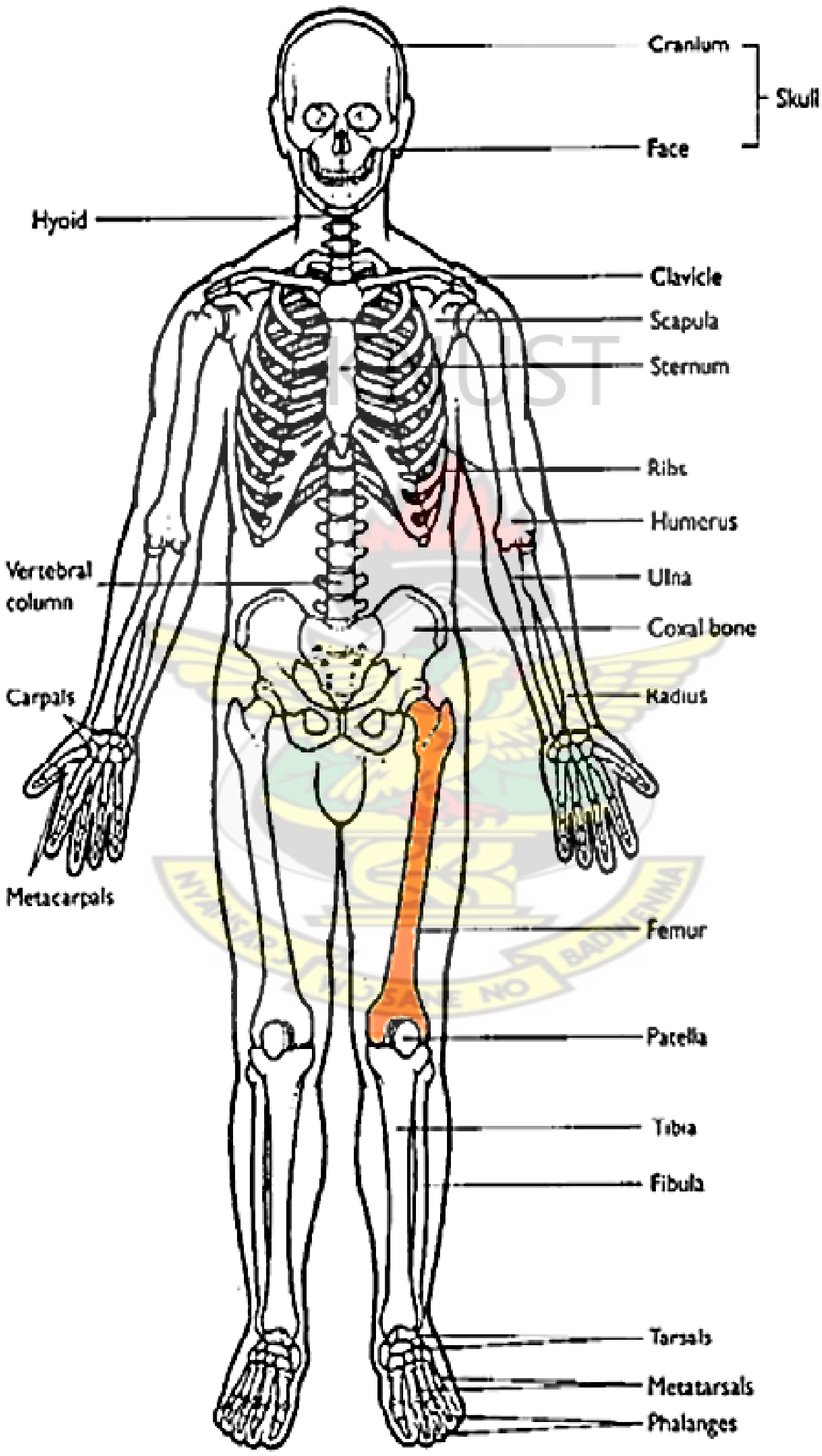
Injuries

Mark out places of injury on the diagram below.



Fractures and Dislocations

Mark out places of fracture and/or dislocations on the diagram below

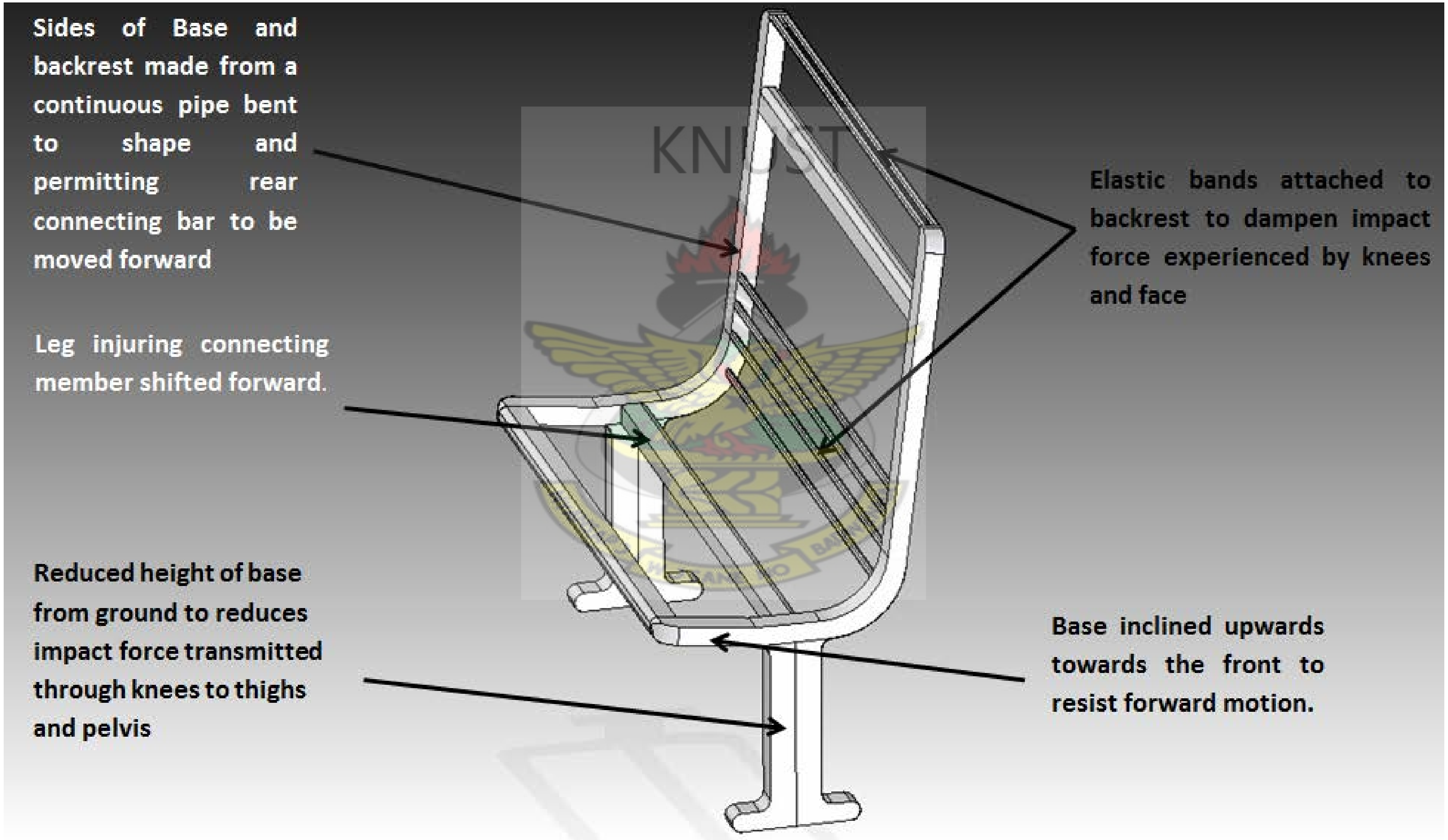


Summary of Collected Data

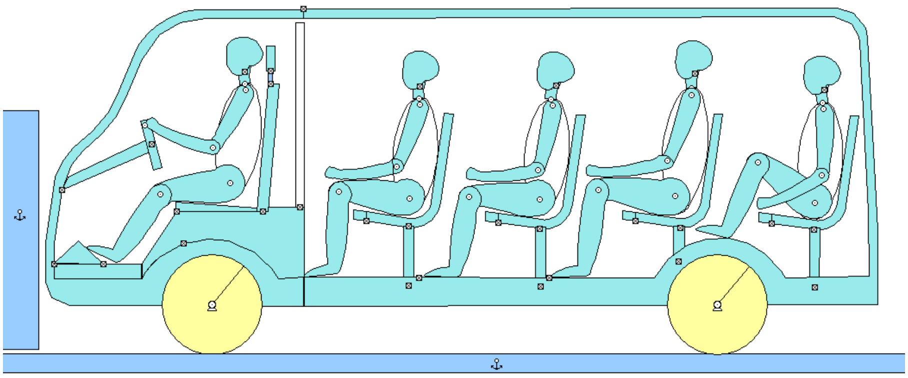
Victim No.	Height	Accident Vehicle	Accident Type	Soft Tissue Injuries	Hard Tissue Injuries
1	124	12/15 seat	Side	Thigh	Thigh
2	148	12/15 seat	Front	Chest	Forearm
2				Forearm	
2				Leg	
3	157	Sprinter	Front	Knee	Knee
4	152	12/15 seat	Front	Pelvis	Pelvis
5	176	12/15 seat	Front	Leg	Leg
6	160	Sprinter	Front	Knee	Pelvis
6				Thigh	
7	150	12/15 seat	Front	Leg	Leg
7				Thigh	
8	156	207	Front	Knee	Pelvis
9	174	12/15 seat	Front	Knee	Knee
10	159	Sprinter	Front	Leg	Knee
10				Knee	
11	157	Sprinter	Front	Knee	Knee
12	162	Sprinter	Front	Knee	Knee
12				Leg	
12				Thigh	
13	152	207	Rear	Shoulder	Shoulder
13				Forearm	Forearm
14	176	207	Side	Shoulder	Thigh
14				Thigh	Leg
15		207	Front	Knee	Knee
16	167	Benz Bus	Rear	Knee	Pelvis
17	169	Benz Bus	Rear	Leg	Leg
18	170	207	Front	Leg	Leg
19	166	207	Front	Leg	Pelvis
19				Knee	
20	174	12/15 seat	Front	Leg	Leg
21		207	Front	Forearm	Knee
21				Knee	
22	165	12/15 seat	Front	Shoulder	Leg
22				Leg	
23	156	Sprinter	Front	Knee	Knee
23				Leg	
24	150	12/15 seat	Rear	Shoulder	Shoulder
25	160	12/15 seat	Front	Leg	Leg
26	164	207	Front	Leg	Knee
26				Knee	
27		12/15 seat	Rear	Neck	Neck

27				Wrist	
28	173	207	Front	Shoulder	Leg
28				Leg	
29	158	12/15 seat	Front	Knee	Leg
29				Thigh	
29				Leg	
30	155	Sprinter	Front	Knee	Knee
30				Leg	
31	160	12/15 seat	Front	Knee	Leg
31				Leg	

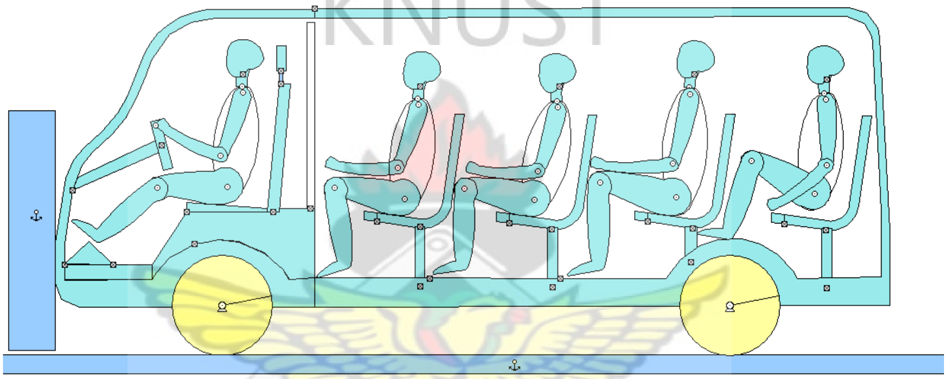
Recommended Seat FRAME Design



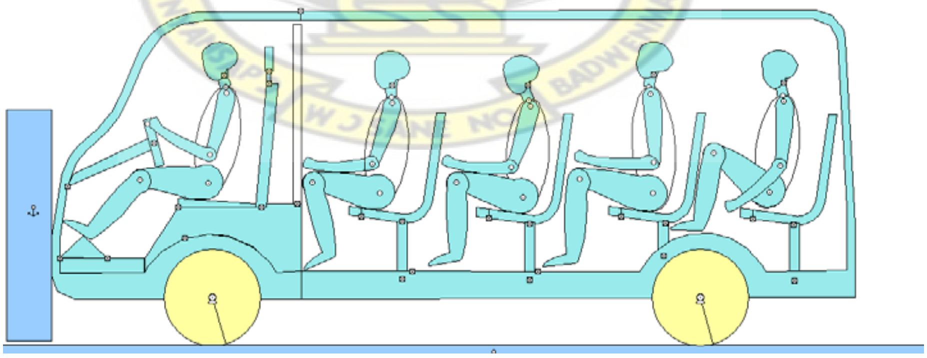
Simulations with Recommended Seat Design



Before Impact



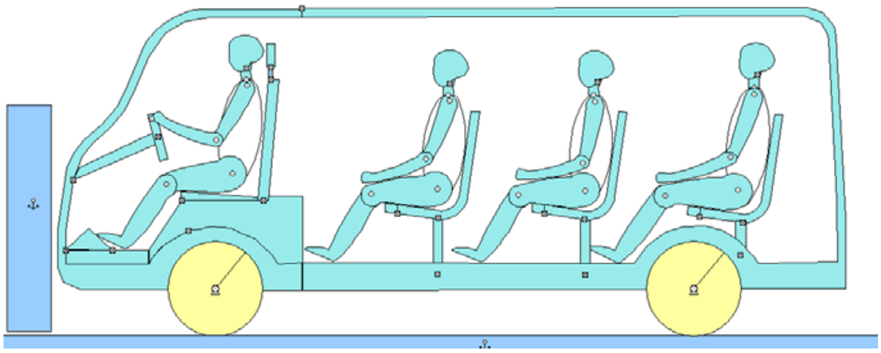
Vehicle Impact



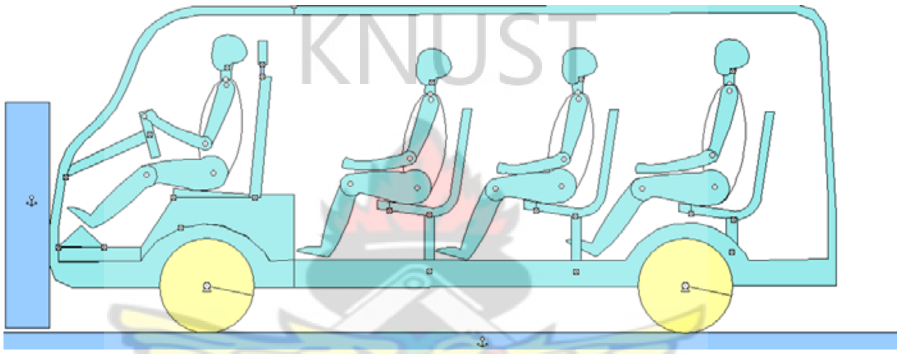
Shortly after Occupant Impact

(Observe upward deflection of occupants legs upon impact. Impact forces will be dissipated as a result of this, reducing what can be transferred to the hips.)

Simulation with Increased Spacing of Seats

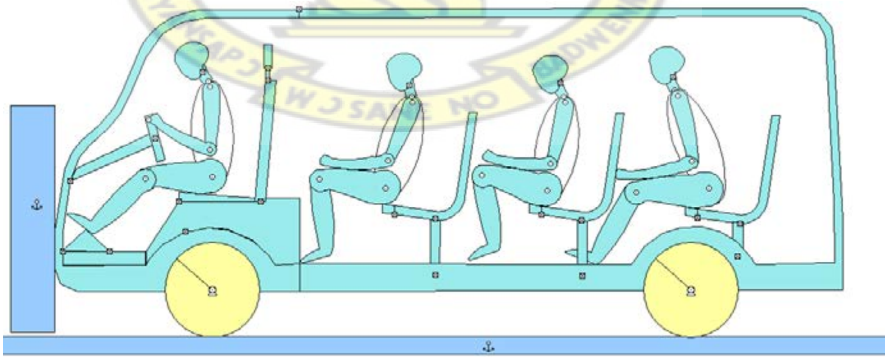


Before Impact



Vehicle Impact

(Occupants still have a distance to move before impacting, unlike closely spaced seats where occupant and vehicle impact sometimes occur at the same time.)



Soon after Occupant Impact

(Observe upward deflection of legs of second occupant and leg impact of third occupant.)