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Conceptual Design of a Bus Emergency Exit Ramp

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Abstract: ***Bus mass transport vehicles are designed to ferry passengers along routes in cities and between cities. Advancement of technology in the 21st century has resulted in various designs of buses. Innovation in bus design has been centered on lightweight materials, formability and aesthetic appeal of the bus interior and exterior. Meanwhile the bus structure has not developed in terms of emergency exit tools to aid quick passenger egress in the case of emergency. This paper focuses on the design on a bus emergency exit tool. This tool will be applicable at designated emergency exit windows. The tool will assist passengers to escape the bus as soon as an accident occurs while emergency services have not yet arrived. The design will be modelled using SolidWorks software.***

Keywords: emergency, exit, bus, conceptual design, safety

1. Introduction

The nature and cause of a bus accident cannot be predicted and designers and engineers can only use past experience as design review tools. According to [1] accident scenario analysis can also be used as a tool for material selection and design modifications.

In this paper the ideal design will be derived from analysis of various accident scenarios in order to produce a product that will be functional in most situations. The paper focuses on generating the design of an emergency exit tool that can aid quick egress from the bus, in the case of accidents or fire. The first section will analyze accident scenarios and current exit methods. From this section data obtained will help to determine the shortfalls in the current design provisions on buses. Using the data obtained and conclusions a concept and its working principle are then developed and explained in the last section. SolidWorks 2014 computer aided design software will be utilized to generate a cad model of the device.

1.1 Literature Review

Research on bus safety has been carried out mainly by institutions on contract with regulatory bodies in different countries. According to [8], rear exits are the most preferred in buses as they are accessible in most accident situations. The analysis however does not consider exit for disabled or aged persons. Another researcher, [5], acknowledges the various types of passengers in terms of age and physical ability and analyses their response and options in an accident situation.

Fire risk in bus crashes is analyzed by, [9], reflecting on the importance of timely evacuation. A significant amount of research work is ongoing in various countries on the dynamics of passenger safety and how to better protect passengers. This paper focuses on a mechanical solution to the egress of passengers from a bus wreckage considering the various age groups and their physical ability.

2. Accident scenario and crashworthiness

An accident scenario is the post-accident condition of the event comprising the concerned mobile object and its surrounding environment. Crashworthiness can be defined as the ability of a vehicle structure (land or air) and its internal systems to protect occupants from injury in the event of a crash **[2]**.A bus crash can occur in any one of several ways. The circumstances that lead to a crash are so varied to an extent that no one single crash is similar in every detail. Factors that cause this variance are, relative speed of units at impact, weight of units, angle of impact, and position of impact relative to bus structure. Three impact scenarios are identified by **[3]**, namely;

- Frontal impact ,
- Side impact,
- Rear impact ,
- Rollover.

The crashworthiness of a bus structure has an effect on the survivability of passengers after the accident. Considering the case of frontal impact, the door may be damaged to the point of not opening, and thereby it becomes an obstruction. Secondary factors like the destruction of a fuel tank can affect survivability when a fire breaks out due to fuel tank implosion. Therefore the crashworthiness of a vehicle is improved if the survivability of occupants is increased.

2.1 Evacuation/Egress in Accident Situations

In the event of an accident, inability to evacuate or egress is one of the major causes of fatality in a post impact scene. According to a presentation by the National Transport Safety Board (NTSB)[i] in 2007 the lack of government sponsored research on emergency evacuation has left passengers at the mercy of raging fires and explosions when an accident occurs [4].

2.2 Accident Scenarios

2.2.1 Frontal Impact Scenarios

Egress in accident situations depends on the nature of the accident. For example in a head-on collision (frontal) the front screen may be blocked and the door at the front end maybe damaged and stuck such that it will not open. Figure 2.2 shows a bus that has been damaged due to frontal impact and the front door can no longer be used for egress. In a situation like this the passenger would turn to other emergency exits such as the windows, back door, if provided. Egress through the windows also provides a new challenge, according to a report by the NTSB one of the challenges is the height of the window on the outside of the bus. There is likelihood of a passenger getting injured from exiting the bus in this manner since the average window height on most buses is two metres. Figure 2.3 shows the height that one is supposed to encounter and this becomes impossible for older persons, disabled persons and children. There is need for devices that make egress through the windows effective for all groups of people. Some of the challenges encountered in accident scenarios is the absence of hammers to break the windows. Window structures have at times been impossible to break because they have been installed without provision for emergency kick out. To alleviate this, there is also need to design a user friendly mechanism to eject windows in case of emergency.

Figure 2.3: Height of Emergency Exit Windows

2.2.2 Side Impact Scenarios

In this kind of impact the side structures of the bus are damaged, depending upon the point of impact, this means that, the emergency exits on the side of the bus are rendered useless for egress. This kind of situation only the front and back exits may be accessible to the passengers. Another case could be when the bus lands on its side, in this case, the roof exits are also accessible.

Figure 2.2: Bus in Frontal Impact

However, in this orientation there is limited room to move towards the front and rear exits, with overhead luggage now strewn all over the passenger compartment and passengers falling.

2.2.3 Rear Impact Scenario

Rear impact scenarios cause damage to the rear end of the bus and if the bus remains on its wheels the front and side exits can be used as escape routes. However the window exits still pose the same challenge as shown in figure 2.3

2.2.4 Rollover Scenario

Rollover scenarios have the potential to cause a lot of physical harm. The use of safety belts has been recognized as the most effective way to avoid fatal injury. Due to the uncertainty of the kind of damage that may occur, the options of emergency exit remain as varied as the nature of such accidents

3. Current emergency Exit Solutions

Buses are equipped with various tools for use in the case of emergency such as fire extinguishers and hammers to break windows .Some manufacturers design their windows in such a way that they can be kicked out of place, and these are usually called emergency exit panels. Other safety provisions are in the form of an added door at the rear or near the rear of the bus. In some cases the door opens in such a way as to form a ramp for easy exit. As shown in figure 2.2 the height of the windows from the ground makes it difficult for older passengers disabled persons and children to easily exit the bus. Evacuation tests were carried out by [5] in which three groups were selected and divided as follows;

- Group 1: 7-15 years old
- Group 2: 20-45 years old
- Group 3: 60-75 years old

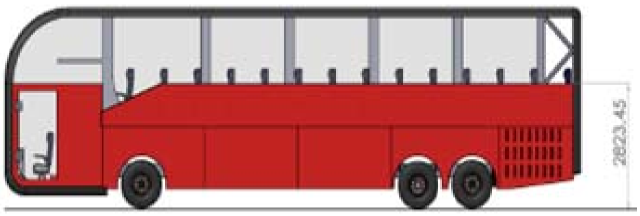

Figure 3: Bus Model

The test was carried out via two exit points ,door and window, as shown in table 3.0, each exit had two variances namely;

- With podium
- Without podium

Table 3: Bus Evacuation Times

Evacuation method	Group 1 Time	Group 2 time	Group 3 time
Emergency door with podium (600mm)high	120secs	150secs	240secs
Emergency door without podium	210 secs	210secs	**
Emergency window with podium	270 secs	330 secs	600 secs
Emergency window without podium	**	540 secs	**

** Participants could not complete exercise

Figure 3 below shows a full bus model of the type of bus considered in this research paper. The following conclusions can be made from the results of the experiment;

- Emergency exit windows are not suitable for the aged and the young
- Exit through windows requires more time than through doors
- Without a tool or device to aid exit, in either case the time to exit increases.

In the case of a bus fire, this means that most passengers will not be able to exit in time to avoid burns and further deterioration of injury while in wreckage.

4. Conceptual design

Design may be defined as [6] "the process of applying the various techniques and scientific principles for the purpose of defining a device, a process or a system in sufficient detail to permit its realization". AIS 052[ii], [7], states that the minimum window width and height is 550mm. For the design a window of the following dimensions will be adopted- 1700mm X600mm. Figure 2.3 shows the side view of a bus with a window level approximately 2800mm above the ground. The ideal device should be able to deploy a ramp from that height in order to allow passengers easy exit from the bus.

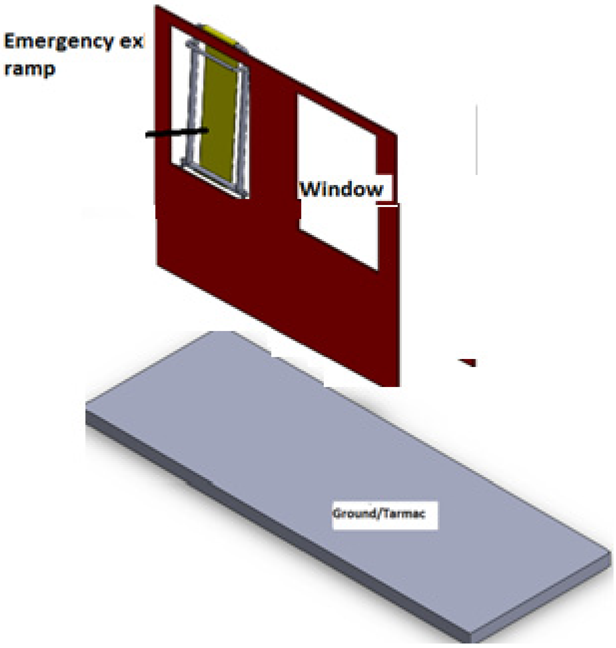

Figure 4: Model Bus Window and Ground

The ramp is composed of a telescopic ramp with one revolute joint. When an accident occurs, using the ramp frame, the window is pushed out of place and the following motions will occur in deployment.

1. Using the revolute joint the frame will rotate to a defined position.
2. The telescopic boom extends to the ground spreading the cloth film which will guide passengers to the ground floor.

Full deployment length of boom = 4.5 metres.

As shown in the figure 4 a representation of a bus window and the outside ground is shown. The three main components are labelled. The following images show the emergency exit ramp operations.

4.1 Stage One

Figure 4.1 shows the normal fixed position of the ramp whilst the vehicle is in operation. As shown this is an upright position in front of the window and inside the bus .Ideally this will be the position of the exit ramp as the bus is travelling.

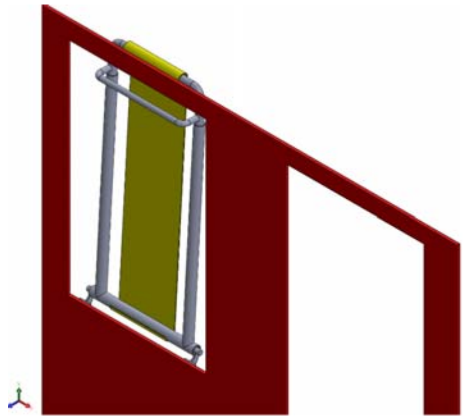

Figure 4.1: Stage One and Two Operation

4.2 Stage Two

In the event of an accident the bar on the frame is used as a hammer with the whole leverage of the frame. This is used to break or displace the window.

4.3 Stage Three

Using the revolute joint the frame will rotate to a set position. This position can be held by a mechanical method or simply a restrictive feature. Automation of the device could also be done at this stage. One example would be the design of a limit switch that actuates a pneumatic pressure release to quickly open the boom as described in the next stage.

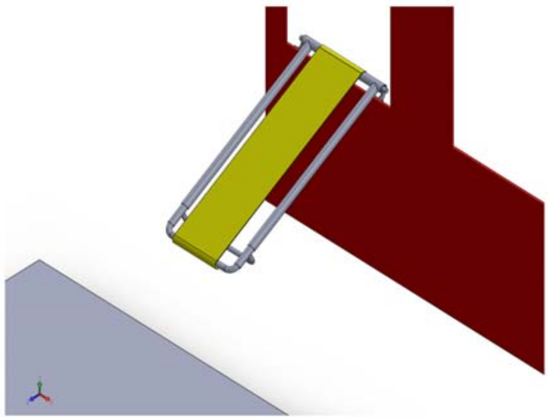

Figure 4.2: Stage Three Operation

4.4 Stage Four

The telescopic frames are now extended to reach the ground and passengers can slide on the cloth film to safety.

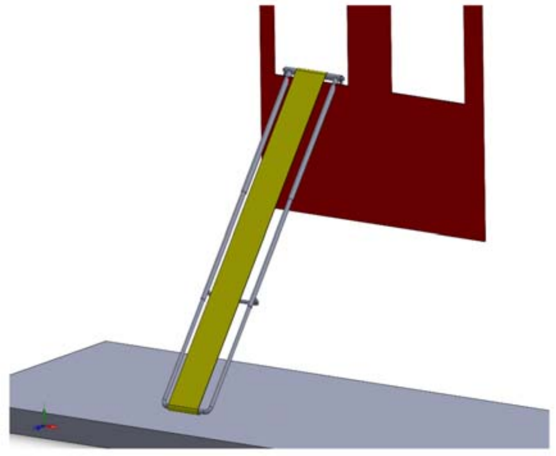

Figure 4.3: Stage Four operation

5. Conclusions

This research paper has explored the conceptual design of a tool to aid passenger egress in the case of an accident .the most critical operating parameters of the design would be efficiency and timely execution. Areas of further research and improvement would be;

- To automate the system
- Increase ergonomics of design
- Easily operated with minimal force or input.

It is also important to note that the advancement of such technology can be accelerated by appropriate legislation to improve the survivability of passengers in the event of a fire.

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Author Profile

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[i] The NTSB is an American organization that regulates transport safety issues.
[ii] AIS 052 is an Indian standard on code of practice for bus body design approval.