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Traffic models in the presence of Autonomous Vehicles I - Special Session

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Freight modelling and operations - Special Session

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Vehicle design and communications

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Optimization in public transport management II

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Modelling and ITS II

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Smart Mobility: an evaluation method to audit Italian cities

Rosaria Battarra
National Research Council
Institute of Studies on Mediterranean Societies
Naples, Italy
battarra@unina.it

Floriana Zucaro
University of Naples Federico II
Department of Civil, Architectural and Environmental Engineering
Naples, Italy
floriana.zucaro@unina.it

Maria Rosa Tremiterra,
University of Naples Federico II
Department of Civil, Architectural and Environmental Engineering
Naples, Italy
mariarosa.tremiterra@unina.it

***Abstract*—In the debate on smart cities it is widely shared that smart mobility plays a key role, as (i) is one of the most important facilities to support the functioning of the urban area, (ii) produces several negative impacts (such as: pollution, traffic, street congestion), (iii) allows to use broadly ICT to improve its efficiency. ICTs help transportation managers deliver the most dynamic, flexible and cost effective transport options and contribute to achieve cities' climate targets by lowering energy use and greenhouse gas emissions. Nevertheless, if the current ICT use puts forward many opportunities for developing a more sustainable mobility system, it also raises many challenges. For instance, it is difficult to measure the real effectiveness of these solutions, if not in terms of the consensus achieved by the local authorities and in budget increase of seller companies. Furthermore, ICTs need sophisticated management systems and have operating costs which seem to be not comparable with the benefits that they provide for. According to this backdrop, EU in the latest communication on ITS (EC, 2013) underlines that "despite a high number of technical solutions and mature applications the uptake of ITS applications is fragmented and large differences between cities remain". In this framework, the aim of the paper is to analyze how Italian cities are interpreting the topic of Smart Mobility, with particular attention to the use of new technologies in urban mobility. According to scientific literature review, a set of indicators was identified and organized into three categories representing the main aspects of Smart Mobility: ICT, Sustainability and Accessibility. This set was applied to the Italian small and medium sized provincial capitals with a population from 50.000 to 250.000 inhabitants in 2016. Lastly, a graphic and synthetic representation of the collected data has been developed, in order to give an easy overview of Italian cities regards Smart Mobility characteristics. The analysis showed that the use of ICTs mainly concerns the introduction of devices and sensors for improving performance of transport system and information to users, as well as the promotion of a more sustainable mobility. The spread of ICTs in most of the cities appears still unsatisfactory: Italian cities are oriented towards a more sustainable and accessible urban mobility model rather than a smart one. Indeed, ICT solutions for Smart Mobility seem to represent isolated initiatives, without indispensable scientific and disciplinary quality criteria. Furthermore, ICT initiatives are not included in shared and coordinated strategies integrated with the urban transformation governance, as part of a global policy framework, such as SUMPs.**

Therefore, to ensure that mobility can be "smart" and sustainable in order to improve the quality of life, a more integrated approach is required in order to consider the complex trade-offs between city and mobility. Smart Mobility means not just about using ITCs, but being able to function as an integral part of a larger system that also regards participation and urban quality.

Keywords—smart mobility indicators; smart city; Italian smart mobility performance

I. Introduction

Numerous cities have long undertaken the Smart City paradigm, although with different approaches and outcomes. One of the key concepts, common to most definitions in both theoretical and academic field [1], [2], [3], [4], [5], and industrial one [6] is that a Smart City is certainly an "accessible" city. This property entails that several actions and solutions are implemented in order to improve the performance, usability and environmental sustainability of urban services such as transport.

If accessibility is an essential feature of a contemporary city, it seems suitable for raising questions about how the Smart City paradigm can effectively support the transition towards a more sustainable mobility, through a broad use of new technologies.

In general, transport companies promote high-tech equipment, facilities and products to increase the efficiency of the mobility system, emphasizing the fundamental role of ICT for the implementation of the Smart City model[a] and this consideration seems to be confirmed also in a wide part of scientific studies and research on this issue [8], [9].

In this perspective, what are the elements that contribute to transform the urban transport supply in a successful smart mobility model? Numerous, heterogeneous and sometimes contrasting are the interpretations of what are the essential characteristics of a Smart Mobility, such as there are many

[a] "Transport has a central role for accessibility, connectivity, social and civic inclusion and competitiveness dimensions of an urban system (and more generally of a State): a more efficient and 'intelligent' mobility is a driver to realize the new urban models of smart city [7].

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approaches and theories developed to define, measure and evaluate the labelling elements of a Smart City, depending on the expert's point of view.

The interrelations between the concepts of smart mobility and sustainable mobility have been investigated by transport and land use literature [10], [11]. Some authors noted that since the transport sector contributes significantly to lower the environmental quality of the city, both in terms of the pollutants emission and high energy consumption, smart mobility is first and foremost a sustainable mobility.

Therefore, if smart mobility means mainly a wide use of ICTs in the transport system, at the same time the integration between the smartness and the sustainability of the urban mobility can be reached through the use of devices and innovations that make the transport system more compatible with the urban environment (e.g. reducing emissions, using alternative fuel sources, favoring soft transport systems, etc.).

In this regard, Lyons [10] highlights that although it would seem obvious that smart and sustainable mobility are closely linked, it is possible to detect opposing positions: "... being either focused on smart in a technology-centric sense or focused on sustainable in a planning-centric sense. Each may tacitly or superficially acknowledge aspects of the other's paradigm and both may have as their reference or departure point a current paradigm that is neither especially smart nor sustainable".

This statement draws attention to a much-debated topic with different standpoints that is the relationships between ICTs and smart mobility. Numerous researches [12], [13], [14] have focused on how the introduction of ICTs in many urban activities would have reduced the need for some types of physical movements (e.g. home-to-work commuting flows), leading to positive impacts on urban mobility. Although most of the scenarios defined in such studies did not meet this kind of expectations, in terms of congestion and traffic reduction, there is no doubt that "[13] the interactions between mobility and ICT, be it new or older ICTs, turn out to be very diverse and complex".

In addition, the Smart Mobility definition used in a study of 2014 by the European Parliament is focused on the technological component [15]: "By Smart Mobility we mean ICT supported and integrated transport and logistics systems. For example, sustainable, safe and interconnected transportation systems can encompass trams, buses, trains, metros, cars, cycles and pedestrians in situations using one or more modes of transport. Smart Mobility prioritises clean and often non-motorised options. Relevant and real-time information can be accessed by the public in order to save time and improve commuting efficiency, save costs and reduce CO_2 emissions, as well as to network transport managers to improve services and provide feedback to citizens. Mobility system users might also provide their own real-time data or contribute to long-term planning." Finally, there are other many studies promoted by large companies that highlight the role of products, devices and technologies to make mobility more sustainable, more efficient and more responsive to the needs of users [16].

Several studies [17], [18], [19] highlight the lack of efficacy of a technocentrism perspective which considers an important use of ICTs for making more efficient urban mobility, without combining it with integrated planning of all the components of the transport system: from the network (both transport of goods and people and information) to more strictly managerial aspects. Furthermore, some authors point out that in some cases if the use of ICTs is a priority in order to improve the performance of transport system, city user transits (made easier by ICTs) can increase. It can be considered a secondary and unsustainable effect of application of ICTs. For example, there are digital applications that indicate in real time alternative routes to "traditional" ones affected by congestion thanks to the collaboration of users. However, such information can produce an unsustainable pressure on networks that are not able to support increases in traffic flows [18]. Finally, considering the lack of researches about levels of the pervasiveness and the use of ICTs according to user types, it is not clear how and how much technologies are able to change user habits and behaviours that are key factors for reaching a sustainable mobility [18].

Beyond the different positions synthetically described, it is evident that one of key sectors on which cities are investing resources and experiencing innovations is mobility. The challenges of sustainability and climate change and the improving of quality of life in urban areas make necessary the definition of policies and strategies aimed at improving the performance of mobility system, i.e. to enhance accessibility to services and urban spaces and increase sustainability through the reduction of the negative impacts of the transport system.

In this framework, the aim of the paper is to analyze how Italian cities are interpreting the topic of Smart Mobility, with particular attention to the use of new technologies in urban mobility. The paper is divided into three parts: the first describes the research method adopted in the study; the second explains the main results obtained; finally, the third highlights some concluding remarks.

II. METHODOLOGY

In the debate on urban mobility ICT infrastructures and devices are increasingly considered as pivot to make transport systems really sustainable and smart [20], [21] [22]. Thanks to sensors, command and control unit and actuators (the main components of a smart technology) [21] huge amounts of data (big data) are collected, processed, communicated in real time by allowing to manage urban transport system in a more efficient way. Nevertheless the consistent use and spread of appropriate technologies within urban mobility can produce positive effects on environment, economy and society, but those benefits are likely to be really limited without taking into account individual and social dynamics through which ICT are integrated with mobility habits of people [17] [23].

In other words, a holistic vision of smart mobility should be required as well as it is happened for the smart city [17] [19]. In addition to the difficult of declining the concept of Smart Mobility in a more comprehensive way, little is known about the performance of cities in the field of smart mobility and how measuring the real effectiveness of ICT solutions, if not in terms of the consensus achieved by local authorities and in budget increase of sellers companies. “According to [21] arguably, the lack of proper concepts and indicators could be a reason for not performing comprehensive benchmarking studies on smart transport cities”.

Based on these premises, the proposed methodology allows describing the Smart Mobility attitude of Italian cities through nine steps. The first step of the methodology was the definition of the main characteristics of Smart Mobility, in order to understand how this goal is pursued and interpreted by local administrations. According to the scientific framework provided in the previous section, there are three main aspects that can make urban mobility a smart one: (i) Smart Mobility needs ICT to improve urban mobility efficiency; (ii) Smart Mobility needs to be Sustainable to achieve climate, energy and environmental targets; (iii) Smart Mobility needs to be Accessible to improve urban organization and functions. The next step was the selection of indicators. The choice of the parameters is related to the willingness of measuring in a quantitative way the effects of local actions and initiatives developed to improve urban mobility system. The set of parameters has been defined according to the few studied on this topic [24] [25] [26] and their selection is related to the aim of measuring the effectiveness of local actions, often developed under the “catchy” slogan of Smart Mobility. After selecting indicators, each of them was associated to one of the three main aspects identified, according to which part of Smart Mobility is able to measure.

Then, the sample of Italian cities was defined. Most Smart Mobility studies have been focusing on metropolitan areas or/and big cities[b],- as they are more affected by congestion, air pollution, noise than small ones, according to their major economic attractiveness and urban population growth [28] [29]. On the contrary, this work aims at investigating Smart Mobility status in Italian small and mesidum sized cities (from 50.000 to 250.000 inhabitants in 2016), in order to understand if this urban dimension can encourage and facilitate the fulfillment of actions oriented to ICT, Sustainability and Accessibility. Furthermore, “according to [30] small towns and cities have a critical role to play to connect the rural areas to the bigger cities and to preserve the territorial cohesion of the EU. In other words, the EU needs a polycentric territory, with small-and-medium sized towns in the countryside, and networks of towns as alternatives to the large metropolises”.

After selecting both indicators and the sample, the related data were collected by consulting ISTAT (Italian National Institute of Statistics) database. Among the several available and open source database, ISTAT was used as (i) in Italy it is the most authoritative and reliable source of data; (ii) it collects data related to a significant number of territorial entities, compared to the other database; (iii) the classification and cataloguing criteria are homogeneous for all cities and for all the years.

[b] Big cities have a population more than 250.000 inhabitants [27].

It is worth noting that most data linked to Sustainability and Accessibility categories were available from 2006 to 2015, while for ICT just for the period 2012 – 2014. This difference of data availability can be due to the fact that before this period (2012 – 2014) ICT for transport applications were really isolated. Therefore, authors referred their analysis only to 2014. In this regard, at least in Italy, it is still very difficult to analyze the evolution of some spatial phenomena related to the use of ICTs. Urban systems evolve more rapidly than the connected statistical data collection processes, and so there is a “collapse” between the ongoing processes and the tools used to analyze them. Italian spatial statistical data are still fragmentary and often available only for some territorial entities.

All the ISTAT data were available for the Italian provincial capitals, so the sample was composed by 102 small and medium sized cities. Before comparing the Italian provincial capitals, the indicators were standardized because: (i) ICT parameters were binary while Sustainability and Accessibility ones were continuous and so not comparable. Therefore, continuous parameters were transformed into binary type. This operation was made by Natural Breaks classification.

The next step was calculating the average of binary values of all parameters (n) of each category (ICT, Sustainability and Accesibility), for every city “(1)”:

$$ICT_a = (ICT1 + ICT2 + \ldots + ICTn) * n^{-1} \qquad (1)$$

These values were then expressed as a percentage, in order to attribute a qualitative weight to each city according to the three components of Smart Mobility and hence understand how each provincial capital is declining the Smart Mobility topic. To grasp and interpret the results according to the three main components of Smart Mobility, these ones were represented in a ternary diagram. The diagram has been divided into 7 areas, in order to identify which are the main issues related to Smart mobility in the Italian urban context (Fig. 2). Those areas are:

a) Area 1: Accessibility

b) Area 2: ICT

c) Area 3: Sustainability

d) Area 4: Integrated Mobility

e) Area 5: Attractive Mobility

f) Area 6: Inclusive Mobility

g) Area 7: Balance Area

Finally, to understand if Italian Smart Mobility status is affected by demographic dimension, the sample of cities was articulated into three clusters equal-sized sets, based on their statistical rank, by percentile method: first cluster (Cluster 1) collects cities with a population less or equal to 54.912 inhabitants; second cluster collects cities with a population between 54.912 and 96.303 inhabitants (Cluster 2); third cluster collects cities with a population between 96.303 and 259.544 inhabitants (Cluster 3).

The last step was the comparison of results, through the four ternary diagrams, the first one for all the sample and the other ones for each cluster.

TABLE I. Parameters selected for the three Smart Mobility categories

ID	ICT		
	Indicator	***Unit***	***Source***
ICT1	Road traffic signal systems	n°/km^2	ISTAT
ICT2	Variable message signs	1 or 0	ISTAT
ICT3	SMS for traffic alerts	1 or 0	ISTAT
ICT4	Electronic payment park systems	1 or 0	ISTAT
ICT5	Applications for mobile devices	1 or 0	ISTAT
ICT6	SMS for public transport information	1 or 0	ISTAT
ICT7	Electronic bus stop signs	1 or 0	ISTAT
ICT8	Electronic travel tickets	1 or 0	ISTAT
ICT9	Electronic purchase of travel ticket by mobile devices	1 or 0	ISTAT
ICT10	Information on routes, schedules and waiting times	1 or 0	ISTAT
ICT11	LPT travel planner	1 or 0	ISTAT
ICT12	Travel tickets online	1 or 0	ISTAT
	SUSTAINABILITY		
	Indicator	***Unit***	***Source***
S1	Ecological buses (electric, natural-gas, GPL)	n°	ISTAT
S2	Pedestrian zones	m^2/100 inh.	ISTAT
S3	Restricted traffic zones	km^2/100 km^2	ISTAT
S4	Cycle lanes	km/100 km^2	ISTAT
S5	Ecological cars (electric, natural-gas)	n°	ISTAT
S6	Bike sharing supply	n° bikes/10,000 inh.	ISTAT
S7	Bike sharing density	n° stations/100 km^2	ISTAT
	ACCESSIBILITY		
	Indicator	***Unit***	***Source***
A1	Public tranpsort demand	n° passengers/ inh.	ISTAT
A2	Public tranpsort supply	n° seats*km/inh.	ISTAT
A3	Public transport lanes	km/100 km^2	ISTAT
A4	Bus stops density	n° stops/100 km^2	ISTAT
A5	Rail network	km/ km^2	ISTAT
A6	Rail network stops	n° stops/ km^2	ISTAT
A7	Car sharing demand	n° users/1,000 inh.	ISTAT
A8	Car sharing supply	n° available vehicles/ 100,000 inh.	ISTAT
A9	Toll parking	n° stalls/1,000 vehicles	ISTAT

III. RESULTS AND DISCUSSION

The methodology proposed for analyzing the status of Smart Mobility in Italian small and medium sized cities, led to significant comments, according to the distribution of selected indicators into three categories.

The ternary diagram of all the selected cities (Fig. 3) showed that there is not a specific tendency towards a unique category, even though most provincial capitals are concentrated within the Balance Area (about 24%), the Area 5 (about 10%) and along the ICT axis (about 29% of the sample). According to such distribution, the average value of the ternary diagram was located into the Area 4 (Integrated Mobility). These results seem to highlight that Italian cities pay attention mainly to Accessibility and ICT aspects. The ternary diagram of Cluster 1 seems to confirm such Italian attitude. Indeed, the average value of the Cluster 1 sample is located within Area 4 (Integrated Mobility) and the majority of cities are placed in the Balanced Area (Area 7) and located along the ICT axis. As regards Cluster 2, even if its average value is positioned within the Area 4 (Integrated Mobility) of the ternary diagram, such cluster is more oriented to the Accessibility area, compared to results of the previous two diagrams. In fact, there is a great concentration of cities in the Accessibility vertex. Finally, the ternary diagram of Cluster 3 shows that the three Smart Mobility categories are more balanced than the other two clusters. Area 7 (Balance Area) and Area 5 (Attractive Mobility) collect the most part of cities.

Summing up, even though there is not a leading category, Italian cities seem to particularly focus on Accessibility and ICT issues (Fig. 3 and Fig. 4). With regard to the demographic dimension, it seems that the most populated cities of the sample (Cluster 3) pay more attention to all the three Smart Mobility aspects.

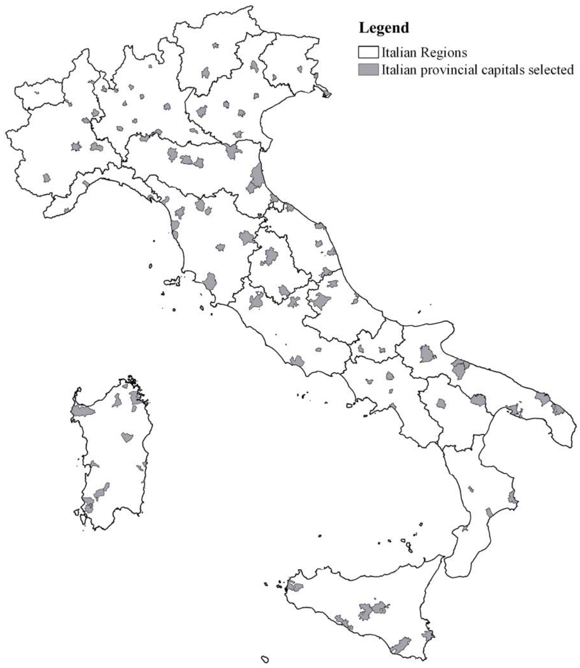

Fig. 1 Maps of selected Italian cities

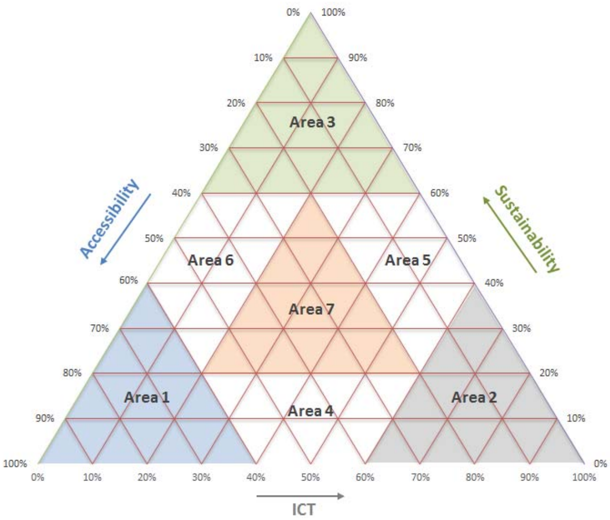

Fig. 2 Areas of ternary diagram

Such a difference is related to the fact that the smaller cities are more oriented to a traditional mobility model. Generally, small sized cities have limited budgets and less specialized expertise in the urban mobility management field and their transport habits are different from biggest city's ones, like shorter and low number of trips because of the limited presence of urban functions in the urban context. Furthermore, they tend to invest more both in transport supply (Accessibility), as they are oriented to satisfy the essential mobility needs, and in new technologies (ICT), and their use and spread require fewer efforts and represent an alternative to the construction of new physical infrastructure. This could represent also the reason why the small and medium sized cities do not try to make mobility more sustainable.

IV. Conclusions

The set of parameters related to the Accessibility and Sustainability aspects and the use of ICTs in the transport system provided an overview of how in Italian urban areas are interpreting the topic of Smart Mobility, drawing some suggestions and cause for reflections. Italian small and medium sized cities (with a population between 50,000 and 250,000 inhabitants) are implementing - although in different ways - a mix of actions geared towards improving accessibility and sustainability as well as the use of ICTs. Considering this latter aspect, most of the interventions (especially in Southern Italy) are the result of the wide range of EU funds on transport sector in the last programming period in order to overcome mainly the issues of air pollution and energy consumption.

A first result is related to the interrelationship between city-size (population) and Smart Mobility actions. The smaller cities depend on "polarizing" urban areas located within their territorial context from a functional point of view. Such relation could explain why larger cities (Clusters 2 and 3), characterized by large flows of people and goods and by related problems, implement integrated and innovative actions aimed at making mobility more sustainable.

Another consideration is about the role of ICTs within Smart Mobility policies. At present, the lack of reliable and accredited data on the use of new technologies in urban transport sector is a limit of this research, especially regarding the large amounts of data that users daily provide to local transport companies in order to improve public transport supply, ensure optimal traffic and freight transport management, or improve road and freight safety. Moreover, this lack of information could distort the interpretation of some results. ICTs seem to be used as "fashionable" technologies, able to provide smart applications and information to users, without adding value to the efficiency of the mobility system as a whole. Therefore, ICTs seem to not improve mobility management and organization models with the aim of sustainability and efficiency. In other words, if the use of new technologies is implemented in a "unequipped" social context, "innovation" becomes only an appealing and superfluous label.

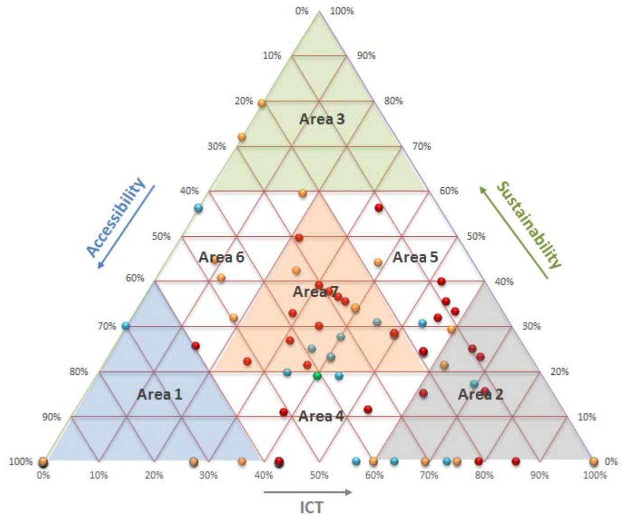

Fig. 3 Ternary diagram of the whole sample (in green the average value; in orange Cluster 1; in blue Cluster 2; in red Cluster 3)

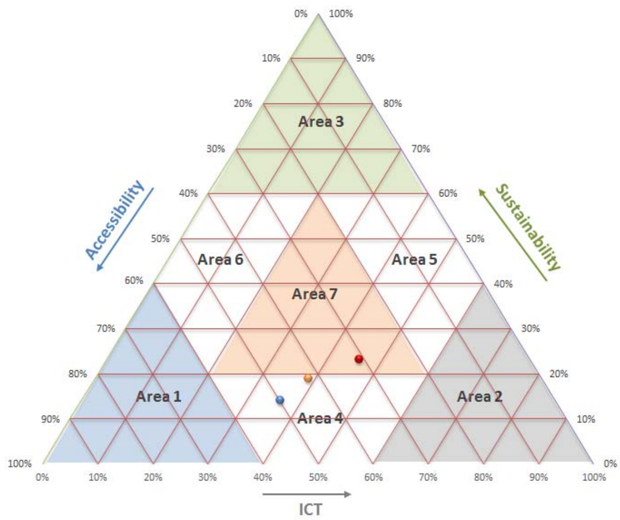

Fig. 4 Ternary diagram of average values of Cluster 1 (in orange), Cluster 2 (in blue) and Cluster 3 (in red)

For example: is it useful a mobile application that informs users about the "real time" waiting at public transport stops if it does not provide information as the waiting is longer than 30 minutes? Such case could explain why the Southern Italian cities record the presence of messaging systems at public transport stops, e-ticketing systems, etc, even if they are in late to promote policies and measures related to sustainability and accessibility. Therefore, despite the push of the European funds, the Smart Mobility approach seems to be not suitable to the less developed urban contexts of Southern Italy, characterized by an obsolete and unsustainable transport system [29]. Instead, in the larger and Northern cities (in particular, Cluster 3) the three Smart Mobility categories are better balanced, considering the implemented actions.

In conclusion, the proposed study allows to state that most Italian cities are oriented towards the adoption of a more sustainable and accessible urban mobility model than smart one. In such context, the use of ICTs, indeed, seems to represent isolated initiatives, which are not included in shared and coordinated strategies integrated with the urban transformation governance, as part of a global policy framework (e.g. SUMPs). Therefore, in order to implement a real "smart" mobility and contribute to improving the quality of life and developing a sustainable urban mobility model, a more integrated approach is required in order to consider the complex trade-offs between city and mobility. A smart mobility means not just about using ICT, but being able to function as an integral part of a larger system that also regards participation and urban quality.

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