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Review Article

Smart mobility and public transport: Opportunities and challenges in rural and urban areas

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HIGHLIGHTS

- Smart mobility solutions differently benefit both smart cities and smart lands.
- Key challenge: standardized metrics for optimal routes' detection.
- Key challenge: employment of a dynamic definition of optimal route.
- Key challenge: informed coordination between public authorities.

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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.

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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 technologies (Gubbi et al., 2013; Whitmore et al., 2015) have made it possible to easily and effectively collect and analyse information, since the "things" and devices included in the information flow network directly perform all the 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, local associations, and the local public. They contributed with their own knowledge and experience on local peculiarities and possibilities to the planning and the operation of the new bus services. Local stakeholders were involved at various levels: the development of routes and bus schedule, and the identification of the most suitable locations for additional bus stops. Further, the public was asked to support the project with voluntary drivers. Among the properly trained voluntary drivers were also senior citizens that, by so doing, were allowed to support their local community and feel useful. This model is efficient in communities with dense populations. Vehicles, bus stops, and routes to bus stops are well accessible.

Urban areas are often associated to IoT-enabled opportunities for innovation, as the ubiquitous concept of smart city testifies. However, since our main goal is to investigate whether and how rural transport systems' solutions can benefit from the implementation of IoT technologies, we focused on the smart land, which is a wider concept than the smart city (Bonomi and Masiero, 2014; Bria and Morozov, 2018; Rosati and Conti, 2016). In particular, this review strives to answer the following research questions (RQs).

RQ1. Can rural areas benefit more from certain smart mobility opportunities than urban areas? If yes, from which opportunities?

RQ2. How the complexity of well-known smart mobility challenges varies in the rural and urban context, respectively?

The document is structured as follows: in Section 1, we frame the context of our study and define the research questions; in Section 2, we discuss the related work on the smart mobility; in Section 3, we describe the adopted research methodology; in Section 4, we compare 10 smart mobility projects focusing on their impact on the rural and urban context; in Section 5, we report the results and discussions; in Section 6, we draw our conclusions.

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 around urban areas.

On average, European cities can rely upon high-quality PT, and are usually more committed to promote sustainability and low-carbon solutions, particularly if compared to other cities around the world. Nevertheless, pollution, especially carbon dioxide emissions, can still be extensively reduced. With this respect, restrictions on traffic and parking in downtown areas have been already implemented in several European cities, through scheduled industrial production interruptions, or via 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 difficult to justify considering the number of potential users. Nevertheless, the need for transport services for socially disadvantaged groups (e.g., elders, very young people, disabled) in rural and remotely located areas is undeniable (Interreg Central Europe, 2019a).

A well-organized PT system can enhance economic growth by improving social inclusion, accessibility, and mobility in rural areas. In this respect, IoT can support the development of sustainable PT services for rural communities. Regarding sustainable mobility, the performance achieved by different cities can be evaluated with the 22 indicators for parameters and methodologies reported in the report for Sustainable Mobility Project 2.0 (World Business Council for Sustainable Development (WBCSD), 2017). Among these indicators, several can be used to gauge smart urban mobility (e.g., comfort and pleasure, traffic safety, 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.

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.

The smart mobility projects reported in Table 1 often deal with collecting, organizing, sharing, and providing access to meaningful transportation data. More specifically, projects such as COMPASS4D and Array of Things are focused on data collection, whereas MOBiNET and oneTRANSPORT are focused on accessing, aggregating, and sharing transportation data.

On the other hand, informed rural passengers, on-the-go rural mobility 2.0, and TEAM show that the vehicle routing problem (VRP), which refers to optimization problems in transportation, distribution, and logistics industry, is regarded as a central topic which significantly benefits from the application of IoT to mobility. With regard to this subject, it must be noted that the comparison between route planning solutions can be performed taking into account that (1) different case studies can leverage different route's metrics, and (2) the same metric is not necessarily relevant for one case study as it is for another. For instance, Collins and Muntean (2008) considered "journey time cost", "used capacity cost", and "fuel consumption and emissions cost". In Nha et al. (2012), the authors discussed the input data to be used for vehicle routing algorithms, which should be divided into three categories: road information (congestion, incidents, weather), destination information (purpose of travel), and mobile information (vehicle- and traveller-related features). In addition, they compared different route planning algorithms focusing on a specific selected set of route's metrics.

Starting from the previous considerations, the results of the comparison between the smart mobility projects have led to highlight opportunities and challenges in rural and urban areas respectively, and also singled out subjects which are of interest for both contexts, as reported in the following sections.

4.1. *Opportunities*

As reported by Davidsson et al. (2016), evolution fostered by IoT applications will bring about new opportunities for nearly all aspects of PT, including (1) planning: opportunities of interest to strategic transport planners, and (2) operations: opportunities of interest to operators. These two types of opportunities enable new smart mobility models and have different impacts on the urban and the rural contexts.

A major opportunity which is currently untapped is the increasing the number of transport users in rural areas. Following the analysis, it became apparent that a key aspect for improving rural transportation is to properly adjust and balance PT services within the limits of a territory with fragmented settlement structure, while improving quality of services for all segments of population and increasing attractiveness of PT in order to gain new passengers. With this respect, IoT technologies can be leveraged to provide the necessary data to improve transports usage monitoring and

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

Project	Date	Leader	Context	Description	Main outcome
COMPASS4D (Mitsakis et al., 2014)	Jan 2013 –Dec 2015	ERTICO	Cooperative intelligent transport systems	COMPASS4D focused on three services aiming at increasing drivers' safety and comfort by reducing the number and severity of road accidents, by optimizing the vehicle speed at intersections and by avoiding queues and traffic jams. COMPASS4D leverages technologies such as 3G/LTE, on-board units (OBUs) and road-side units (RSUs) based on dedicated short-range communication technologies (ITS-G5).	Three services (equipment and services). • Energy efficient intersection • Road hazard warning • Red light violation warning
MOBiNET (MOBiNET Consortium, 2012)	Nov 2012 –Jun 2017	Rasmus Lindholm, ERTICO ITS Europe	E-marketplace for mobility services	MOBiNET envisages a new "internet of mobility" which would open the door to harmonized transport services, seamless connectivity, instant access to transport data, single subscription and billing for travellers and a one-stop shop for mobility services.	• Federated directory of online services • Identity authentication with single sign-on (SSO) on multiple services • Unified accounting and billing • App-directory • Access to subscribers • Negotiation through service agreements
TEAM (Bellotti et al., 2019)	Nov 2012 –Oct 2016		Collaboration between travellers, drivers, and road infrastructure operators	Tomorrow's elastic adaptive mobility (TEAM) turns mobility from static into elastic by joining drivers, travellers and infrastructure operators together into one collaborative network. TEAM uses mobile devices such as smartphones to significantly improve transportation safety and efficiency, implementing environmental aspects.	11 collaborative software applications focused on the following aspects. • Coordination of traffic control • Traffic map database and visualization tools • Virtual coach to maximize travel's cost/benefit • Vehicles prioritization, traffic lights synchronization, speed recommendations • Dynamic routes/timetables • Dynamic road lanes use •Inter-urban with dynamic lanes for heavy trucks • Adaptive cruise control with vehicles-infrastructure-user information sharing • Localization of free parking spots through real-time interaction between infrastructure (sensors) • Serious game with game community to improves drivers' driving behaviour • Alternative route suggestion based on individual/community needs' balance
Array of Things (AoT) (Catlett et al., 2017)	Started in 2013	Argonne National Laboratory	Urban sensing	AoT is an urban sensing project, and a network of interactive, modular sensor boxes that will be installed to collect real-time and location-based data on a city's environment, infrastructure, and activity for research and public use.	• Data collection on urban environment, such as data on air quality, sound, vibration, temperature, flooding, etc. • Healthier walking times and routes • Block-by-block micro-climate data
oneTRANSPORT (Carlton et al., 2014)	2014 –2026	InterDigital Europe	Smart city	The oneTRANSPORT data marketplace is an open, standards-based environment that both public and private sector organizations are using to publish their data, where it can be discovered, consumed and used in any kind of application or service.	A data marketplace platform which is an open, cloud- and standards-based environment that both public and private sector organizations use to publish their static and real-time transport-related data.

Informed rural passenger (Corsar et al., 2013)	2013–2014	University of Aberdeen	Rural mobility	Informed rural passenger aims at creating a transport information ecosystem within which it is possible to explore issues such as data provenance, reliability of passenger-sourced information, and travel behaviour change.	The GetThere system, based on a semantic infrastructure that integrates data from multiple sources (including users). The GetThere app allows to view timetabled and real-time bus locations for a selected bus route, contribute bus locations while making a journey, report a disruption event, and assess the quality of real-time locations with and without the presence of disruption.
Social Journeys (Gault et al., 2014)		University of Aberdeen	Rural mobility	The project explores how social media updates can be combined with existing (open) datasets to further enhance real-time passenger information.	Methods to combine social media updates with existing open datasets to obtain real-time passenger information in rural areas.
On-the-go rural mobility 2.0 (RAMSES, 2016)	Jan 2016–Dec 2016	Berlin University of Technology	Rural mobility	The RAMSES on-the-go platform provides an intermodal trip planner and ticketing for users of rural transportation services, and specifically aims at empowering small-scale providers of mobility services in rural areas (e.g., voluntary community transport providers).	On-the-go digital platform, which includes on-demand, peer-to-peer, scheduled and non-scheduled services in rural areas. The components of the platform are as follows. • A routing assistant • Multimodal trip planner • Driver shift planning • Vehicle and fleet management • Accounting • Monitoring • Communications
Smart mobility suburbs (SMS) (European Commission, 2016)	Jan 2016–Dec 2020	Universitetet i Oslo (Norway)	Smart multimodal passenger transport in urban and suburban areas	SMS is a multi- and trans-disciplinary project that addresses the conditions for transition towards energy-smart mobility in suburban centres. It focuses on two types of under-addressed innovations: (1) innovations in mobility practices, and (2) innovations in collaborative and multi-scalar governance to enable low-energy smart cities/micro-cities.	• Provision of new knowledge on organizational, regulatory, and market challenges which are to be tackled by smart energy systems, cities, and towns • Employment of mixed qualitative and quantitative approaches to investigate energy-smart mobility practices and innovations in governance (such as surveys, interviews, policy and institutional analysis)
SMARTA (Sustainable shared mobility interconnected with public transport in European rural areas) (European Parliament, 2018)	Started in 2018	MemEx	Rural mobility	SMARTA is a two-year research project commissioned by the Directorate-General for Mobility and Transport in order to develop the concept of "smart rural transport areas" (SMARTAs); SMARTA focuses on how to exploit existing mobility policies and solutions in European rural areas, and explore ways to support sustainable shared mobility interconnected with PT.	• Analysis of mobility challenges in rural areas • Deployment of shared mobility services on two pilot sites, with the aid of innovative digital solutions • Devise, plan and implement an awareness-raising campaign about sustainable shared mobility interconnected with public transport in European rural areas • Involvement of two European sites to address rural mobility • Workshops

also understand usage patterns, eventually allowing for dynamically adjusting and balancing transport services.

4.2. Challenges

Challenges relevant to the IoT application to PT, again as reported by Davidsson et al. (2016), fall into the following categories: business models, privacy and integrity issues, security, interoperability, scalability, usability, data collection, and deployment. Such challenges can differently impact on a rural or an urban environment.

In general, high-level challenges have been identified and evaluated against the rural and urban context in Section 5, but three most apparent challenges which involve both contexts and are related to data collection, are to be singled out: the definition of standard metrics for route evaluation, the exploitation of dynamic optimal routes, and the planning and programming of public investments in transportation.

4.2.1. Definition of standard metrics for route evaluation

Data collection and analysis projects that focus on the identification and selection of the most suitable features to evaluate routes should be promoted, and ultimately harnessed for the proposition of standardized metrics appropriate for routes comparison (Su et al., 2010). Indeed, routes can be characterized by a plethora of metrics that are not often all taken into consideration, or that are taken into account only in one case study, but not in others. Having commonly agreed basic metrics for route's comparison will allow for better comparing solutions which aim at suggesting optimal routes to the users. More specifically, a route can be thought of as composed by a certain number of uniform route segments, each of which with its own characteristics. Some of them are fairly stable in the long term (e.g., pavement material and conditions, road's width, slope, lanes), while others are variable in the short term (e.g., parked vehicles on either side, car-free areas with timetables). A proper combination of basic metrics could ultimately lead to the definition of a set of standardized metrics, which could therefore be employed to synthetically evaluate routes and easily compare route planning solutions.

4.2.2. Dynamic optimal route

Nowadays, the availability of urban sensors allows to consider factors relevant for route suggestion which reflect real-time conditions of the environment (i.e., traffic-disrupting local events, floods, bad weather, pollution). The availability of the related metrics, together with others such as the location of the route (e.g., urban, suburban, rural areas) and specific user needs (e.g., elderly and retired people have different needs from employees and students) can lead to a dynamic definition of the "optimal route". The "optimal route" should be environment- and user-dependent, that is, dynamically defined according to the context. Setting dynamic criteria for optimal route identification could also consider general constraints to be set by the local policy makers. This would allow national authorities to issue recommendations to fine-tune the criteria for the calculation of the optimal route according to the needs of the sometimes considerably different characteristics of diverse regional areas (a region could define stricter requirements in terms of pollution due to historical environmental issues, whereas another might need to focus more on prioritizing certain vehicles types that, even if more polluting than others when taken individually, could lead to minor overall congestion and pollution). Employing an adaptive definition of optimal route would ultimately lead to the assignment of different weights to the standardized metrics previously mentioned.

4.2.3. Planning and programming public investments in transportation

The coordination in the national, regional or local context is complicated further by the variety of the modes of transport involved, and because of the many national, regional, and/or local governments with financial, infrastructure or operating responsibilities. IoT technologies can speed up data collection and provision on rural transportation, making it possible for local authorities to provide exhaustive information of the current usage trends in a specific area. This could lead to a more effective action coordination between authorities at different levels.

To summarize, from the study of the aforementioned projects, it became apparent that standardized metrics for optimal routes' detection and a dynamic definition of optimal route are major challenges that, if successfully tackled, can prove fundamental for the evaluation of smart mobility transport schemas based on optimal route selection. Moreover, investments planning and programming appears to need consistent simplification, especially with regard to the coordination between planning authorities at different levels, which can be eased through leveraging IoT technologies in providing historical data on local transportation usage and current trends.

5. Results and discussions

In Tables 2–4, opportunities for smart mobility applications have been compared by focusing on their impact from the perspective of planners, travellers, and operators, both in the rural and urban contexts.

Similarly, the complexity of the challenges has also been evaluated in the two different contexts, as reported in Table 5.

The analysis shows that the territorial context has a significant influence on the issues dealing with the spatial and demographic aspects (population distribution/concentration, potential market size, and available communication infrastructures).

Table 2 – IoT applications suitability for planners in the rural and urban contexts.

Application for planner	Suitable for context
Collection of traveller data	Rural and urban
Collection of vehicle data	Rural and urban
Collection of traffic data	Rural and urban
Collection of air quality data	Rural and urban
Collection of infrastructure data	More suitable for rural
Collection of transfer point data	Rural and urban
Online service for modelling support	Rural and urban

Table 3 – IoT applications suitability for travellers in the rural and urban contexts.

Application for traveller	Suitable for context
Real-time service information	Rural and urban
Co-traveller information	Rural and urban
Real-time vehicle information	Rural and urban
Low level service compensation	Rural and urban
Traveller support	More suitable for rural
Collection of transfer point data	Rural and urban
Enriched travel experience	Rural and urban

The analysis of the project also confirmed that people living in rural areas have considerably fewer PT options than in larger urban areas. While residents of these areas travel to work, school, the medical practitioner, or the local store, as much as urban dwellers, their main means of transportation is the car, since they cannot benefit from the transportation infrastructure or services available in cities. PT services in rural areas are usually provided by bus operators or demand-responsive transport, as such transport mode is the least expensive in less populated areas. PT in rural areas still needs to be improved and much more support is needed for the local communities. Freedom, independence, and access to local services in rural areas can be brought about through continued innovation, public investment, and broad political and community.

Within the RUMOBIL project, between 2017 and 2019, several measures that were deployed in the pilots in low-density rural areas were tested and evaluated in seven different European countries (Germany, Italy, Czech Republic, Croatia, Slovakia, Poland and Hungary). It was possible to test a variety of innovative applications, all aimed at connecting scarcely populated peripheral areas to a primary, secondary, or tertiary transport node. These pilots were small-scale, short-term projects, which can be qualified as experimental trials which would function as a testbed for larger-scale projects in specific peripheral regions. These pilots also highlighted several areas of improvement that could benefit from the use of IoT technologies.

A strong PT, supported by IoT technologies, can improve the future prospects of rural areas, as also testified by the numerous recent projects focused on rural transports, which have been selected and analysed in this paper. Well-designed and organised PT supports general development along PT corridors and more homogeneous countryside. Improving PT between urban and rural areas can increase connectivity between them, help to develop local economies, contribute to the growth of local business and integrate the rural environment into the mainstream economy. With the support of local authorities, PT services can be even more effective, employ local people, and also benefit multiple stakeholders, as well as promote cultural heritage, natural landscapes, and other points of touristic relevance. Tourists are considerably interested in discovering rural areas through well-planned routes, especially when combined with natural adventure, sport or other activities.

Table 4 – IoT applications suitability for operators in the rural and urban contexts.

Application for operator	Suitable for context
Management of operation	Rural and urban
Demand responsive transport (DRT)	Rural and urban
Maintenance-wear	Rural and urban
Maintenance-damage	Rural and urban
Self-driving vehicle	Rural and urban
Transport related service	Rural and urban

Table 5 – Smart mobility issues complexity in the rural and urban contexts.

Issue	Complexity by context
Sustainability of the business model	Higher for rural
Data privacy and integrity	Same in rural and urban
Security	Same in rural and urban
Interoperability	Same in rural and urban
Scalability	Higher for urban
Usability/accessibility	Higher for rural
Data collection	Higher for rural

6. Conclusion

To understand how IoT technologies can be leveraged to improve transportation in rural areas, this study tries to understand whether only urban areas are suitable for the successful application of IoT technologies, or whether smart mobility systems can be deployed successfully for smart land too. For this purpose, we tried to answer RQ1 and RQ2 by leveraging the results stemming from the analysis of 10 different projects related to smart mobility.

With regard to RQ1, as previously reported, we found that smart mobility solutions can bring different benefits to smart cities and smart lands; however, even if we consider the heterogeneous levels of population scattering, technological infrastructures, social maturity, and economic opportunities, almost all solutions can be implemented in rural as well as urban areas. More specifically, different opportunities can have very positive impacts for both smart cities and smart lands: indeed, Tables 2–4 show the results of our evaluation, reporting a comparison of all the main opportunities.

On the other hand, Table 5 tries to answer RQ2, by showing that the rural and urban context each has its own strength and weaknesses, and also by providing more details on the nature of such similarities and differences. In particular, we identified two pivotal challenges for both rural and urban smart mobility applications, namely, the need for standardized metrics for optimal routes' detection and the employment of a dynamic definition of optimal routes. In addition, investments planning and programming appears to need consistent simplification, especially with regard to the coordination between planning authorities at different levels, which could build upon historical data on local transportation usage and current trends provided by IoT technologies.

The successful experiences proved that one of the good approaches for the organisation of PT is the integration of transport systems, which will have positive effect mainly for rural areas. Urban and rural transport networks must be properly designed to face an increasing number of people that will travel in and across urban and rural centres. Rural areas are the key challenges to provide a basic transport offer, and the PT system has to be properly designed and funded in order to satisfy the potential increase in demand.

As for the future transport planning, it is up to all policy levels to take into account all the challenges deriving from expected trends, and exploit all the untapped potential of IoT technologies in order to satisfy future traveller needs and to drive the changes on a sustainable track.

Conflict of interest

The authors do not have any conflict of interest with other entities or researchers.

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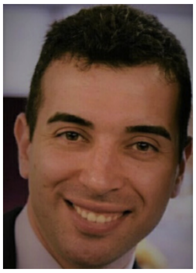

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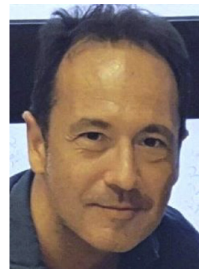

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