Abstract

Demographic changes in peripheral areas are pressuring the regional public transport systems to adopt innovative strategies. The employment of internet of things (IoT) technologies has proven to be a valid response to mobility challenges in rural areas, and has brought up the concept of "smart land". Framed within the context of the Interreg Central Europe project RUMOBIL, this study tries to shed light on how the deployment of smart mobility solutions within the rural context compare to that within the urban context. Following a literature review, we compared the ease of implementation of different IoT solutions on the urban and the rural contexts, for planners, travellers, and operators, and the relative complexity of common smart mobility issues. In addition, we identified three major challenges for both rural and urban mobility, namely the need for standardized metrics for optimal routes' detection and a dynamic definition of optimal route, as well as the simplification of investments' planning and programming. Both smart cities and smart land can benefit from smart mobility solutions, even if in most cases, each of the two contexts can gain more advantages than the other from the same solution. Even considering the different levels of population scattering, technological infrastructures, social maturity, and economic opportunities, both rural and urban areas offer comparable advantages. For the future of transport, it is up to all policy levels to consider the challenges deriving from expected trends and leverage the untapped potential of IoT technologies to satisfy future travellers' needs and ensure sustainability.

1. Introduction

The main goal of this work is to shed light on the different impact that opportunities created by the employment of networked telematics (internet of things, IoT) currently leveraged for the improvement of the quality of public transport (PT) services have on rural and urban areas, and also to highlight the challenges that the associated "smart mobility" solutions must currently deal with. In particular, the development of sustainable PT in rural areas is the main focus of a strategy which will be defined also on the basis of this study, eventually supporting the promotion of sustainable mobility in rural areas. Indeed, the latter is the main goal of the Interreg Central Europe project "RUMOBIL" (Interreg Central Europe, 2014), under which this study has been developed by building upon the research work reported by Porru et al. (2018).

Central Europe regions are intended to take advantage from the adopted transnational strategy by understanding how to employ innovative and transferable PT approaches on the basis of a comparison between good practices, partners' and stakeholders' know-how, lessons learned from the pilots, and innovative ideas put forward through a transnational social media-based competition. The strategy outline takes into account the mobility needs in rural and peripheral areas, gathered from, among others, scientific literature, technical visits, best practices, and already deployed solutions, which have been analysed to evaluate their efficacy in resolving or, at least, reducing the identified critical points. The identified actions and solutions require to collect and process information efficiently, in order to be improved. IoT required operational steps (Talari et al., 2017, Zanella et al., 2014).

Regarding PT, the research activities conducted within the RUMOBIL project allowed to identify several areas of improvement for an effective PT service strategy, among which investments on IoT were listed, as well as other aspects that can benefit from the employment of IoT and the data that these technologies can provide, such as tailoring services to specific market segments (e.g., individuals with disabilities), enhanced security, and optimized frequency, time of service, and number of stops.

Flexible transport systems bring a promising approach to improving the efficiency and performance of passenger transportation services in rural areas. They provide passengers with flexibility in choosing routes, times, modes of transport, service provider or payment systems. The flexibility is based on integration of different modes of transport, or possibly spanning multiple service providers. Service is more sophisticated, comfortable and cost-effective. This concept is especially suitable within rural areas, which usually suffer from a lack of service availability and demand uncertainties. Flexible transport systems can cover specific time frames. For example, partners in Saxony-Anhalt (Ministry for Regional Development and Transport of Saxony-Anhalt) tested new bus service supplementing existing regular bus service in selected days of the week on specific routes, connecting rural settlements with higher level transportation nodes (e.g., railway stations).

The most interesting aspect of the pilot was the involvement of local public authorities

2. Related work

Urban infrastructure is being optimized through increasing capabilities to process large amounts of real-time data, leading both travellers and operators to perceive the PT as more efficient than in the past. The most relevant services for a smart mobility user at a specific time and place can be easily identified thanks to location-based data analysis. Hence, smart mobility, being deeply connected to sustainable mobility, contributes to higher life quality (Olaverri-Monreal, 2016).

Mehmood et al. (2017) focused on building theory, knowledge, and critical understanding of the social implications of cities' growth and the role that big data-and smart cities-could play in developing a resilient and sustainable city transportation system. The authors tried to understand how big data could transform smart city transport operations, and presented preliminary results obtained through a Markov study.

Nowadays, urban dwellers can take advantage of diverse PT and sharing services and, at the same time, slow mobility (walking and cycling) is gaining increasing attention. As driving skills deteriorate with age, the elder will inevitably modify their long-term mobility patterns relying more and more on PT. The observed trends of re-urbanisation and consumers' increased preference for walkable neighbourhoods will probably slow down urban sprawl and reduce car dependency (European Commission, 2013, Gogola et al., 2018).

According to the UITP statistics (Union Internationale des Transports Publics (UITP), 2016), the use of PT in the EU is currently experiencing its peak since 2000, with a total of 57.9 billion journeys made in 2014. However, this change is mainly recorded in and a speed limitations, which significantly reduce the currently high levels of carbon dioxide emissions.

As for rural areas, which cover half of the entire European territory, are occupied by the 20% of the total population. The life quality of such a large number of Europeans is fairly different from what is perceived as the European standard. This condition is characterised by several aspects that add up to lead to a specific scenario.

On the one hand, rural areas are affected by a consistent demographic change, which is mainly driven by the asymmetric distribution of economic activities between rural and urban areas. Business headquarters, workplaces, and universities are usually located in large cities, leading rural inhabitants (in particular, young adults) to make a fundamental choice: move to the city or stay in the village, in the latter case by dealing with additional efforts to reach their destinations of interest (e.g., workplace, school). People often choose the former option, with the result that in rural areas the average age grows as entire families move to the city, eventually making elderly people the main part of the rural population (Interreg Central Europe, 2019b). This leads to additional issues for rural areas: in certain sites, it can be observed a lower population density than expected, with the consequence that these areas become even more isolated. This leads to a poor public PT offer: it is difficult to provide a proper PT service in scarcely populated areas, since the demand is not high enough and the service can end up being underused, consequently generating unsustainable costs. This, in turn, is an additional reason behind the out-migration towards the city.

As PT services in low-density regions are usually economically convenient, many governments all over the world have to confront with the challenge of effectively providing them. In their quest to find the right approach, governments have tried to combine many aspects in PT services (Gogola et al., 2018). Nevertheless, low-density regions can be fairly different from each other, both depending on the different needs of their dwellers and other pre-existing conditions related to their specific context. These differences make it difficult to optimally tailor PT services to the area of interest. However, it appears that the presence of three ingredients is crucial for success: the availability of financial means, cooperation between stakeholders, and a flexible supply of scheduled and on-demand transports (De Jong et al., 2011). The attitude of rural regions dwellers is another factor that must not be underestimated. Notoriously, technological innovations, and above all the awareness of them, arrive at a later stage in these areas. As a consequence, rural inhabitants need more time to get acquainted with the most recent technologies.

The aging process, together with the in-migration of the elder and the out-migration of the younger generation, has negative impact on socio-economic conditions of rural areas, which reflects, for instance, in the reduction of the provision of local services (e.g., shops, post offices, doctors, education) (Interreg Central Europe, 2019a). Some characteristics of rural areas also present barriers to improve and develop PT. For instance, the demand for transport services is often to foresee, since population is distributed over large areas and passengers are usually very few, causing the transport demand to be low and unpredictable. Therefore, the provision of frequent and widespread commercial PT services is d congestion and delays, mobility space usage) by identifying synergies between technologies such as vehicle manufacturing, transport information systems, communications technologies, and logistics.

The employment of IoT technologies in transportation brings about its own set of unique opportunities and challenges, which have been identified and discussed by Davidsson et al. (2016). In their work, the authors identified the opportunities and challenges of the employment of IoT for the improvement of PT services, focusing on how IoT can be leveraged to foster sustainable society development. The authors analysed the existing literature and explorative studies from an environmental, economical, and social perspective, concluding that IoT creates great opportunities for both transport operators and planners, as well as travellers. On the other hand, they also identified challenges that need to be addressed, ranging from issues related to data collection, interoperability, scalability, and information security, to non-technical challenges including issues related to usability, business models, privacy, and deployment. Nevertheless, such opportunities and challenges were not analysed to differentiate their relevance for urban and rural areas.

As reported in the following section, these opportunities and challenges have been considered to compare several recent smart mobility projects, and thus evaluate them in the rural and urban context.

3. Research methodology

State-of-the-art solutions and tools discussed in this paper have been leveraged to forecast how PT will evolve and adapt in the coming years, considering all the most relevant opportunities and challenges. More specifically, smart mobility solutions have been evaluated to understand whether they can lead to successful mobility solutions for rural areas, as well as to provide a general overview on the smart mobility state of the art, focusing on innovative applications of the IoT technologies to transportation.

Since innovative applications are to be found in recent initiatives, relevant smart mobility projects have been identified, selected, and analysed to effectively answer RQ1 and RQ2. More specifically, we selected ten projects focused on applications of IoT to mobility, which have also been compared to support our evaluation and comparison of the opportunities and challenges reported in Section 4. Among all the projects analysed, we only selected a subset which could be considered relevant both for the RUMOBIL project and the purpose of this study. More specifically, the subset is constituted by 10 projects which: (1) include both dedicated solutions for rural and urban areas, thus allowing for comparing them by focusing on the differences and similarities between urban and rural smart mobility applications; (2) are fairly recent if not yet concluded, which make them suitable for a state-of-art study; (3) are mostly constituted by projects which received considerable funding (several million euros), which make them stand out among other minor smart mobility projects; and (4) involve European pilot sites, since also the RUMOBIL project focuses on the European context.

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To effectively discuss the aforementioned opportunities and challenges, and to identify innovative solutions for the PT in rural and urban areas, we have selected publicly available documentation related to smart mobility projects, and considered scientific literature, companies' reports, and publications regarding both ongoing and closed projects relevant to smart mobility. Hence, the examined information has been leveraged to compare the different IoT solutions' ease of implementation and the related opportunities on an urban and rural context for planners, travellers, and operators. Moreover, we also compared the degree of complexity of common smart mobility issues in the urban and rural context (Kolosz and Grant-Muller, 2015).

4. Projects comparison

The application of the selection criteria reported in the previous section resulted in the identification of 10 smart mobility projects. To effectively discuss and compare these projects, we identified the application context and the main outcomes, as well as other relevant features (name of the project, start/completion dates, leader, and description), all reported in Table 1.

Table 1. The selected smart mobility projects with all the most relevant features.

Project	Date	Leader	Context	Descripi
COMPASS4D (Mitsakis et al., 2014)	Jan 2013–Dec 2015	ERTICO	Cooperative intelligent transport systems	COMPAS focused three se aiming

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