

Smart City and Industry 4.0

New Opportunities for Mobility Innovation

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Abstract. The manufacturing industry is undergoing profound changes, so much so that it recognizes a new phase, called Industry 4.0 both for the shape and structure of the supply chain, production of goods and energy transition. An example of this epochal change is the auto and boat motive sector; a sector that sees the increasingly marked electrification of its products, characterized in parallel by a percentage modification of materials and production methods (new materials, 3D print). The development of the smart city is closely connected with the phenomenon of Industry 4.0, both in terms of mutual capacity for innovation, integration and digital transition, which makes its effects felt as well as in production lines, supply chains, with tangible effects in the urban spatial distribution of goods and services. The goal of the paper is to investigate the effects of industry 4.0 on slow and ecological mobility and in new environments: protected areas (natural and semi-natural parks) and historical and cultural areas. The case studies are: Natural Park of Molentargius and Archaeological Park ok Nora in the metropolitan city of Cagliari (Sardinia, Italy) that represent a significative case of contamination lab (Luna Rossa team, Atena and Dicaar of University of Cagliari).

Keywords: Smart city · Industry 4.0 · Sustainable city · Slow mobility

1 Introduction

From the first industrial revolution we are proceeding into the fourth industrial revolution, the digital one, which is not only an advancement of internal processes, but an absorption and improvement of all emerging technologies [1].

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Industry 4.0 optimizes the overall traditional production cycle, making all phases and processes interact and represents a radical change in industrial production with profound implications for the city and its community [2]. The focus is not only on large numbers, those approved by consumers, but also on the individual buyer who, with his choices, can change the dynamics of production (3D print). Industry 4.0 is based on digital manufacturing technologies: Internet of Things (IoT), Big Data, Cloud Computing and Robotics.

Industry 4.0 today also finds concrete application in Smart Cities, or cities based on sustainable development in order to ensure a high quality of life for their inhabitants. In this case, the Internet of Things (IoT) is applied to logistics and intelligent mobility services (IoS) and the use of natural resources (IoE) [3, 4].

In this synthetic framework, the city is not only a reality of stone [5], but above all a place of highly expressive cultural conceptualities with multiple meanings between past, present and future. In fact, in the city all our aspirations are possible, which manifest through the progression of "innovation" [6], capable of reaching new cultural and technological goals, also through a new image of the city [7, 8]. Since the 19th century, the interaction between industry and technologies has guided the spatial distribution of both cities and transport and the community and related services [9].

Industrial development is in fact the engine of urban development. The 'industrial cities' grew rapidly and from that moment in Europe all urban development models contemplated industry, in all its phases, up to industry 4.0, which in the Smart City finds application through internal/external connections in all network directions, both physical and digital [10].

In fact, the Smart City, characterized by an essentially instrumental system, is aimed at regulating all urban circuits in a faster and more comprehensive way, through communication networks inside and outside the city, which is well suited to industrial processes 4.0 [11].

However, even the Smart City itself has evolved and manifests itself through 'digital ecosystems' without apparent limits and with the aim of global "Urban Quality". Industry 4.0, in short, favors the optimization of resources and products in the complex global fluidity of urban markets, between digital sociality (social network), personalization (3D print, just on time) and process and result quality (digital ecosystem) [12].

In this synthetic framework, the objective of the paper is to evaluate the opportunities that can be generated by recent innovations in mobility to promote sustainable accessibility in areas of environmental protection (natural and semi-natural parks) and/or historical and cultural areas (archaeological parks).

After the introduction (Sect. 1), the paper develops: Sect. 2 - Industry 4.0 and sustainable mobility (Sect. 2.1 Sustainable mobility and opportunities for territorial enhancement; Sect. 2.2 Sustainable mobility and circular economy; Sect. 2.3 Sustainable mobility and smart city); Sect. 3 - Materials: GoGo, innovation in slow mobility (Sect. 3.1 GOGO: main characteristics); Sect. 4 - Case study: Natural Park of Molentargius and Archaeological Park of Nora in the metropolitan city of Cagliari (Sardinia, Italy) and Sect. 5 - Discussions and conclusions.

2 Industry 4.0 and Sustainable Mobility

Digital, artificial intelligence and electrification have long since become part of the great theme of urban mobility. In the next few years, urban vehicles (land and naval) will have a profile and functions that are very different from the current ones, becoming real concentrates of innovation [13]. Technological development combined with the need to reduce energy consumption, together with the digital transition, has a decisive influence both in production processes, on the creation of increasingly smart models, and on consumer habits, more oriented towards sharing than possession [14].

2.1 Sustainable Mobility and Opportunities for Territorial Enhancement

Electric mobility, which derives from industry 4.0, offers greater opportunities for accessibility and sustainable use of places to the entire population [15], not only in urban areas but also in contexts of protected natural and cultural value, where accessibility is often denied or severely limited. Furthermore, the growing innovations in this research field introduces new contents in urban mobility planning, which concern both the management of potential impacts [35] and, particularly, the design of roads and waterways, which become a fundamental component of more comprehensive urban regeneration policies and projects [16]. This is even more evident in the cases of waterways which nowadays do not properly constitute communication routes. Here, not only energy supply systems but also the entire organizational and functional structure of the immediate context should be planned, especially when this is not yet adequately served due to scarce use. It means that the introduction of electric vehicles and electric boats may significantly affect the processes of enhancement and use of urban and suburban settings characterized by a different degree of naturalness, opening new scenarios also in terms of tourism development [17] (Fig. 1). More precisely, when we consider the ancient core of the city and its consolidated parts, it is expected that the existing road network will constitute the main network infrastructure on which to organize the electric charging points and related services (parking, car and bike sharing, e-mobility, refreshment points) in contexts not yet equipped. The introduction of electric cars, e-micro mobility and electric public transport makes it possible to promote a sustainable use of the ancient core, which is essential for ensuring an integrated conservation of cultural heritage. Even in the rural context, the existing roads will constitute the network infrastructure for electric cars, electric farm machinery, and e-micro mobility, which is strongly related to slow tourism. In the latter case, the growing use of new forms of sustainable mobility supports an overall regeneration and enhancement of the territorial capital (tangible and intangible) in response to the demand for slow tourism [18, 19]. Moreover, electric vehicles and boats may represent an extraordinary opportunity to rethink the entire system of accessibility and use of protected natural areas, both terrestrial and marine, characterized by different degrees of conservation. In Italy, Natural Parks constitute significant components of the natural heritage, both in quantitative and qualitative terms. In the Sardinia Region, the extension of the Natural Parks and their morphological features [20] make the introduction of electric vehicles (electric car, e-micro mobility) essential to allow sustainable accessibility.



Fig. 1. Sustainable mobility in the metropolitan city (Authors: M Ladu and G Balletto, 2022)

Also in this case, the need to ensure an efficient energy supply system requires the selection of the most suitable areas for creating charging stations for electric vehicles, car parks, interchange nodes and, where necessary, refreshment points. Finally, in the case of marine protected areas, the main effects of the introduction of electric boats may concern the landing and mooring points of the boats, coinciding with the starting and ending points of the planned routes. As a matter of fact, the design schemes of these new hubs should include the construction of piers equipped with the necessary infrastructure, shading and refreshment points. Similar design schemes may also concern underwater archeology sites, which cannot always be visited before the introduction of the recent electric boats.

2.2 Sustainable Mobility and Circular Economy

In the paradigm of sustainable mobility, sharing, innovation and sustainability are the cornerstones to which are added: modularity, longevity and recyclability of products and services and consumption models based on the logic of sharing economy and "product as a service", abundantly referred to in the National Resilience Recovery Plan (PNRR) [21, 22]. In this sense, the fundamental factors that identify and guarantee efficiency in terms of environmental sustainability and reduction of waste of resources are represented by:

– The use of renewable energy and recyclable raw materials;
– The product is offered to the customer no longer as an owned asset but as a service to be used for a certain time and with specific methods;
– The development of platforms for sharing goods and services, to encourage savings and the efficiency of resources.

– Design and manufacture of goods with a long-term life cycle;
– The recovery and recycling of waste for the creation of new production cycles.

Furthermore, the right to mobility, precisely because it is recognized in the Constitution of the major international countries, has contributed to the renewal of the corresponding economic sector. Furthermore, this sector, in line with the 2030 objectives, innovates towards the circular economy of: sharing, slow and e-mobility, which represent new mobility opportunities also for areas of environmental/cultural protection. In addition, the thrust of the system of increasingly stringent laws in terms of emissions (Green Deal) and management of the vehicle end-of-life phase has led to a consequent remodeling of the products offered on the market. In particular, the electrification of vehicles combined with reuse/recycling deriving from design for disassembly continues to emerge. However, the problems associated with the batteries of electric vehicles are not negligible [23, 24]. In this synthetic picture, it emerges that the circular economy constitutes a fundamental dimension of sustainable mobility.

2.3 Sustainable Mobility and Smart City

The binomial sustainable mobility in the smart city represents the set of networks (both transport and technological) in support of economic progress and the improvement of citizens' quality standards, managing to ensure safe travel with a minimum environmental impact. The goal that combines sustainable mobility and the smart city is ecological and economic sustainability of travel within the urban network, protecting health and developing a renewed sense of community and belonging to places. Furthermore, the progressive innovation of digital technologies strengthened the pillar of Smart Mobility, sometimes making it the characterizing pillar of the smart city [25]. In other words, Smart Mobility intervenes on two levels, that is, it makes "intelligent infrastructures", developing applications such as Telepass Pay, easy Park, etc.; it makes intelligent vehicles" by developing sharing associated with electric motors on cars, bikes, micro-mobility and boats. In particular, boat sharing has all the characteristics to become the new strategic frontier in urban mobility of waterfront cities, similar to Uber and BlaBlaCar for cars [26].

3 Materials: GoGo, Innovation in Slow Mobility

Strategic urban metropolitan planning represents the tool for harmoniously governing urban innovation in all its forms, trying to identify shared scenarios of municipal urban planning. On the occasion of the drafting of the Strategic Plan of the Metropolitan City of Cagliari (2021) in the participation phase with the local community, the proposals from the community were collected. In particular, innovative mobility proposals were collected which are also capable of enhancing protected environmental and cultural areas. Among the proposals received, the one called GoGo was consistent on two planning levels: the Metropolitan Strategic Urban Plan of Cagliari and the Sustainable Mobility Plan of the Metropolitan City of Cagliari. In particular, the GoGo is an electric boat

suitable for navigation, and has the aim of becoming part of the growing offer of sustainable mobility. Furthermore, the GoGo project (poject of ing. D. Tagliapietra) is part of the stay in Cagliari of the America's Cup Luna Rossa Prada Pirelli team in which Tagliapietra actively participated, thus being able to evaluate the main geographical and environmental characteristics of the navigable contexts. The contamination between the strategic policies of the metropolitan city of Cagliari, the Luna Rossa team, and in particular with the engineer Tagliapietra made it possible to systematize the GoGo project, which in 2022 was also included both in the Urban Plan of Cagliari and in the seaside part of the archaeological park of Nora.

3.1 GOGO: Main Characteristics

The GOGO is an electrified boat, a trimaran of 3.85 m in length and 2 m in width, having the ability to carry from four to six passengers depending on the variants and the ability to recharge the batteries through photovoltaic panels that also perform the dual function of protecting the passengers themselves from solar radiation. GOGO is a boat particularly suitable for use in inland waters and protected marine areas, guaranteeing environmental protection and passenger safety. The GOGO is built in thermoplastic material - multilayer polyethylene - entirely recycled, allowing energy savings - and raw material cost - during construction, as the Table 1:

Table 1. Operation during construction

Operation	MJ/Kg
Plastic recycling	22.00
New plastic production	86.00
Energy saving with recycled plastic	64.0
Energy recovered with burning plastics	48.00
Electric energy converted from thermal energy	24.00

In addition, the Solar Roof allows you to perform multiple functions (Fig. 2):

Battery charger and passenger screen function creation of a possible hub for energy exchange between different boats.



Fig. 2. Energy interchange scheme - joystick for direction and speed control and max speed 4 knots – mooring (source: D. Tagliapietra and L. Carboni)

The GOGO also allows access to protected marine areas, maximum environmental and underwater archaeological protection:

– absence of environmental pollution
– no wave motion formation
– no use of fuel and consequent emissions into the atmosphere and water

Finally, the living deck configuration allows a wide view and passenger involvement. The recycled multilayer polyethylene structure ensures sturdiness to the hull, which does not require maintenance [27].

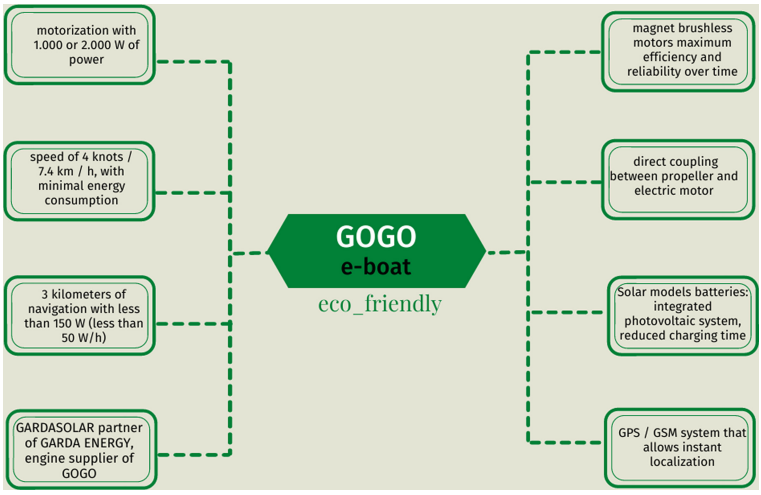


Fig. 3. Characteristics of the GoGo

In summary, the GOGO is an extremely innovative, eco-friendly, customizable boat, made with entirely recycled thermoplastic material, to the benefit of production costs, whose main technical characteristics are summarized as in Fig. 3.

4 Case Study: Natural Park of Molentargius and the Archaeological Park of Nora (Metropolitan City of Cagliari Sardinia, Italy)

The Metropolitan City of Cagliari was established in 2016 and consists of 17 Municipalities: covers a territory of about 1250 square km with a resident population of about 414,370 inhabitants. The Strategic Plan of the city and the Sustainable Urban Mobility Plan (SUMP) represent the main forms of government of the Metropolitan City of Cagliari in the aftermath of the health crisis [28] and in the light of the urgent energy transition. In this sense, the health crisis and the energy crisis have confirmed how to give priority to the design of open spaces and their external mobility (pedestrian, cycling, boat and micro-mobility) as well as the simultaneous containment of consumption and production of automatic energy and circular economy [29–31]. Open spaces include natural parks and archaeological areas that are an integral and substantial part of the ecosystem services of metropolitan cities and the surrounding area [32, 33]. Moreover, the strengthening of outdoor activities such as street sports have implicitly confirmed the latent urban and territorial walkability [34]. In this sense, the Strategic Plan of the metropolitan city of Cagliari has understood as sustainable mobility, energy efficiency, improvement of the quality of life of people and reduction of air pollution, are decisive goals for the near future, a change in people's lifestyle that passes for the health and well-being of the community. Below is the combined framework between the stress levels of cycling and sharing e-boat proposed both in the city of Cagliari, which connects the Molentargius natural park and the train station. Below is the combined framework between the stress levels of cycling and sharing e-boat proposed both in the metropolitan city of Cagliari, which connects the Natural Park of Molentargius with the train station and Archeological Park of Nora with the nearby aquarium.



Fig. 4. E_Boat sharing proposal for the Molentargius natural park, in the metropolitan city of Cagliari (Authors: M. Ladu and G. Balletto, 2022; Source: https://bicistressatedaltraffico.it/#13.55/38.99162/9.01987).

The result is shown in Figs. 4 and 5.

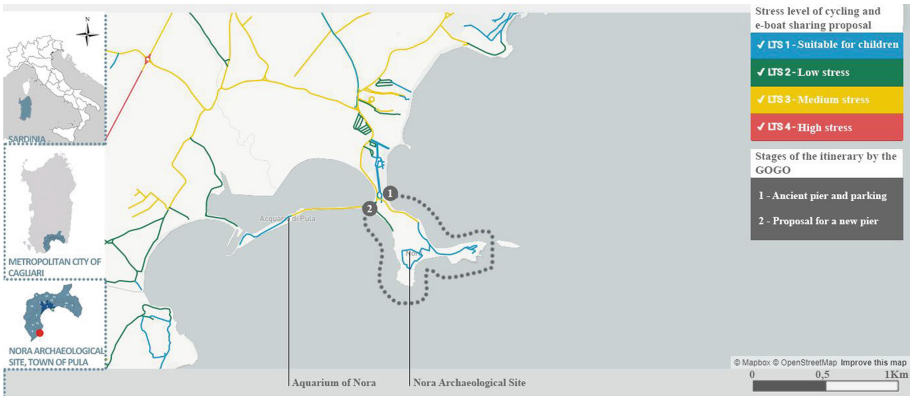


Fig. 5. E_Boat sharing proposal for the Nora archaeological park, in the Metropolitan city of Cagliari (Authors: M. Ladu and G. Balletto, 2022, Source: https://bicistressatedaltraffico.it/#13.55/38.99162/9.01987)

5 Discussions and Conclusions

Innovation in mobility are key factors for fostering the ecological and energy transitions, with reference to how cities and territories will cope with the challenges they are - and will be - facing in the present and in the years to come. The topic examined here address different aspects of the planning process in transition (ecological, energetic and circular). What is examined here in fact deals with two aspects tightly connected: the network side and the means side. On one side mobility at urban level is still mostly referred to private cars/mopeds and bikes, with a modal share. Observing data from the Plans for Sustainable Urban Mobility (SUMP) the municipality of Cagliari, touches 60%, with bigger figures for other municipalities part of the metropolitan city - i.e., Capoterra reaches 79% of private transport share over the entire traffic composition. There is a need in a such sense to keep moving the traffic share towards more sustainable transport means, including walking, biking, local public transport and other forms of mobility. These are generally referred to landforms of transport and means, that can be integrated, in cities and settlements located in proximity of sea, rivers and canals and other water bodies, by waterways and related means that can contribute to moving away people's movement from land, decongesting it and therefore reducing the pressure on the urban environment. This process passes through the design of new routes on the water, changing the lines and orientation of communications and using and reinterpreting connecting lines, in many cases not used for long periods of time. In the case of Cagliari, the presence of the sea is related to the organization of the same city following capes, gulfs and inlets and, in parallel, the presence of other water bodies as lagoons, lakes and canals. These can host alternative routes to other more traditional ones, in line with the most recent trends of modal shift towards more sustainable transport means, by covering in parallel similar destinations as those touched by traditional transport means, and also allowing a re-discovery of locations that can be more easily reached by water transport instead of land-based ones. In such a sense, a mixed of integration and decongestion of traffic can be reached.

On the other side the attention is on the new transport means and opportunities for fostering a proper transition towards less pollutant and more sustainable vehicles. In such a sense, our attention was on new solutions for water mobility, where the new water routes and lines as above can be coupled with an electricity-based propulsion that can therefore allow moving pollution out from the urban and related environments. Not only electricity, however, represents the effort to move towards more sustainable transport means, but a full re-design of transport vehicles represents a promising direction to head towards. The GOGO boat can be considered an interesting example of such an application of this concept. Attention over design, materials, power units and weight is, in fact, important for realizing new transport solutions. A similar attention must be, however, put also on the network itself, with the presence of charging stations along the routes and, possibly, with the creation of low-carbon emission energy production systems to supply them. In such a sense, integrating a combination of traditional charging points and the implementation of micro-gridding systems could highly benefit a modal shift and a more sustainable mobility.

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