IBIS PROJECT: THE INNOVATIVE, SUSTAINABLE AND INTEGRATED BUS.

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ABSTRACT
The paper presents the results of studies on sustainable mobility, conducted by a multidisciplinary research group. The aim of the activity is to design and assemble a totally modular and innovative bus. This vehicle, designed for sustainable mobility in Italian cities and sites of monumental artistic interest, is equipped with the latest generation of electric motors and batteries. It will therefore be made with environmentally friendly materials. The project aligns with the most recent European research lines on the theme "Building an integrated intelligent transport system". The methodological approach used is oriented towards the creation of a "collaborative ecosystem" between researchers and companies for the definition of a working prototype. The work is in line with the European guide on eco-sustainability of products, the reduction of pollution in urban centers and the so-called "circular economy" that minimizes the risk of non-recyclable waste. The project includes the main specialized multidisciplinary sectors.
Key Words: modularity, sustainability, recyclability, versatility.

1. INTRODUCTION

In recent years there have been numerous specialized contributions offered by research related to the sustainable mobility sector that have proposed new models oriented towards the environment, aimed at experimenting with solutions and operational methods with the aim of "rethinking sustainable mobility". This orientation is always impregnated by an innovative perspective, which tends to "contextualize" the approach, adapting it to the state of the art of urban infrastructures and to the requirements indicated by current environmental policies. At the same time, inexorably, the harmful effects caused to the indiscriminate use of resources to the environment have shown the limits of the previous model of industrial development linked to the logic of the exploitation of non-renewable energy sources. Consequently, this approach has had a negative impact on the socio-economic development of the industry and, in particular, on the automotive sector. In this scenario, it is crucial for the automotive industry to identify a new and more coherent motivation that combines new mobility needs with sustainable design and production practices (Vezzoli, 2014). This orientation, unfortunately, is not completely exhaustive for the definitive implementation of sustainable mobility models, as it would require a fundamental revision of the approach that has been maintained until now, integrating the different "actors" participating in the new sustainable approach, with the current urban infrastructure system that is not yet adequate. In fact, it is evident that the seniority of urban infrastructures (roads, parking lots, pedestrian zones) does not allow the ecological "mobility manager" to benefit from all the sustainable options defined in the design, production and use of means of transport. Therefore, when approaching sustainable mobility, it will be essential not only to pay the utmost attention to the "green" characteristics of powertrains and energy accumulators, but, above all, to operate with the greatest consistency of strategic and planning options in a more complex and integrated mobility system which also includes the various alternative modes of transport. In the last two years, a great driving force has been given by the promulgation of a decree that has significantly opened the legislative horizon on ecological prospects at the same level as those of other European countries and in particular: the legislative decree of 16 December 2016, n° 257, specialized in the creation of an alternative fuels infrastructure, with entry into force of the law starting from 14/01/20171.

2. ITALIAN SCENARIO OF SUSTAINABLE MOBILITY

With reference to the mobility scenario (road transport) of our country, of particular interest is the statistical data emerged on the report prepared by the “Centro Studi Isfort” (Higher Institute of Training and Research for Transport). The results emerged from the analysis of data with reference to passenger transport, describe how the movements of Italians are decreasing in percentage, despite the increase in the use of private cars to the detriment of public transport and therefore as a result of the environment. In the biennium 2017/18 Italians have spent over 40 million hours traveling for their travels. According to the Isfort report, in the last 15 years, overall mobility demand in Italy contracted by 15.2% and even the total number of passenger-kilometers decreased by 23.9% (from 1,561 to 1,188 million passengers at km 2016). Mobility has also been reduced due to the effects of the crisis, but the share of transport on private vehicles has increased. Regarding the modal split, the data of the first survey 2018 indicate a further increase in the weight of active mobility of about one and a half points compared to 2017 (about 23% by bike, 6% by bike). The share of the motorcycle also increased (from 3% to 4%), while public transport remained stable at around 11%. The expectation is therefore that the modal split of 2018 will be in line with that of 2017, with a possible further consolidation of the modal share of low impact vehicles. To this not encouraging scenario we must add the lack of structural interventions in terms of construction of adequate infrastructure and production of new ecological vehicles, in order to contribute to making the park bus less and less old and inefficient from an environmental and travel comfort point of view of sight. The option for public transport is clearly confirmed as the preferred choice of citizens: 94% of respondents consider it useful to "improve and improve public transport services" and of these over half (57% of the total) evaluate this action “absolutely priority". Only 6% of respondents are considered a data considered not useful. For the next decade, new implementation methods will be envisaged for the renewal of the bus fleet; in fact, the government has announced new government offers with the latest stability law for the supply of vehicles for passenger transport. The data previously described highlight the need to operate on the aging of the circulating "vehicle fleet"; according to the ANFIA (National Association of Automotive Industry Factories) elaborations on the data of the Transport Archive of the Ministry of Transport, the bus market by type is as follows: 1.547 buses (+ 14.3% on 2014), 124 minibuses (+ 9, 7%) 487 minibuses (+ 39.5%) and finally the 262 school buses (-21%). Another significant figure is represented by the ecological share represented by "green" vehicles; out of 2,420 new registrations, the electric traction buses sold were only 35 and those with natural gas 92, representing therefore only 5.2% of the total. As already highlighted, it is not easy to find a more effective and efficient model of sustainable mobility that characterizes the carriers for the public/private passenger transport service, since the innovative solutions for the infrastructures and services connected to them are not always integrated with each other. A research report provided by the E-Mobility Report of the Milan Polytechnic[2]underlined that in 2017 in Italy there are only 2750 public places used to recharge electric vehicles, on the national territory and just fewer than 10 thousand private columns used for the same purpose. Comparing the previous numerical values with the data collected with reference to the upgrading of the Italian infrastructural network, it should be noted that these numbers are totally inadequate compared to the quantity of electric car charging stations present on average in the European territory; in particular in Europe, they would be 80% more than in Italy. However, these values, albeit small, showed a significant growth trend as the installations of "green" infrastructures, such as public recharging points, increased in total by about one thousand units in the course of 2018. The data collected express the nature of infrastructural deficiency, highlighting that the number of electric car columns in Italy compared to that of other European countries is 1/5 and 1/10. As reported in the work of Köhler et al., in addition to the implementation of integrated systems and infrastructure for sustainable vehicles, the impact of transport on the environment, to implement a transition to sustainable mobility requires their change of "lifestyle", “the model shows that technological transitions are more likely: the transitions of lifestyle change require sustained environmental pressure on society and behavioral changes by consumers” (Köhler et al., 2009). Awareness that the individual levels are able to work in synergy between the different strategic levels of action: legislative, production and use of carriers the dissemination of intangible transport services shows that the communities are willing to experiment with new models of public transport shared in the active participation in the choice of vehicles for mobility (Vergragt, Brown, 2007). The data collected in the last two years 2017/2018 in which the reports on climate analysis refer to the 28 EU Member States show that around 31% of greenhouse gases and a similar percentage of carbon dioxide emissions, as well as a significant rate attributable to urban air and noise pollution, they are linked to transport and mobility. These European values demonstrate how the European transport system has not been able to operate independently the reduction of its "environmental weight" on the global economy, in terms of environmental protection and protection of the health of the inhabitants of urban and extra-urban areas. The statistical trend shows an exponential increase in emissions, and more significantly in the last period due to surveys conducted in 1990 and 2018, in which the record values of greenhouse gas emissions were recorded due to public transport and private. Wanting to segment the distribution of pollutants, it emerges that 73% of the greenhouse gas emissions produced by transport are referred to road transport, with this distribution in the distribution between carriers: private transport is with 65% of total emissions of harmful gases the main "pollutants", heavy vehicles for the transport of goods and buses are "responsible" for 20% of harmful emissions and finally the commercial vehicles used in urban distribution the remaining 15%. On the basis of data provided by the European Environment Agency (EEA), the 1990-2018 figures for the European Union are worrying, in which the polluting weight caused by the road transport sector increases emissions from around 125 millions of tons of carbon dioxide C02. Even in the road transport sector, the large car manufacturers have invested on average a part of their turnover in research and development at the European level with a value of around 5%. In addition, the European Environment Agency highlighted important signs towards clean and intelligent mobility with 26% of total investments in research and innovation in Europe, based on the European Commission data estimates of 2018. It will therefore be necessary to apply new strategies for the transport sector, and in particular it would be appropriate to pursue those linked to the "modal shift", that means an inversion of the route that leads to the transfer of the demand for mobility, from means of transport, more polluting to those less polluting. The modal distribution in transport, the "green" technologies will demonstrate a virtuous path able to combine the ever-increasing need for travel with a diversified type of transport in the perspective of sustainable mobility (Vezzoli et al., 2009). The new urban vectors configured as "service platforms", may be characterized by greater specific typological diversification in the optimization of uses such as electric, hybrid and low-emission buses, characterized by a technological renewal of the engines, with a view to energy efficiency, passenger safety and environmental sustainability (Vezzoli et al., 2014).

3. A MODEL OF SUSTAINABLE MOBILITY: THE IBIS CASE

In this scenario we insert our research and experimentation contribution focused on the objective of designing and building an "eco-oriented" bus as a product/system for urban passenger mobility to be carried out in the historic centers of our cities. The project proposal of the vehicle "IBIS", Innovative Bus, Integrated and Sustainable3 is based on the concept of an innovative urban bus design and production platform. The goal is to provide a means

[2] Digital Energy Report: Smart Cities and Digital Energy in Italy: an overview of light and shadow Presentation Digital Energy Report February 14th 2019 Polytechnic University of Milan.

3 Project "Innovative Bus Integrated and Sustainable" - IBIS-PON I & C 2014-2020 ", (03/04 / 2017-31 / 12/2018), funded by the Ministry of Economic Development - (project budget: 3 million euro, budget Local: 317 k €) Scientific Coordination P. Ranzo, R. Veneziano, F. Fittipaldi postdoc reaserch.

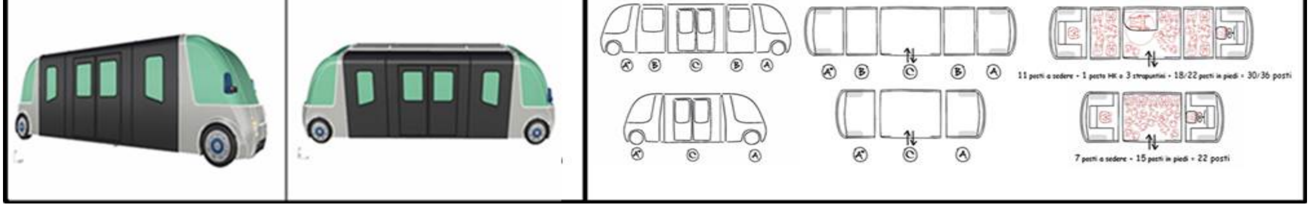
of transport for sustainable, collective and competitive urban mobility. The approach used in the research has made possible a design and production process, which had the objective of maximizing the benefits, environmental and economic linked to the industrial development of the carrier (Verganti, R., (2009). The research and experimentation project focuses on the following areas of research and experimentation:

- Definition of functional and morphological aspects of the main vehicle components;
- Study of the frame module, body panels, interior coverings and furnishings;
- Study of eco-oriented materials to be selected for vehicle components;
- Analysis of the assembly and disassembly methods of the components;
- Study of propulsion and power supply solutions (engines, batteries, on-board electronics);
- Definition of production technologies for the optimization of the production cycle.

Particular attention was paid to the definition of an abacus of eco-oriented materials for the realization of the components and the internal and external finish of the vehicle. The design of particular devices (body panels) and their functional parts (interior panels, roof pavilions and finishing elements) has been integrated into the experimentation of a polymer matrix material with appropriate structural reinforcements, oriented in the directions of maximum mechanical stress , which confer strength and rigidity / rigidity in specific points. This part of the research, conducted by the Institute of Polymers, Composites and Biomaterials (IPCB) of the National Research Council (CNR) of Naples, concerned the engineering of polymeric and cellulose materials and thermoplastic polymers based, treated with traditional methods (manual lamination/stacking, molding, compression molding) and Nano composites with specific mechanical characteristics and eco-oriented properties.

3.1. The modular structure and the production platform

The IBIS project is structured around the concept of an evolved modular platform and consists of sub-modules that aggregate, making possible different functional configurations of the bus, optimization of production processes and materials used. The approach to this operating model is not unpublished in the automotive panorama as it was developed following the economic crisis of the eighties by US and European car manufacturers. In particular, this methodological/operational approach was tested and implemented, following the adoption of practices of the "lean product development", particularly in Japan, where they have increased the use of outsourcing, transferring to the development of suppliers an increasing number of components. This trend has increased interest in modularity as a tool to facilitate the integration of external sources of innovation; Specifically, a series of advantages is evident in the development of a standard platform that can be used for various vehicle models such as: benefits of economies of scale, instead of the development and production of different platforms; acceleration of the production process and development of new models and finally a better use of production capacity and flexibility to respond to changing market dynamics. In the automotive sector, the standardization of the "module" concept is intended as a re-proposition in the compositional schemes of common elements, with the definition of a "product platform" that allows the creation of a family of products characterized by a structural and facility. A "platform" can therefore be defined as the basic mechanical structure of the car on which to build more diversified typological models (Berlina", Station wagon, SUV "Sport Utility Vehicle"). The effectiveness of this approach lies in the ability to share subsystems during the development of differentiated solutions for the bodywork and for all other elements that must be harmonized with the needs of different markets, segments and individual preferences. In relation to the configuration of the platform designed for the IBIS it was possible to define the various customizable configurations with the aggregation of three main modules; "module A" (front and rear cabin), "module B" (element corresponding to the passenger compartment) and finally "module C" (element characterized by double doors with folding doors).



[Figure 1] IBIS bus style sketches (conceptual proposal) Modularity scheme

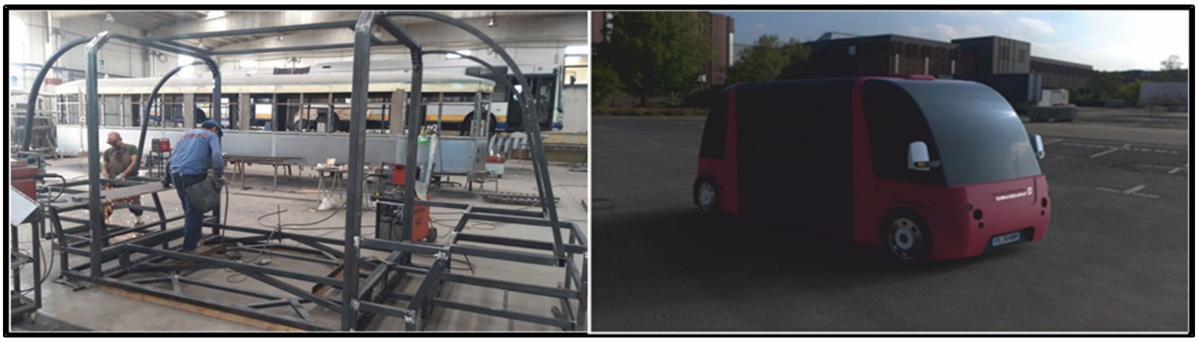
The vehicle can therefore be configured in a long wheelbase version, that means the wheelbase, also called wheelbase (distance between two vehicle axles), indicates the distance between the axle of a front wheel and the axis of the rear wheel placed on it side. In this way it will be possible to set up the vehicle with the ACA modules for the vehicle "short wheelbase" and with the ABCBA configuration for the "long wheelbase" declination (figure 2). The IBIS vehicle module is based on the mirroring of the front and rear of the vehicle for the elements (A), the mirroring of the passenger module (B) and the uniqueness and reversibility of the central module (C). This compositional scheme, unpublished in a means of road transport, but very used in the railway sector, has allowed to reduce by 30% the costs of design and construction of structural components and bodywork (chassis, body panels, mudguards and wheel arches)) that those of interior finishes, with related to sustainability for the project from the environmental point of view. Also for the vehicle chassis the modular solution allows a productive and therefore ecological saving using a "space-frame" type, that means frames characterized by reticular structures consisting mainly of a network of standard elements or metal segments with circular or square section for the tie rods and struts, connected to the ends to form triangular base geometries, with permanent connections that can be traced back to the type of rigid joints. The geometrical / functional scheme thus defined, allows the overall structure to be optimally stressed all the structural elements involved by the forces both at bending and torsional loads and at the same time allows a characterization of the modular frame with high rigidity. The advantages of this solution can be summarized as follows:

- decrease in the number of common parts with a consequent reduction in costs of 20%;
- reduced investment on machinery reduced by 20% and reduced production costs by 30%;
- 20% Time-to-Market reduction with maximum flexibility for changes in the bodywork;
- improvement of dynamic performance and better crash behavior + 15%;
- reduced overall dimensions in production plants as most of the sub-components are prepared before assembly of the bodywork.

The vehicle is designed to accommodate 22 users with a single lowered platform, with no "step-up" in the rear area, typical of competing electric buses. This is possible thanks to a battery compartment located between the axles that guarantee an excellent balance of the vehicle. The low belt line emphasizes the permeability of light and space in the "interior / exterior" ratio, such as the large glazed surfaces, the transparent roof, the large front panel also free of cumbersome pillars characterizes the vehicle setting with destination housing for passengers of the "open space" type. The rationalization of the components of the frame and of the body, involves concretely the reduction of the weights to manage in the movement of the vehicle optimizing the performances and the consumptions. The possibility of reducing the use of the material component of the materials for production, has the purpose of simplifying the "bill of materials" of the elements making up the vehicle in the production phase, and consequently can reduce the costs of assembly, maintenance and not from less the final price of the vehicle on the road.

3.2. Battery

In today's reference market, battery-powered electric vehicles are significantly favoring significant sales volumes. To date, there are many types of batteries for the automotive industry and the choice of the right choice is always the result of a careful analysis in terms of costs / benefits with reference to performance. The most important features are essentially the efficiency of energy storage, construction features, cost price, safety and useful life. In this activity the research is oriented towards a family of main products: lithium ion (Li-Ion), molten salt (Na-NiCl2), nickel metal hydride (Ni-MH) and lithium sulfur (Li-S), all with the same ability to accumulate electricity. Some important studies in the scientific literature have highlighted the possibility of comparing four different types of electric vehicle batteries on the same model to evaluate the vehicle's autonomy and the efficiency of these types of batteries on a real-time, digitized driving cycle, by computer simulation. (Zhang, 2015). In reference to the energy accumulators to be allocated to the project vehicle, a specialized consultancy offered by the Department of Industrial Engineering / University of Salerno advised to implement in the vehicle the type of "ultra-capacitors", which presents a higher energy density and actions to devices plus area for holding a charge. Specifically, the use of lithium ions allowed the accumulation of energy on the market. In particular, the choice of telling the accumulation of energy was even more effective considering also the most important scientific experiments in the literature that have validated as a priority the use of "super-capacitors" in rubber traction systems have the advantage of accumulating the energy on board, unlike traditional electrochemical batteries, with the same mass and at the same time can deliver and receive energy from almost two orders of magnitude higher. Next was faster and more efficient. Not least must consider the useful life that is at least a million cycles written; specifically on an automatic recharge of electricity lasting 5-10 seconds the bus will travel 2-3 km. Charging takes place at each stop during the time of ascent and descent of the users through an automatic connection between a "catch" under the vehicle and a "conductive carpet" positioned on the road. It will be possible to use a "photovoltaic shelter" for the single stops where there will be, for example, charging columns for batteries with pedal assisted bikes. With a view to an effective system, the bus is obviously equipped to accommodate disabled people. Energy support story will serve an integration of the vehicle's electrical consumption in parallel, compared to that provided by the alternators. As described in the latest EUROBAT report, the significant advantage of lithium ion electrochemistry is its ability to allow and control very high charge rates (including regenerative breaking energy recovery) and the associated discharge. Full charging is achieved in less than an hour with the appropriate equipment. The benefits include less downtime, resulting in greater availability for the return to the bus passenger services. The lithium-ion battery also offers better long-term performance. Therefore, while the high initial costs of acquiring a lithium-ion battery seem high, the reduced need for maintenance and the life of the same battery will present an added value in the cost / benefit analysis typical of TCO (Total Cost of Ownership).



[Figure 2] IBIS bus design: construction and visualization of prototypes in full scale

4. CONCLUSION

The research carried out in the IBIS project made it possible to realize a vehicle with electric power and alternative propulsion with a modular compositional scheme and to evaluate its benefits both in terms of sustainable design and in relation to the economic balance of design / construction costs. The expected result was validated by the performance of the real-scale and functioning project vehicle simulator as a further "demonstrator" of the effectiveness of the design approach. The project aims to achieve the following results:

- support a dialogue between different scientific disciplines, in which to share experiences of integrated research;
- supporting the competitiveness of companies through design methodologies oriented to the overall sustainability of the design and production process;
- experiment with new production models to optimize production in the automotive sector.[4]

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4 The paper, realized in the full collaboration of the authors, has a paragraph attribution: 1, 4, edited by P. Ranzo, section 2 and 3 edited by R. Veneziano; section 3.1, 3.2, edited by F. Fittipaldi.