A NEW ROBOTIZED VEHICLE FOR URBAN FREIGHT TRANSPORT

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ABSTRACT

In recent years, the research in the field of urban area delivery drew the attention of the scientific world. Many problems arise from the lack of a well-defined urban logistic, aimed at an efficient parcels distribution. Also technological issues arise; the current technology does not satisfy the needs of this specific context, in particular for what it concerns the vehicles and the transportation process.

In this research we present the FURBOT vehicle result of the FURBOT (Freight Urban RoBOTic) project, funded within the Seventh Framework Programme of the European Union, which aim is to develop a new vehicle to improve the urban freight transport. The vehicle represents an integration between a mobile robot, a van and a forklift. The new vehicle design is presented.

Keywords: electric vehicle, urban freight delivery, robotized freight handling, sustainable transport

1. INTRODUCTION

Freight transport is a critical issue for urban areas: the European population is mainly concentrated in cities and therefore the bulk of industrial production is dispatched to these areas. Moreover, the demand for freight transport is growing at a fast rate due to changes in industry logistics and consumer purchasing patterns.

Also the consuming behaviours have changed rapidly in the past years and they have transformed the way people travel for shopping. Surveys show that home deliveries are not marginal anymore. As a result, the scope of urban freight ranges from large trucks delivering full loads to single destinations, through to courier vans that visit many destinations, picking up and delivering many separate consignments.

These urban freight movements cause problems within cities, as the BESTUFS (Best Urban Freight Solutions) European network underlines (BESTUFS 2008). The main ones are related to:

- the lack of suitable infrastructure for deliveries (ramps, areas for loading and unloading, reserved parking spaces, etc.),
- noise emissions,
- conflicts with other users during delivery operations (loading and unloading),
- access of goods vehicles to pedestrian zones or historic centres,
- environmental pollution.

Therefore, it is clear that the modern reality requires a change of paradigm for goods delivery. Thus, it is necessary to carefully analyse the needs of the next generation of freight.

A sustainable freights transport has to fulfil all the following objectives (Behrends 2008):

- ensure the accessibility offered by the transport system to all categories of inhabitants, commuters, visitors and businesses;
- reduce air pollution, greenhouse gas emissions, noise to levels without negative impacts on the health of the citizens or nature;
- improve the resources, the energy-efficiency and the cost-effectiveness of the transportation of goods, taking into account the external costs;
- contribute to the enhancement of the attractiveness and quality of the urban environment, by avoiding accidents, minimizing the use of land and without compromising the mobility of citizens.

2. STATE OF THE ART

The urban freight transport is a research field that started to become active in recent years. In fact, due to the continuous development of the commercial activities in the urban areas, it is necessary to improve the freight transport systems currently in use in order to achieve better results in terms of efficiency and quality of life. Also the European Union is trying to promote this topic through appropriate research programme, offering specific calls for urban clean transport.

FIDEUS (Freight Transport System for Urban Shipment and Delivery) is a project of the 6th Framework Programme which focuses on the concept of “cooperative transport” (Bruning 2011, Burzio 2006). Three classes of vehicles have been proposed: a lorry used for long distance transport of a big amount of parcels; a van to transport a smaller amount of goods from the storehouse to the neighbourhood of the city centre; a micro-carrier which is an uni-axial transport unit that can be used both as a part of a multiple trailer vehicle or as a hand-guided transport unit. This last element is used to travel from the van to the collection place, usually located in the pedestrian area (/low-traffic area).

On the other hand, CityLog (Sustainability and efficiency of city logistics) is a project of the 7th Framework Programme which exploits the idea of "modularity". The especially designed container, named BentoBox, plays a key role in the delivery logistic (Dell'Amico 2011). The delivery of the parcel is decoupled between the couriers, who transport the goods up to the collection area, and the customers, who pick up the parcel by himself. In order to optimize this process, the BentoBoxes are installed in an area of the city centre that is easily accessible by public transport and by foot. CityLog has been conceived in parallel to another EU-funded project, CITY MOVE (City Multi-role Optimized VEhicle). The latter focuses on innovative vehicle technologies and it is meant to be a complementary work to CityLog.

CITY MOVE proposes a vehicle based on hybrid powertrain architecture in order to improve the efficiency, decrease the environmental impact and increase the safety (Aimo Boot 2010). Great attention has been paid to the latest technology in freight transport in order to accelerate the introduction of such product in the market.

A different aspect of the urban traffic has been studied by INRIA (Institut National de Recherche en Informatique et en Automatique). They proposed Cybercars, a family of new vehicles especially designed to achieve a more effective organisation of urban transport (INRIA 2006). The idea is to extend the advantages of a car in a public context, like in a car sharing system, and going beyond offering a doot-to-door service. One product of this family is CityMobil, an autonomous vehicle for passengers and goods, funded by the 6th Framework Programme (Bouraoui 2011, Nashashibi 2012).

The main difficulty of all these systems is related to the integration with the existing urban environment. In fact, the objective is to realise an aid for the urban transport which must be accepted by the deliverers, customers and also pedestrians.

During the development process it is necessary to organise field tests in order to collect opinions directly from the end-user. In addition, asking for the support of municipalities and public authorities is going to help the introduction of these new products from a logistic point of view.

3. VEHICLE REQUIREMENTS

In this research, we propose and analyse a new concept architecture of a light duty fully electrical vehicle for efficient urban freight transport, namely FURBOT (Freight Urban RoBOTic vehicle). The strong points of FURBOT are:

- small size - the reduced size of FURBOT will make easier the delivery of the goods in pedestrian and historical centre, where roads are usually narrow.
- zero emission and zero noise - FURBOT is an electrical vehicle, so it is environmentally cleaner and also less noisy. Due to the low noise level, off-peak and night-time deliveries can be performed.
- intelligent behaviour - FURBOT is endowed with proprioceptive and exteroceptive sensors which allow to understand the internal state of the vehicle and the environment surrounding it. Furthermore, the control system allows the driver to choose among different control modes. Each control mode is designed in order to help the user during his task. For instance, the driving might be fully manual or assisted, according to the situation. The loading and unloading operation will be automatized to reduce the labour that the user should perform.
- multi-functional - FURBOT is an integration of a mobile robot, a van and a forklift. It is able to perform various tasks as robot; it transports pallets as van; and it loads and unloads pallets as forklift.
- transport optimization - fleet management is studied by UDC (Urban Delivery Centre), taking into account the freight transport demand, the road network with the passenger traffic flows and the governance measures. Then the shortest route will be sent to each FURBOT, so that the total trip travelled by all vehicles will be optimized.
- intuitive HMI - FURBOT will be easy to drive thanks to the intuitive HMI and driving assistant.

These characteristics make FURBOT suitable for a sustainable urban freight transport.

In what it follows, particular attention will be given to the vehicle design, Human Machine Interface and the control system logic.

4. VEHICLE DESIGN

4.1. Design methodology

The development of the new concept FURBOT vehicle requires the use of application-oriented design tools obtained by integrating specific design modules with traditional functional and structural general purpose modelling packages. The aim is to study all the main life-cycle design aspects in a simultaneous way and to develop a modular scalable architecture with a set of software and hardware modules re-usable for different vehicles and a new service-oriented infrastructure. Attention is paid from the beginning to the in-use (easy maintenance, energy efficiency, safety, ergonomics, wellbeing of users) and post-use (modules reuse, disassembly, recycling) phases.

Modularity, intelligent mass reduction, suitable manufacturing processes, off the shelf components, and recyclable materials use, have driven the cost oriented design-production process. All the design activities, throughout their development, have been made transparent to and discussed by researchers, freight delivery companies, municipalities and users in order to achieve solutions jointly agreed. The points of view of end-users, such as urban transport service managers and city public authorities, are considered vital for reducing the risk of wrong decisions and ensuring the success of the chosen solution in terms of both life-cycle cost and user satisfaction.

In order to address all main risk issues from the very beginning of the project development, an extensive use of computer simulation, digital mock-ups and virtual reality testing is adopted, to provide the complete characterization of the vehicle in different urban scenarios; this allowed the testing, at the design phase, of alternative competing architectures and the selection of those which improve the overall system performances against manufacturing cost. The computer simulation, moreover, offers, during the vehicle use phase, an important aid for the work management and tasks allotment.

To guide the design, a set of specialized tools and procedures have been exploited. During the definition of the design rules, both state-of-the-art packages for CAE and codes purposely written to solve particular aspects were used, allowing: parametric design by 3D CAD packages; kinematics and dynamics analysis and simulation; resort to digital mock-ups and to virtual reality testing; models tuning with purposely developed blocks (using C, Matlab, Maple, Simulink codes, etc.); to deepen the relational frame and to deal more precisely the reference kineto-dynamics and statics outputs.

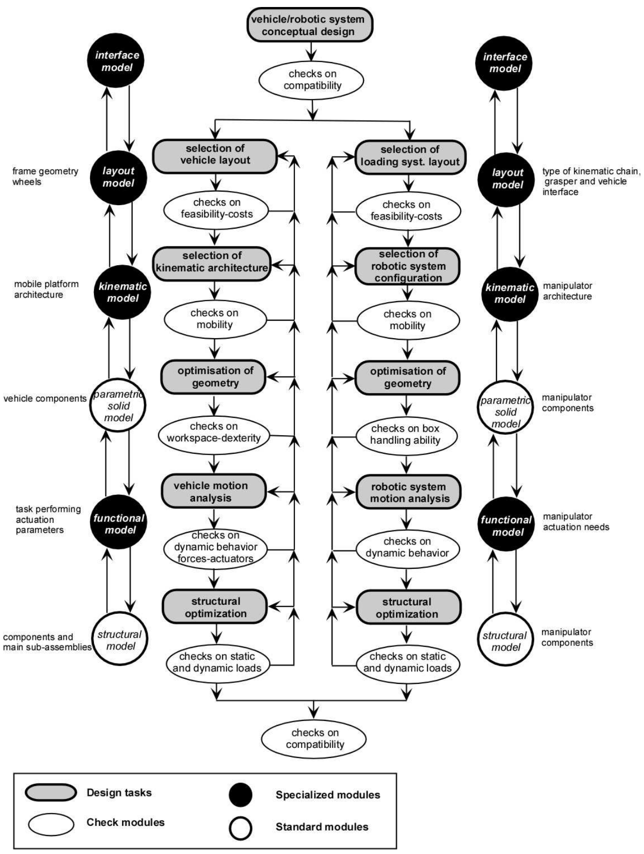

Figure 1: Scheme of the mechanical design process

The vehicle design process is sketched in Fig. 1. The design processes of the vehicle chassis and on board handling system are parallel but integrated at each progress step in order to achieve harmonic solutions.

4.2. Vehicle architecture

4.2.1. Mobile platform

The mobile platform is designed with the aim to tightly envelop the maximum freight volume consisting of two Euro pallet or dedicated boxes (800x1200 mm). The freight weight is supported by a minimalist network of welded stainless steel tubes with square and rectangular section, Fig. 2. The material used for the frame is stainless steel due to the mechanical performance that allows the creation of robust and light frames. The manufacturability and weldability of the material were also considered. Static and dynamic analyses were performed for optimizing the frame cage.

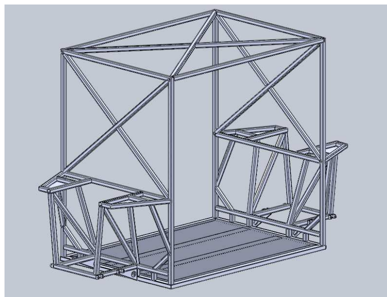

Figure 2: FURBOT frame early solution

The suspension of the vehicle is constituted by a McPherson strut with a telescopic dumper. It allows reduced transversal dimensions and high distance between the lower and the upper attachments, resulting in a reduction of the stress applied to the body. The suspension is integrated with a lifting hydraulic cylinder that allows to move vertically the entire chassis, making possible to shift from the driving configuration to the loading/unloading one and vice-versa, Fig. 3.

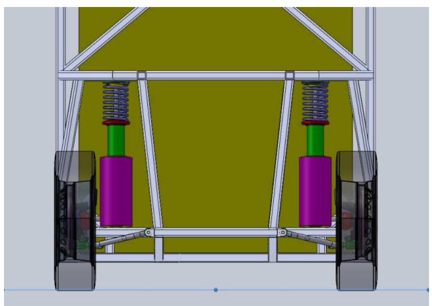

Figure 3: FURBOT chassis configuration

The steering wheels are placed in the front part of the vehicle, while the traction wheels are located in the rear part. Two electric motors are mounted near to the wheels, due to the lack of in-wheel motors with suitable diameter and power available in the market.

The batteries, electronics and service devices are hosted in the rear part of the vehicle.

Ergonomics and life cycle paradigms guided the vehicle chassis and body design. On the upright part of the vehicle a solar panel of 2 square meters is positioned.

4.2.2. Freight handling device

The final design of the FURBOT vehicle will allow the movement of the two Euro Pallets, Fig. 4. The handling system has been designed in order to realize the loading and the unloading operations on the right side of the vehicle. The loading bed space determines heavily the length of the vehicle.

The handling system will be within the loading bed space of the vehicle, Fig. 5. The devices needed to develop the handling system must be designed in order to simplify as more as possible the loading/unloading operations. The interface between the frame of the vehicle and the handling devices must be simple and robust.

The weight of the handling system must be as less as possible in order to achieve the main target of the project to limit the weight of the entire vehicle and consequently the energy consumption of all its devices. At the same time, a simple mechanism to load and unload the freights guarantees these targets.

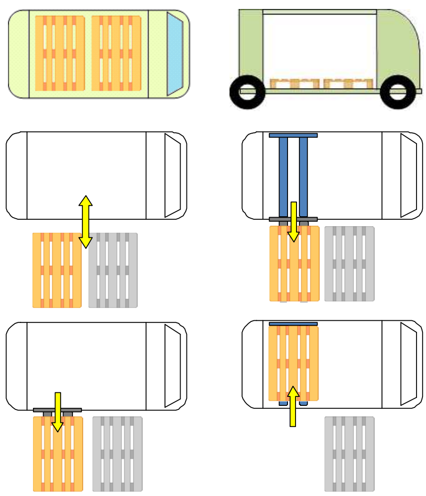

Figure 4: Robotic handling device – loading phase

The handling device is developed in order to move pallets from the ground (or a step) to the vehicle platform's level. This feature plays an important role from the urban logistic point of view; the pallet can be left in any free area of the city, without modifying the urban environment in order to make dedicated collection area.

The loading/unloading movement can be assured through a system that realized at most 2 DoF: vertical and transversal displacement.

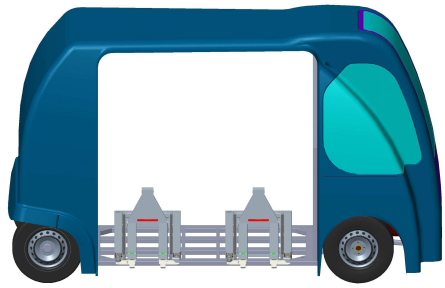

Figure 5: Robotic handling device on FURBOT

5. HMI AND CONTROL SYSTEM

5.1. Human Machine Interface (HMI)

The HMI is designed in order to be easily used by a not specialized user; it is intuitive and training is not necessary. The main components of the HMI are:

- a tablet - it is used to provide general information to the driver. It will display a map and the itinerary that FURBOT has to follow in order to satisfy the list of missions to be dispatched. Furthermore the tablet is used to monitor the vehicle state such as battery, position, velocity, etc.
- a joystick - FURBOT processes the speed and the direction of motion desired by the driver, reading the inclination and the orientation of the joystick.
- a set of buttons - they allow to choose among the possible control modes offered by the FURBOT's control system.
- an emergency leverage - in case of dangerous situation, the driver can use this leverage as emergency brake. When it is activated, the electronic control unit is switched off and FURBOT stops.

5.2. Control System Logic with Control Modes

As mentioned before, in order to improve driver's experience of FURBOT and simplify driver's job, several control modes are developed to deal with different situations during the whole process of delivery. These control modes are: manual driving, assisted driving, automatic loading and automatic unloading. The first two are used when FURBOT transports pallets, and the other two are designed to implement fully automatic loading and unloading operations of pallets. For each control mode, we will choose suitable sensors to provide required measurements.

Manual driving is the basic driving control mode. When it is on, the driver is fully in charge of the whole vehicle just like the drivers of normal trucks. No extra assistance will be provided to the driver and the locomotion of FURBOT is based on the input from joystick, which is controlled directly by the driver.

Assisted driving is an advanced driving control mode. When it is selected, three functions are activated in order to manoeuvre FURBOT more easily and prevent any dangerous situations. These functions are obstacle avoidance, adaptive speed control and parking assistance.

The obstacle avoidance function detects obstacles in front of and behind FURBOT. We define two levels of safety distance: when any obstacle reaches the first level, FURBOT will slow down giving sound alarms to catch driver's attention; when an obstacle reaches the second level, FURBOT stops itself, and then driver can only move FURBOT away from the obstacle. To detect the obstacles, two laser range finders are mounted on the front and the rear part of FURBOT.

The adaptive speed control function helps the driver to control the speed of FURBOT according to the maximum velocity (40 km/h) or according to the speed of vehicle in front of it.

The parking assistance function gives driver visual or sound alarms during parking, when the vehicle is approaching a not desirable configuration. Here rear laser range finder and rear camera information will be combined together.

Automatic loading simplifies the driver's work: instead of lifting pallet by manpower, FURBOT will load the chosen pallet automatically and this process is triggered by a button. The whole loading process consists of three main steps. First, the pallet is detected and recognized using computer vision methods. Then the position of the pallet with respect to FURBOT will be calculated. The images are acquired by a camera mounted on the operating side of FURBOT, where by operating side we mean the side of the vehicle where the loading and unloading is performed. Then, after the pallet's position is identified, FURBOT adjusts his position in order to be close and parallel to the pallet. The precision of this step is crucial: the fork-system must be correctly aligned with the pallet slots; a misalignment will compromise the whole loading operation. Finally, the pallet is lifted up onto FURBOT by the fork-system. When the operation is completed, the driver will be informed by the HMI whether the task has been accomplished correctly or not.

Automatic unloading helps the driver to pick one pallet from chassis of FURBOT and leave it on the ground automatically, without any manpower. This process is also triggered by a button and when the process is done, a message will be displayed on the tablet.

In Fig. 6 it is possible to see in details where the sensors are going to be placed. In particular four different sensing zones are defined. The lasers are mounted in the front and the rear part of the vehicle in order to cover zone 1 and 3, intended for obstacle avoidance and parking. The laser mounted in the front will have a bigger range distance compared to the one mounted on the rear part, since it has to detect frontal collision which results to be more dangerous. In order to provide a visual feedback to the driver, two cameras are mounted: one on the operating side of FURBOT and the other one on the rear part. These two cameras are used to monitor the loading/unloading process (zone 2) and the parking (zone 4). As it can be seen from Fig. 6, zone 3 and zone 4 are partially overlapping, so both the information from the camera and the laser are processed in order to perform the parking.

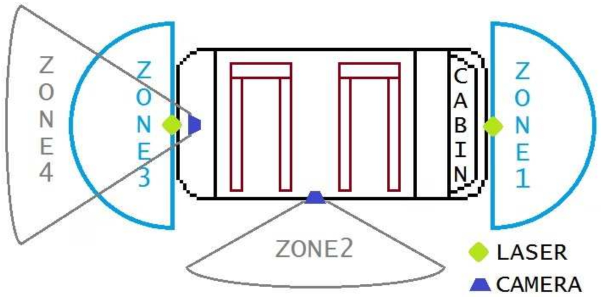

Figure 6: Sensor configuration on FURBOT

6. CONCLUSIONS

In this research a new robotized vehicle for urban freight transport has been presented. FURBOT aims to be an innovative solution in the field of delivery from different point of view. The vehicle architecture has been designed in order to get the best compromise between the load capacity and the size of the vehicle itself. A dedicated handling system has been proposed in order to improve the loading/unloading time and reduce the human effort during this task. The driver's experience is enhanced by an intuitive HMI and a set of control modes. Field tests are planned with the collaboration of the municipality of Barreiro, Portugal.

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