1* Is "LS-DYNA" a software program? If not, you should identify the acronym at its first occurrence in the Abstract and again in the main text.

[sentence-style capitalization]

Bus Rollover Protection Analysis with LS-DYNA as an approval method according to American and Europe Standards

1* r p a an s [European]

Abstract: ~~The~~ A bus rollover is one of the most ~~awful~~ devastating vehicle accidents. When ~~a bus rollover~~ such an accident ~~happens~~ occurs, because of the ~~capacity~~ large number of ~~the~~ passengers, the casualties are usually severe. The ~~satisfying~~ satisfaction of rollover requirements for buses and coaches ~~are~~ is obligatory. ~~For this reason~~ Therefore, this paper report presents a physical ~~meaning~~ comparative analysis of ~~the~~ regulations No. 66 of the European ~~Economic Commission for Europe~~ Economic Commission EEC (~~ECE~~ R66) and ~~the standard~~ No. 220 of the U.S. Federal Motor Vehicle Safety Standard ~~in American~~ (FMVSS 220) by using the finite element solver LS-DYNA. This investigation first~~ly~~ provide~~d~~s a comparative analysis of the ~~absorbed energy~~ ability to absorb energy of the superstructure and its main regions ~~and secondly gave out~~ also presents an evaluation of the displacement level of the window-door upper bars, ~~which are~~ being the main components that strongly obstruct the opening of emergency exits in the FMVSS 220 test and ~~may~~ possibly violate the survivor space in the EEC ~~ECE~~ R66 test. ~~These~~ The results show a difference between ~~ECE R66 and FMVSS 220~~ the two standards and also provide a means ~~in~~ for evaluating ~~bus~~ the superstructure strength of a bus.

[avoid redundancy] [diction] [S-V agr: satisfaction . . . is] [space] [space] [hyphens] [comma] [avoid redundancy] 2* *1

Keywords: Rollover, Superstructure, ~~ECE~~ EEC R66, FMVSS 220, LS-DYNA

1. INTRODUCTION

Avoid verbosity and redundancy!

~~There are a lot of heart-breaking bus accidents~~ Many catastrophic bus accidents occur. ~~As a result, according~~ According to ~~the~~ worldwide ~~rollover~~ accident statistics, ~~only from 1973 until now, there are~~ more than 570 bus rollover accidents have been since 1973 [1, 2]. Although ~~the bus rollover~~ such accidents are less frequent than other kinds, ~~it is so~~ the casualties are usually severe. ~~For this reason~~ Therefore, in the U.S.A, Europe and certain ~~some~~ other countries, ~~the bus~~ rollover safety standards have ~~has~~ already been enforced for buses and coaches ~~approval~~ to reduce occupant injuries ~~injury~~. On Jan 4th, 1977 the U.S. Department of Transportation,

[redundant] [delete comma]

2* It seems to me that this agency is actually called the European Economic Commission. Yes, my Google search verified the accuracy of my hunch; therefore, you must revise accordingly throughout this report.

1* "Besides" is a colloquialism; avoid in formal academic/technical writing. 2* Identify the acronym.

United States of America had enforced the FMVSS 220 standard for the school bus rollover protection which included transit buses and vans, having the length less than 35 feet **[3, 4]**. On Jan 1, 1987, Economic Commission for Europe had enforced Regulation No.66 for Bus Strength of Superstructure in order to provide protection to bus and coach occupants during rollover accident-type through maintenance of a survival space **[5, 6]**.

Besides, other countries have regulations or standards for this accident type too. For example, the SANS 1563 regulation for the strength of large passenger vehicle superstructures (rollover protection) in South Africa, the ADR 59/00 for the Omnibus rollover strength in Australia, which are the modified versions of ECE R66 **[7]**. All of them are obligatory in each country. However, the methods in use and its effecting power of those regulations are different. Furthermore, The Bus Manufacturing Factories want to bring their products onto the Europe or USA or both of the markets. While the Bus rollover safety in Europe is evaluated by ECE R66 and by FMVSS 220 in USA for school bus. Therefore this paper is investigating the comparative analysis between ECE R66 and FMVSS 220, two main regulations for bus rollover safety base on computer simulation.

In recent years, automotive industries are concentrating more on vehicle rollover. There were many researchers to study the structure strength of buses and the injury analysis of passengers in accordance with tests of the ECE R66 **[5, 6]**. Brow (1990) **[8]** tried to use the CRASH-D program to be a tool for design and type approval of coach structures for rollover. Examples are given of CRASH-D analyses on a coach bay structure and on various structure joints and section. The program has been validated against full-size physical rollover tests. Kecman et al. (1990) **[9]** discussed that the effect of "finite stiffness hinges" on the energy absorbing capacity of a bus body structure subject to the type of approval procedure (according to the ECE R66) on rollover safety. Modeling aspect of the same effect in the finite element analysis of the collapsing ring have also been presented and illustrated by comparative tests on components and portal frames. Toni et al. (1997) **[10]** showed that they have developed a simulation procedure using finite element analysis

3* If you say, "tried to use," it implies that the trial might have been unsuccessful.

1* Which noun does "this" refer to? 2* Is this actually the European Economic Committee? Yes, a Google search verified my hunch. Since this name has the same acronym as that of the European Economic Commission, use the acronym EEC only when referring to the Commission. Spell out the phrase to refer to the Committee.

for studying the structural resistance comply with ECE R66 without actually performing a rollover test. Aleksandar et al (1997) **[11]** pointed out to the improvement of vehicle stability and crashworthiness to reduce rollover and to provide increased occupant protection in the event of rollover, requires that the effects of design parameters on vehicle rollover propensity are thoroughly understood. They showed that the roof configuration can be modified by replacing the longitudinal bars with diagonal bars across the entire length of the structure. The sensitivity design studies have identified this as a viable approach resulting in lower mass of the bus frame (by up to 3%) and in a reduction of the height of the centre of gravity (by up to 2%), thus producing a better rollover of the bus. Matyas (1998) **[12]** gave an analysis about rollover process of a bus in case of a standard accident simulation. International regulation requires certain strength and energy absorbing capacity of the superstructure to ensure survival space for passengers. The kinetic energy of a rolling bus is transformed into deformation work and involving the energy losses too, an energy balance can be set up, and studied. Sandor (1998) **[13]** showed that the European Committee of Economy has accepted and issued a new regulation related to the bus superstructure's strength in 1986. The previous methods and all the four test methods, accepted in ECE R66, are discussed the technically and critically in this paper. And also pointed out that the recently used combined Hungarian method based on quasi-static tests of bus-frames and simplified computer simulation of rollover proves is presented too. Jame (2000) **[14]** reported that the ECE Regulation 66 is a regulation for all newly registered coaches to be type-approved for rollover crashworthiness. Additionally to the approval type, a computer model was developed to predict the full-scale rollover test. This model comprised a detail finite element mesh and analyzed dynamically using LS-DYNA software. It was approved by the Vehicle Certification Agency in UK, so that it could be used to gain future extension to the ECE R66 approval type of the Bova coach, without the need for repeat rollover test. Matyas (2001) **[15]** pointed that the ECE R66 did not say too much about the problems and details of body section rollover test. This paper collected and discussed these problems and tried to find solutions. And showed that it is a big problem to decide the standard of body sections and evaluate the test results.

5* Are you still reviewing Jame 2000 within [ ]? If not, further revision is needed. 6* A "paper" cannot do these things, but human researchers can. Revision needed, but the identity of the researcher(s) is unclear.

3* I assume that "this paper" here refers to your own research report. If not, then further revision is needed for clarity. Or are you still discussing Sandor 1998? Options: the present report if yours; Sandor's report if his. 4* Fill in the blank to tell what is proven.

1* What is "MB-FE"? 2* What does "S.A." designate? South America? If so, the syntax must be changed to Hispano Carrocera Company, S.A., for.... [note the position of 2 commas]

Belingardi et al. (2003) **[16]** studied the effect of a rollover accident over the structure and the passengers. ~~For what concern the rollover of bus, in Europe the regulation for safety approval is ECE R66.~~ The effect of occupants mass over the superstructure and the injury risk for passengers in a rollover accident was evaluated considering different configurations. ~~The program being chosen to carry out the simulation is MADYMO, the MB-FE software developed by TNO.~~ The mass increment due to presence of passengers effects significantly the deformation of the superstructure and the absence of any prescription of restrain systems does not permit to protect the passengers against very serious or fatal injuries. Castejon et al (2004) **[17]** showed a simulation technical for the rollover test. ~~This technical is~~ based on Geneva regulation number 66. Moreover, a prototype of the composite bus in the Hispano Carrocera S.A. Company ~~has been developed and manufactured, in order to be~~ tested under several load cases, enclosing dynamic and static measurement with strain gages at representative points. Belingardi et al 2005 **[18]** investigated the influence of the seat and the restraint system on ~~bus body~~ structure strength ~~and affects~~ of injury on passengers themselves by using Bay section multibody (MB) and EUROSID-1 dummy model. ~~And~~ they also developed the MB seat model ~~to use~~. Lin ~~et al~~ (2006) **[19]** built CAE model and used ~~the~~ sensitivity and optimization analysis methodology to study the relationship between the lowest shear mode and the weight of the bus to ~~find out~~ the optimized parameters for building a new model meeting the ECE R66. Although many studies have been done on bus structure strength, almost of them are flowing or based on ECE R66 to carrying out their researches. The ECE R66 is a main regulation about the strength of superstructure that prescribes a test to be chosen ~~between its different kinds~~. Another regulation about the structure strength is FMVSS 220 **[3]** ~~that describes~~ the school bus rollover protection. However, the comparative analysis between ECE R66 and FMVSS 220 is still limited. *5

Until now, the capacity of computer and FE software are confirmed in predictive analysis and computing assistances of Bus structure **[8, 10, 14, 16-21]**. That is also new point in ECE R66 version 2006 in which the computer simulation with full scale model is official using as an assessing method for the bus rollover protection requirements **[6]**. This paper used LS-DYNA code

*4 "Research" is an uncountable noun. Do NOT attempt to make it plural.
*5 This paragraph is much too long, having begun on page 2 and extending to here.