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OPTIMIZING VEHICLE STRUCTURE ARCHITECTURES FOR LIGHT TRUCKS

Eduardo del Pozo de Dios
Applus IDIADA
Spain
Juan José Alba
University of Zaragoza
Spain
Oscar Cisneros
Centro Zaragoza
Spain
Massimiliano Avalle
Alessandro Scattina
Politecnico di Torino
Italy
Aritz Esnaola
Mondrauto
Spain
Giorgio Pochettino
Italdesign-Giugiaro
Italy
Paper Number 13-0363

ABSTRACT

Electric Vehicles (EVs) have experienced an incredible fast evolution. In the last few years almost every car manufacturer has presented its own EV prototype or fully functional vehicle and developing dedicated vehicles instead of the classical “General Purpose” concept is becoming more common. Most Electric Light Trucks existing already in the market still adopt the classic powertrain lay-out used in thermal engine vehicles. The EC co-funded OPTIBODY project is developing new modular structure architecture for a European L7e category vehicle focused on safety improvement and exploring the capabilities of modularity applied to safety and reparability.

The OPTIBODY vehicle has been designed using a modular structure architecture composed of a chassis, a cabin and several add-ons. The cabin will provide improved levels of comfort, protection and ergonomics to the user and the add-ons will provide protection in case of frontal, side and rear impact, including also crash compatibility and interaction with vulnerable road users.

Europe, U.S.A., Canada, Japan and Australia were targeted for the initial analysis of the electric light vehicle worldwide situation to achieve the objectives of the project. The current light trucks fleet, accidentology and the requirements to be fulfilled by the vehicles were analyzed in the previous regions. The chassis, the cabin and the add-ons have been designed using new light materials and a modular concept to improve self and partner protection safety. The thermal engine has been removed and substituted by electrical in-wheels engines, and the extra space has been use to improve frontal impact and vulnerable road users protection.

The requirements for certification of both L7e and low-speed vehicle categories in Europe and North America are very low in terms of safety and there is no mandatory crash test to evaluate neither pedestrian protection nor impact performance. OPTIBODY project has proposed frontal, side, rear and pedestrian impact tests and they have been use as targets to design the OPTIBODY vehicle to improve self and partner protection. Frontal crash test simulations showed an improvement in the cabin integrity and self and partner protection, as well as an improved pedestrian protection due to the extra space available, the use of new materials and the design of the add-on. The OPTIBODY vehicle adhered to the US commitment of Part 581 Zone, improving the crash compatibility of the vehicle. The use of modular architectures and new materials also improved the reparability of the vehicle.

The OPTIBODY project is developing a new modular architecture for L7e vehicles that will provide an improvement in self and partner protection and reparability. Modularity has been

only considered in this vehicle category and its applicability to other categories should be considered. L7e vehicles in Europe and low speed vehicles in the US have very poor safety requirements for certification. The OPTIBODY project is a good opportunity so show a great improvement in self and partner protection for L7e vehicles and also to explore how electric vehicles can improve the current levels of safety and the benefits of applying modularity to safety and reparability fields.

INTRODUCTION

Electric Vehicles have experienced an incredible fast evolution during the last years and almost every car manufacturer has presented its own prototype. Some of these manufacturers even have fully functional vehicles on the roads, showing the increasing importance that electric vehicles have in the automotive industry.

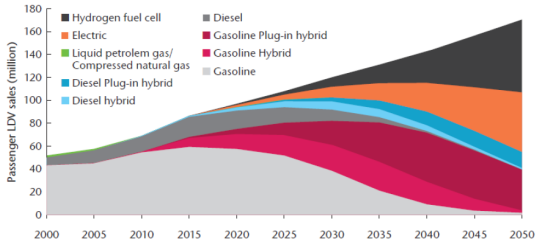

Figure 1. Prediction of annual light duty vehicle sales, according to its technology (International Energy Agency).

Last trends in electric vehicles design show the increasing importance of dedicated vehicles instead of the classic general purpose concept so manufacturers are developing specific vehicles for urban logistics, urban mobility, etc. The current status of the technology impose very light vehicles to optimize energy consumption, so most of the full electric vehicles that we are and we will see on the roads in the near future will still run in urban areas and, in consequence at low-to-medium speed in short range displacements.

For all these reasons, the European Commission co-funded OPTIBODY project (Optimized Structural components and add-ons to improve passive safety in new Electric Light Trucks and Vans –ELTVs-) project is focused in ELTVs that are worldwide homologated as N1 and N2 vehicles and, in Europe, also include the L7e category (Directive 2002/24CE).

Most of the existing ELTVs adopt the powertrain lay-out used in classic internal combustion engine vehicles. Very conservative solutions and technologies are used in their development, mainly because it is done by small and medium sized companies. However, bigger companies are already introducing new solutions in the design of this type of vehicles, such as the implementation of in-wheel motors. In this particular solution the internal combustion engine is replaced by at least two electric motors located in the hub of the wheels. This new design provides a considerable amount of space in the former location of the engine. This space is no longer necessary to accommodate awkwardly-shaped mechanical components.

Introducing these changes in the frontal part of the vehicle, the engineers can concentrate their efforts towards improving the performance and safety when the new frontal part of the vehicle is being designed. Simplifying the vehicles enables engineering teams to perform changes that were considered impossible in the past. These changes include eliminating the entire engine block, reducing the weight, totally flat floor design, chassis design focused on passengers' safety and frontal design focused in vulnerable road users' safety. All these modifications, as well as the possibility of implementing specific systems and add-ons will increase the vehicle passive safety of ELTVs and, more in general, of electric vehicles.

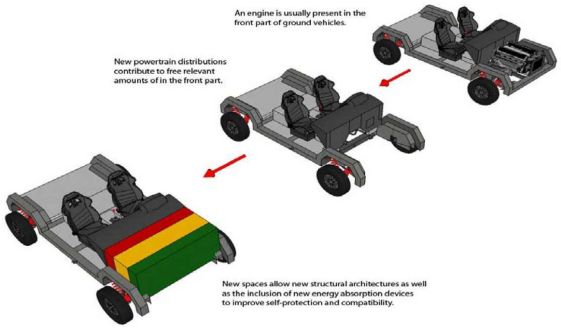

Figure 2. Evolution of vehicle fronts (from classic cars to EVs) and the resulting possibility to use the front for the installation of new safety components

The OPTIBODY vehicle is based on a new structural concept for ELTVs composed of a chassis, a cabin and a number of specific add-ons. The chassis will act as a key structural supporting element for any other components in the vehicle. The cabin will improve current levels of EVs'

comfort, occupant protection and ergonomics. Finally, a number of add-ons will bring specific self-protection in case of front, rear and side impacts, as well as in case of rollover. Additionally, these add-ons will also provide partner protection in case of interaction with other vehicles (crash compatibility) or vulnerable road users (such as pedestrians, cyclists and motorcyclists).

The main objective of the OPTIBODY project is to improve the passive safety of vehicles under the European category L7e. Additionally, theoretical concepts will be shaped as a pilot demonstrator. In order to achieve the main goal of the project, the OPTIBODY concept needs to reach the following specific objectives:

- Enhance vehicle's passive safety
- Enhance crash compatibility
- Optimize the reparability in small crashes
- Optimize ergonomics and space distribution for passengers and main components accessibility
- Improve maintainability

In addition, to these objectives, the OPTIBODY project will also propose the establishment of some requirements for impact-safe ELTV's and will study the applicability of the project results such as the modularity to other vehicle categories, such as N1, N2, M1, M2, etc.

Vehicle included in the OPTIBODY vehicle category (L7e in Europe and Low Speed Vehicles in the U.S.) have very high fatality ratios when crashing with other vehicle categories due to their typically light design and much less restrictive regulations than the existing for passenger cars. The improvement of the passive safety requirements for self and partner protection of this vehicle category is, therefore, the main goal of the project. Some of the structural modifications will include removing the thermal engine to incorporate new load paths and energy absorbing add-ons in vehicle's frontal end. The FP6 project APROSYS already studied the enhancement of pedestrians, cyclists and infrastructure protection based on different add-ons. The OPTIBODY project will implement these add-ons in a much less restrictive concept of modular vehicle than the classic vehicle concept provided with thermal engines.

In order to optimize the damaged parts reparation or substitution cost, reparability will be introduced as a key factor in the design of the different add-ons. Ergonomics and accessibility will be also considered as key factors in the design of the vehicle. Finally, some technical requirements for an "OPTIBODY" quality marking will be determined.

The OPTIBODY concept will aim to improve and provide innovative solutions for three main areas:

1. Pedestrian protection, using the former thermal engine space available to incorporate new optimized front parts.
2. Crashworthiness and compatibility. Self-protection and partner protection can be improved by developing optimized crash energy absorbing add-ons.
3. Reparability. As a modular concept, OPTIBODY will take an extra advantage of reduction of architectural constraints and will make reparability and maintenance procedures easier and more cost efficient.

In the automotive industry, for conventional vehicles as well as for electric vehicles, "crashworthiness" is a measure of the vehicle's structural ability to plastically deform and still maintain a sufficient survival space for its occupants in crashes involving reasonable deceleration load. "Compatibility" is a term that refers to the "quality" of structural interaction in collisions, and this "quality" depends on several factors that are common to all kind of vehicles and means the good performance of traffic participants among each other in the event of an accident.

This paper describes the methodology that is currently been used in the OPTIBODY project and the preliminary results from the analysis of the ELTV regulations in the major geographical areas, the analysis of accidents involving ELTVs and the ongoing work that is been currently carrying out for the chassis, cabin and add-ons design.

VEHICLE DEFINITION

The quadricycles are the vehicles included in the European vehicle category L7e, also referred to as 'Heavy quadricycles'. They are defined by Framework Directive 2002/24/EC as motor vehicles with four wheels "other than those referred to (as light quadricycles), whose unladen mass is not more than 400 kg (category L7e) (550 kg for vehicles intended for carrying goods), not including the mass of batteries in the case of

electric vehicles, and whose maximum net engine power does not exceed 15 kW." Vehicles included in this category shall be considered to be motor tricycles and shall fulfill the technical requirements applicable to motor tricycles of the European category L5e unless specified differently in any of the separate Directives.

The OPTIBODY vehicle is intended to be a urban vehicle for carrying goods. In this case, as being design to be equipped with exchangeable superstructures, the total mass of these superstructures shall not be taken into account for the calculation of the unladen mass and shall be considered to be part of the payload. The basic type of vehicle (chassis cab), on which the above mentioned superstructures are designed to be fitted, shall fulfil all the prescriptions established for category L7e quadricycles for transportation of goods. The superstructure is considered to be exchangeable if it can be easily removed from the chassis cab without the use of tools and the manufacturer shall provide in the information document: the maximum permitted dimensions, the mass, the limits for the position of the centre of gravity and a drawing with the position of fixing devices. In table 1 the European Directives that regulate the L7e vehicle category are listed.

The L7e vehicles in Europe are limited to an unladen mass of 550 kg without batteries and a maximum payload mass (Payload = maximum technically permissible mass - mass in running order - 75 kg driver) of 1000 kg. The mass in running order is not limited. The dimensions are limited to a length equal or less than 4.0 m, a width equal or less than 2.0 m and a height equal or less than 2.5 m.

The maximum speed for this category of vehicle is not limited and the approval test is optional. A declared value from the manufacturer is accepted. The maximum net power is limited to 15 kW. No official verification test is required but a statement from the motor manufacturer according to standard IEC 60034-1 must be provided.

Table1.European Directives for L7e vehicle category

DIRECTIVE	TOPIC
2002/24*1137/2008	Whole vehicle type
93/14*2006/27/EC	Braking
93/30/EEC	Fitting of audible warning device
93/33*1999/23/EC	Protective devices intended to prevent the unauthorized use of the vehicle
93/93*2004/86/EC	Masses and dimensions
95/1/I*2006/27/EC	Maximum speed
95/1/II*2002/41/EC	Maximum power and torque
97/24/1/III*2006/27/EC	Fitting of tyres
97/24/3*2006/27/EC	External projections
97/24/4*2006/27/EC	Installation of rear-view mirrors
97/24/EC Chapter 8	Electromagnetic compatibility
97/24/10/EC	Coupling devices
97/24/11*2006/27/EC	Safety belts and anchorages
97/24/12*2006/27/EC	Glazing, windscreen wipers, windscreen
2000/7/EC	Speedometer
2009/62/EC (former 93/94*1999/26/EC)	Space for the mounting of the rear registration plate
2009/67/EC (former 93/92*2000/73/EC)	Installation of lighting and light-signalling devices
2009/80/EC (former 93/29*2000/74/EC)	Identification of controls, tell-tales and indicators
2009/139/EC (former 93/34*2006/27/EC)	Statutory markings

The passive safety requirements for a bodied quadricycle are limited to three-point seatbelts for all seats with some requirements concerning the location of the effective anchorage points to the H point. A resistance test on the vehicle structure consisting in applying simultaneously 675 kg in the upper and lower seatbelt sections of the seats of the same row and verifying the resistance of the structure is required. No requirements of the performance of the vehicle in a crash are established.

In the United States, the vehicles fitting in the European L7e category are considered as Low Speed Vehicles (LSV) and are regulated under the safety standard FMVSS 500.

Low-speed vehicle (LSV) means a motor vehicle that is 4-wheeled, whose speed attainable in 1.6 km (1 mile) is more than 32 kilometers per hour (20 miles per hour) and not more than 40 kilometers per hour (25 miles per hour) on a paved level surface, and whose gross vehicle weight rating (GVWR) is less than 1,361 kilograms (3,000 pounds). In this case the maximum speed is limited as well as the maximum permissible weight.

In terms of passive safety, the vehicle equipment required by the FMVSS500 standard is a Type 1 (lap belt) or Type 2 (Lap and harness belt) seat belt assembly conforming to Sec. 571.209, Federal Motor Vehicle Safety Standard No. 209.

Requirements for Low speed vehicles in Canada are similar to the ones existing in the U.S. The safety standard, by which these vehicles are assessed, is the CMVSS500 on low-speed vehicles. The main differences of the CMVSS500 with respect to the US Standard are that Low Speed Vehicles in Canada do not use fuel as an on-board source of energy, are required to fit a Slow Moving vehicle emblem and that some Canadian provinces may not allow Low-speed vehicle registration, and some others may impose additional requirements to the ones set forth in the CMVSS500.

In Australia there is no vehicle category equivalent to the European L7e quadricycles. A goods vehicle with a “Gross Vehicle Mass” not exceeding 3.5 tonnes is deemed as a Light Goods Vehicle (NA). The vehicle could be classified as sub-category NA1 (Light Goods Vehicles not exceeding 2.7 tonnes). The passive safety requirements in this case are more restrictive than in the US and Europe.

In Japan there is no vehicle category equivalent to the European L7e quadricycles either. A vehicle within the dimensional limits of Length 3.4m x Width 1.48m x Height 2.0m and with a displacement of 660cc or less if the vehicle has internal combustion engine is considered a mini-sized motor vehicle. For electric vehicles there are no requirements regarding the motor output. Japanese vehicle manufacturers are obeying their voluntary guidelines for mini-sized EV that the motor output is not more than 47kW but there is no such obligation for EVs exported by foreign manufacturers.

ACCIDENT ANALYSIS

After reviewing the legal requirements for the construction of the OPTIBODY vehicle, the identification of the most common accident scenarios in which the L7e vehicles are involved was studied. One of the main problems when analyzing accidents involving the OPTIBODY vehicle is the lack of vehicle category harmonization when the different existing databases are considered. Depending on the database, the vehicle category is defined as “vans and lorries”, “lorries under 3.5 tonnes”, etc. This made very complicated to compare results from the different databases considered.

Focusing in the OPTIBODY vehicle category, there are two important issues to address: self-protection and vulnerable road user protection. Most pedestrian fatalities occur inside urban areas, where the OPTIBODY vehicle is most likely to be circulating. In EU19 the pedestrian fatalities account for 20% of the total number of fatalities and the number grows to 27% when the inside urban areas are considered. When passengers of lorries are considered, the number of fatalities is considerably lower, between 3% and 4% in the last decade. It is important to remark that the percentage of lorries and pedestrian fatalities inside urban areas in EU 19 has grown up in spite of the number of fatalities has decrease in these years. In the “lorries under 3.5 tonnes” the inside urban areas fatalities account for 15% of the total number of fatalities.

Good transport vehicles under 3.5 tonnes accidents in 2009 were analyzed and a total of 12958 incidents with at least one of these vehicles were found causing 139 fatalities. 24.53% of these fatalities were pedestrians, 10.06% were drivers of the vehicle and 5.66% were passengers. When injuries are considered, 17.96% were drivers, 7.28% were passengers and 5.45% were pedestrians, highlighting that the pedestrian accidents are much more severe and more fatalities are associated to this type of accident. For the vehicle occupants, the frontal, frontal-lateral crash and collision with obstacle (including stopped vehicle) were the scenarios with higher number of fatalities, accounting for 75% of the driver fatalities and more than 55% of the passenger fatalities. In terms of injuries they accounted for 57% of the injured drivers and 56% of the injured passengers.

A more detailed study was performed in the Italian region of Piamonte category using the “*Regione Piemonte database*” provided by the “*Istituto Italiano di Statistica*”. This database was the only

one found that includes one category of vehicle, category #21, which refers to quadricycles. In 2009 and 2010, 1 person died in accidents that involved quadricycles in this region and 78 suffered injuries of different severity. In the same period of time, 17 fatalities and 1083 injured people were associated with vehicles included in the trucks category.

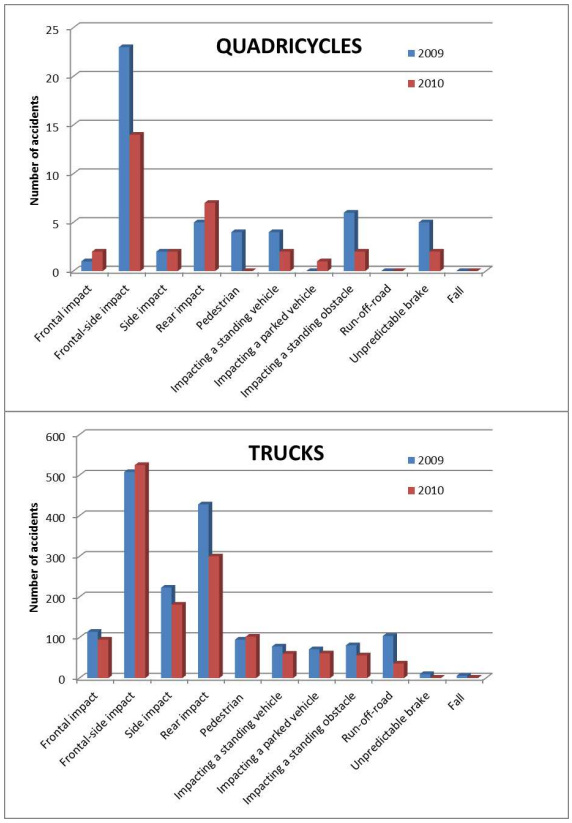

Figure 3. Total number of trucks and quadricycles accidents per type of crash in the Piamonte region

Other geographical areas

NHTSA (National Highway Traffic Safety Administration) initiated a research program to investigate the problem of aggressive vehicles in multi-vehicle crashes. The goal of this research program is to identify and characterize compatible vehicle designs with the intention that improved vehicle compatibility will result in large reductions in crash related injuries. Specifically, the objective is to identify those vehicle structural categories, vehicle models, or vehicle design characteristics which are aggressive based upon crash statistics and crash test data. LTV-to-car collisions are one specific, but growing, aspect of this larger problem. The magnitude of this problem then is not only due to the aggressivity of LTVs in crashes, but also the result of the dramatic growth in the LTV fraction of the U.S. fleet.

In two-vehicle crashes involving a Passenger Car and a LTV, particularly in head-on collisions, 3.6 times as many passenger car occupants were killed as LTV occupants. When LTVs were struck in the side by a passenger car, 1.6 times as many LTV occupants were killed as passenger car occupants. On the other hand, when passenger cars were struck in the side by LTVs they were killed 18 times more than LTV occupants.

The damaged body parts in crashes involving cars and LTVs were also analyzed. The most damaged body regions were the head (25% for cars and 23% for LTVs) and upper extremities (20% and 22%). For the lower extremity, the percentage of injuries is higher for LTVs (20%) than cars (16%). Regarding the chest injuries are lower for LTVs (10%) than cars (14%). Adding together the three most commonly injured body regions in cars (head, upper and lower extremity), they represent 61% of the injuries whereas in the case of LTVs they represent 65% of the injuries.

Injuries in U.S. and Australia side crashes are very similar. Main damages were focused in the upper extremities (23% in U.S. and 20.3% in Australia) and head (21.8% and 24.5%). On the other hand the main differences concern to the spine and chest. U.S. injuries represented 9.7% for spine and 13.4% for chest, while, Australian percentages changes to 14.7% and 7.3%, respectively.

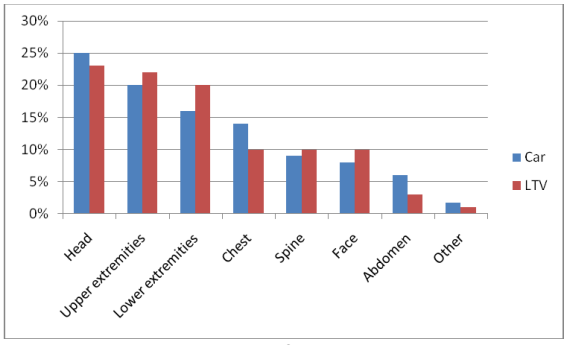

Figure 4. Total number of trucks and quadricycles accidents per type of crash in the Piamonte region

DESIGN OF THE VEHICLE

Currently, the OPTIBODY project is focused in the design of the chassis, cabin and add-ons of the vehicle, as well as the identification and selection of the energy storage and the powertrain. Regarding the powertrain, two in-wheel motors with a maximum power of 15 kW were considered. The battery pack will be placed on the rear axle, on the vehicle structure behind the cabin.

Design of the chassis

The design of the structure includes selecting the materials and also establishing the crash targets that the structure must fulfill based on the regulatory and accident analysis. Different structural architectures are being considered as well as different materials (High strength steel, aluminum, composites, etc.). For the materials selection, aspects like the Greenhouse Gas (GHG) Emissions for production are also considered in addition to the classic selection criteria as weight, strength, etc.

In order to fulfill all the design requirements, the frame of the vehicle was thought in a very simple way made of two main rails and a series of transverse beams welded to them (Figure 5). All these parts are made with aluminum extruded profiles; this solution allows reducing the weight and containing the costs, compared to, respectively, a common steel solution and a normal production aluminum car body. The frame is divided in two main parts. The rear one, aimed at the transportation of goods and, under the floor, the battery housing. The front part is aimed at carrying the cabin, the powertrain devices and to manage the energy in the case of impact. The two parts are joined together by bolts: this solution improve the modularity of the vehicle, because it is possible to exchange the front cabin part with different rear equipment. In the rear part a series of crash boxes and a longitudinal crash beam are fixed to the main rails in order to improve the safety and to protect the batteries in case of side impact. For these two components high strength steels is adopted to improve the energy absorption. Also the cabin is a wireframe structure made of aluminum extruded profiles joined by welding. The cabin is welded on the front structure. To manage the energy during impact, the front part is divided in two main portions. The front one, made with a stamped high strength steel crash boxes and crash beam, is aimed to absorb energy at low speed impact (16 km/h). Behind this part, the second portion is a front rail aimed to absorb energy in impact at higher speed (36 km/h). Crash box, front rail and main rail are joined together with bolts in order to improve the reparability. Different solutions in terms of shapes and materials both for the front and side crash boxes and crash beams were taken into considerations. The final solutions are optimized to obtained the best crashworthiness behavior and consequently to maximize the energy absorption. . The same approach in terms of materials and structural behavior is being considered for the add-ons.

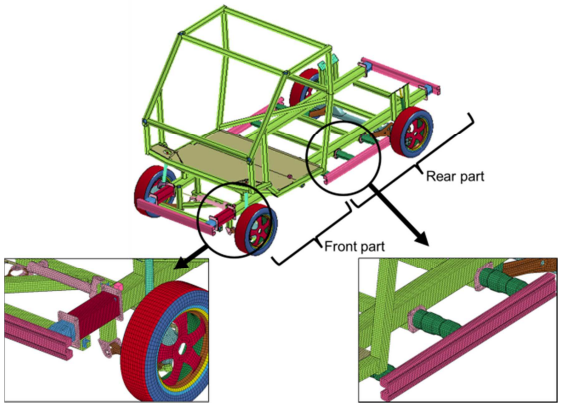

Figure 5. OPTIBODY 3D model chassis. In detail the front and side crash structures.

One of the main objectives of the project is to enhance crash compatibility in the OPTIBODY vehicle category. For that, as shown in Figure 6, the Primary Energy Absorbing Structures (PEAS) of the vehicle fulfill the option 1 specifications of the USA standard 49 CFR Part 581. These specifications require that the light truck's PEAS) shall overlap at least 50% of the Part 581 zone and at least 50% of the light truck's PEAS shall overlap the Part 581 zone.

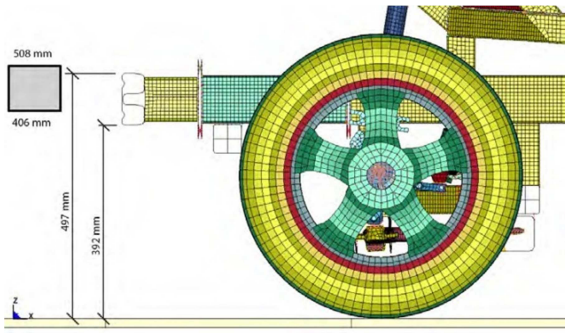

Figure 6. PEAS height compared with 49 CFR Part 581 specifications

Design of the cabin

When this work is being prepared, the design of a cabin for the OPTIBODY concept is still at a very preliminary stage. The cabin is intended to bring an ergonomic and safe space for occupants so, in case of accident, deformations of the structure and intrusion of components must be avoided.

At this moment, the work is concentrating on the protection of the cabin against rollover loads. This test is performed by applying a static load on the top of the cabin. The finite element model is already developed and first results are being used to optimize this design.

Global frontal and side crash tests will bring additional information to understand the behavior of the structure.

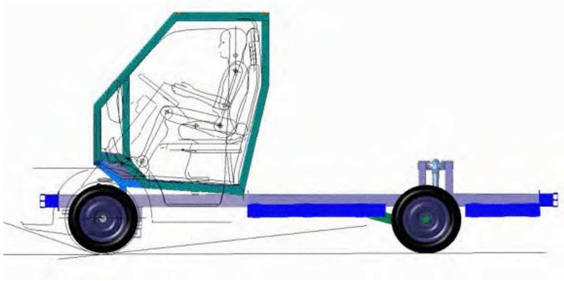

Figure 7. Driver position inside the new cabin

DESIGN OF THE ADD-ONS

Since the thermal engine is no longer needed, new space is available to accommodate the frontal add-on and other potential energy absorber devices. To design the frontal add-on for pedestrian protection, a numerical hybrid III 50th male dummy model is being used in a frontal centered impact simulation. The add-on geometry is being designed to avoid a direct impact of the head against the cabin or the windscreen.

The APROSYS European project considerations concerning the deflection of the pedestrian to one side of the road in case of a run over accident are also considered: a rounded circular shape was adopted in the contact area with the legs.

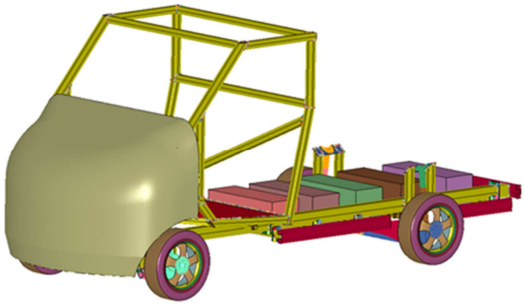

Figure 8. Frontal add-on positioned on the OPTIBODY concept.

Simultaneously, physical impact tests are being performed in order to validate the numerical simulations. These impact tests are carried out by means of simple point impactors that facilitate the analysis of the behavior of the structure during the impact. In this way, data on damaged area, impact speed or energy absorbed are available to be compared to those coming from identical simulated tests.

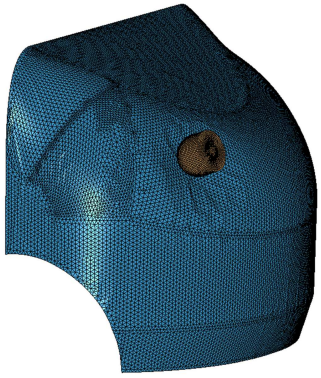

Figure 9. Impact test simulation for the frontal add-on.

When good numerical-experimental correlation is achieved, the process to optimize geometry and materials will start.

In the current add-on design, a configuration of a glass-fiber skin with internal foam is being used to optimize the energy absorption and the HIC15 values. The total add-on weight has been kept below 30kg

CONCLUSIONS

Most of the existing ELTVs adopt the powertrain lay-out used in classic thermal engine vehicles. OPTIBODY has been defined as a new structural concept of ELTVs composed of a chassis (the key structural supporting element), a cabin and a number of specific add-ons, which will bring specific self and partner protection in case of front, rear, side impacts and rollover.

The OPTIBODY vehicle has been defined as an Electric light trucks that have specific regulatory status in Europe as L7e quadricycles, and in USA/Canada as Low Speed Vehicles. In both Japan and Australia, these vehicles are not identified as a particular case and approval requirements are those of upper categories, and thus more demanding (including crash tests). In Europe and the North America areas no crash test is mandatory. In the US the maximum speed of the vehicle is limited while in the other geographical areas no restriction on speed is established. In Europe, the only passive safety requirement is the seat belt in all seated positions and the testing of the seat belt anchorages.

The accident analysis to determine the most common accident scenarios highlighted the lack of harmonization when the category of the vehicle is codified in the databases. The Piamonte Region database in Italy was found the only one that the OPTIBODY consortium could access with the quadricycle vehicle category registered. The small number of fatalities and injuries in accidents involving this category of vehicles in this particular region might me due to: safety measurements integrated in the vehicles, small mass, low speed, and the fact that they mostly circulate in urban areas and/or that the number of vehicles in this category is very small. Frontal-side impact (frontal with offset) and rear impact are by far the most frequent types of accidents. However, frontal impact and pedestrian accidents are much more severe causing more casualties and injuries than the other types of prevailing accidents. The number truck accidents and the number of fatalities associated with those accidents are significantly higher than for quadricycles. Especial effort need to be done to reduce the number of pedestrian accidents in both quadricycle and truck cases. These numbers are in line with the European road accident statistics, where a total of 155 of the deaths related with vans and lorries under 3.5 tones occurred in urban areas. Accidents in urban areas represent a high number of deaths and they require especial attention due to the urban use that the OPTIBODY vehicle will have.

The chassis of the vehicle has been designed using aluminum as base material for the main frame of OPTIBODY. The frame was divided in two different parts to enhance the modularity of the vehicle since it is possible to change the transportation of goods part of the vehicle while keeping the same cabin and frontal protection structure. The compatibility issue was found a key design concept and the vehicle Primary Energy Absorbing Structures (PEAS) have been design to meet the standard 49 CFR Part 581, that has been also considered by the FIMCAR (Frontal Impact and Compatibility Assessment Research) project in Europe.

The cabin is still under design to create a safety space for the occupants while improving the level of comfort of the vehicle. At the moment of writing this paper, efforts in the cabin safety design are focused in the rollover performance of the vehicle.

The add-ons concept that was previously considered in projects such as APROSYS has been implemented in the OPTIBODY concept. The frontal add-on is mainly focused in pedestrian protection while lateral and rear add-ons are improving safety performance optimizing the energy absorption through crash boxes made of high strength steel in lateral and side impacts.

OPTIBODY is being defined as a new modular structure concept to take benefit of the singularities of electric vehicles to fully design a new ELTV focused in the improvement of self and partner protection, reparability and modularity.

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