European Smart City and Urban Transport

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Abstract

Cities are facing challenges to increase sustainability in the current and future scenarios. Smart city is a possible solution for facing these challenges. This paper has the main objective to investigate the level of advancements of the smart city paradigm at European level. A specific focus is on the Urban Transport, which is one of the three pillars of the European smart city paradigm, with Information and Communication Technologies (ICT) and Energy. Two approaches are followed for the investigation: a top-down approach, from the indications of the European Commission (EC) to the smart city projects implemented by the European cities; a bottom-up approach, from the initiative promoted by European cities about sustainable urban mobility, with a specific attention to the Mobility as a Service (MaaS) paradigm. The obtained results show that EC is spending great efforts for implementing the smart city paradigm to increase sustainable urban mobility. However, the integration among the three pillars is, at today, limited. In the smart mobility sector, this is even more apparent. The great part of the MaaS initiatives pay a specific attention to ICT issues but they require more insights about integration among ICT, Transport System Models (TSM) and Energy productions and consumptions. The final aim is improving transport planning and designing processes aimed at improving urban sustainability.

Keywords

Smart city · European Union · Sustainable development · Urban planning · Urban mobility · Transport · ICT · MaaS

1 Introduction

Cities are facing challenges connected to sustainability that, in an imminent future, will became harder. The United Nations focused on these challenges in the Agenda 2030 that sets out the 17 Sustainable Development Goals (SDG). SDG 11 aims to "Make cities inclusive, safe, resilient and sustainable" (UN 2015). The goals have been specified with specific targets and indicators (UN 2018).

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The literature highlights the Smart City paradigm as a possible development urban direction to pursue sustainability (Russo et al. 2014, 2016; Zhao et al. 2021; Correia et al. 2022).

Setting its long-term goals and strategies, the European Commission (EC) posed a specific focus on urban challenges, specifying the smart city paradigm based on three pillars (Fig. 1): urban energy production and consumption (energy); urban transport and mobility (transport); urban Information and Communication Technology (ICT) (EC 2012).

Urban mobility constitutes a critical factor for residents, businesses and visitors. At the same time, it implies relevant effects in terms of traffic congestion, air pollution, and related socio-economic costs, or more in general, economic, environmental and social sustainability (Batty et al. 2015). Sustainable mobility is crucial for reaching different SDGs that directly and indirectly refer to the need of more sustainable, accessible, inclusive and efficient transport and territorial interrelated systems (Akuraju et al. 2020). In this context, public transport and organized city logistics could represent a valid transport alternative because they contribute to increase sustainability in terms of improvements of traffic management performance and reduction of pollution (Campisi et al. 2023; Hickman et al. 2013).

The European Court of Auditors has analyzed the commitment of cities to increase sustainability in the urban mobility sector. The obtained results show that, while many efforts are underway to define plans [e.g. the Sustainable Urban Mobility Plan, SUMP (EC 2019)], the concrete reduction of emissions in the cities is limited (ECA 2020).

The general objective of this paper is to analyze the European process and its related products to implement the Smart City paradigm, with the integration among the three pillars. The specific objective is to verify the progress of the paradigm in the urban mobility sector. To achieve these objectives, two different approaches are used (Fig. 2):

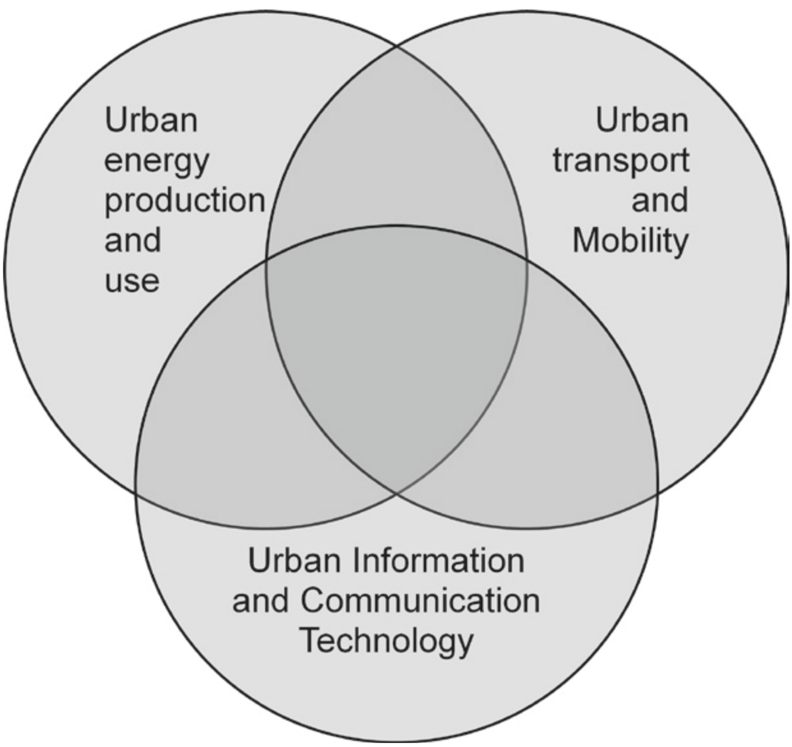

Fig. 1 European smart city pillars (EC 2012)

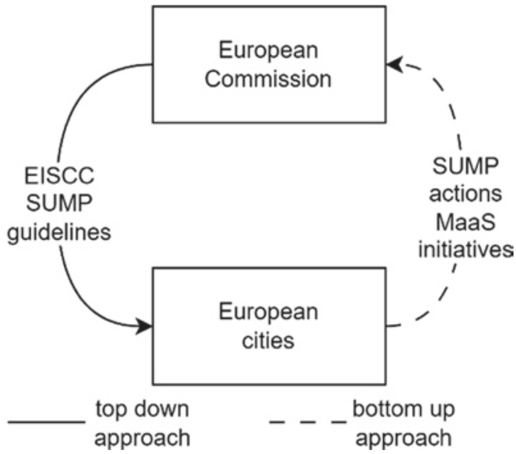

Fig. 2 Top-down and bottom-up approaches

- top-down approach, which starts from the indications, initiatives and guidelines produced by the European Commission and ends with analysis of smart city projects implemented by the European cities (e.g., SUMP guidelines);
- bottom-up approach, starting from the initiatives implemented by European cities about sustainable urban mobility, with specific attention to the implementation of the Mobility as a Service (MaaS) paradigm, and ending with the verification of integration among the three pillars (e.g., SUMP actions).

After this introduction, the paper is organized in three sections. Sections 2 and 3 are organized according to the paper's objectives: Sect. 2 follows the top-down approach and it presents the results of a survey on the main European smart city initiatives promoted by the European Commission (EC); Sect. 3 follows the bottom-up approach and it reports the results of a survey carried out by the main European cities, by focusing on the implemented MaaS initiatives. Section 4 concludes the paper with a discussion about the obtained results and some conclusive remarks and future developments of the research.

2 European Smart City: Top-Down Approach

This section analyzes the European smart city initiatives following a top-down approach: starting from the European Commission indications (Sect. 2.1), the focus is on the transport pillar (Sect. 2.2) analyzing European cities that implemented these indications with specific projects (Sect. 2.3).

2.1 The European Commission Indications

The European Commission defined the Smart City paradigm in 2012, with a directive that introduced the three main pillars set out in the introduction (Energy, Transport and ICT) (EC 2012). The connection among the three areas depends on the advancement of meta-path regarding three main nodes (Russo et al. 2016, 2021, 2022; Russo 2021; Russo and Rindone 2023):

- theories, or science that study urban phenomena;
- rules, or laws, guidelines, and plans aimed at the regulation of urban dynamics;
- implementations, or concrete interventions that modify the actual configuration of cities.

These advancements imply the need to use new interdisciplinary approaches to address current and future challenges related to urban sustainability in its three main components: social, economic and environmental (Martin et al. 2018, 2019).

To put these advancements into practice, the European Commission has activated the European Innovation Partnership for Smart Cities and Communities (EIP-SCC), as a derivation of the Smart Growth strategy (Russo et al. 2014). This is a community that includes universities, companies and public administrations that work together to face the city challenges (Macrorie et al. 2022). One of the first documents of the EIP-SCC was the Strategic Implementation Plan (SIP), subsequently specified with the Operational Implementation Plan (OIP) (EC 2013, 2014).

Smart city European plans indicate three priority vertical areas:

- *Sustainable Districts and Urban Environments* (SDEU), connected with energy production, distribution and consumptions problems and solutions;
- *Sustainable Urban Mobility* (SUM), connected with challenges and solution for increasing people and freight sustainable mobility;
- *Integrated Infrastructures and Processes* (IIP), connected with material and immaterial infrastructures, including ICT.

The integrations among the three priority vertical areas is reached by considering different points of view (for instance private and public). The focus is on eight aspects, grouped in three horizontal classes:

- *Decisions* (citizen focus, policy and regulation, and integrated planning and management);
- *Insight* (knowledge sharing, metrics and indicators, open data and standards);
- *Funds* (business models, procurement and funding).

When the vertical areas are developed in an integrated manner, the EIP-SCC approach becomes effective. It means that all the three priority areas are addressed simultaneously by approaches belonging to the horizontal classes. In the following, we focus on the *SUM* vertical priority area and the *Insight* horizontal class.

A schematic representation of the European Smart City framework is shown in Fig. 3, which focuses on the Sustainable Urban Mobility priority area, its action cluster, and initiatives developed by EIP-SCC.

For making operative the EIP-SCC approach operative, the common working tool is the "Marketplace of the European Innovation Partnership on Smart Cities and Communities" (M-EIP-SCC) (EC 2022a, b), a web platform that collects and groups data and information relevant to smart city development, including policies, guidelines, and implementations. The platform is the main tool for engaging, matching, and committing the main stakeholders involved on SUM vertical priority area and related issues that intersect the other two smart city pillars (Energy and ICT).

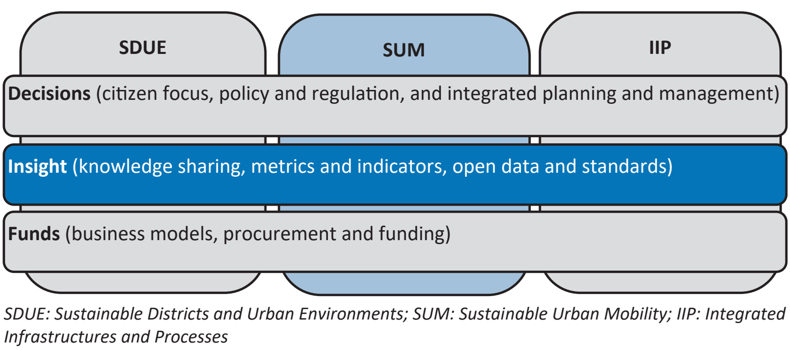

Fig. 3 European smart city framework (adapted from EC 2013). SDUE: Sustainable Districts and Urban Environments; SUM: Sustainable Urban Mobility; IIP: Integrated Infrastructures and Processes

2.2 The Sustainable Urban Mobility Area

The SUM area regards problems and solutions for increasing sustainability of urban people and freight mobility. These issues constitute the contents of the *Action Clusters* (AC) named "Sustainable Urban Mobility" (AC SUM). The AC is an operative tool of EIP-SCC that groups different stakeholders deriving from different public and private sectors (for instance, universities, public administrations, private business operators) (EC 2023). Generally, AC members work together on specific issues related to smart cities. They share knowledge and expertise with the aim to identify gaps at national and local level that need to be filled at European level. In the specific case of urban mobility, AC SUM brings together public administrations and transport operators interested in finding mobility solutions and support their implementation in European cities. The final aim is to increase knowledge for understanding city needs and, then, the corresponding tailored solutions. The last version of the AC SUM involves 213 active members that are working on four initiatives:

- Electric Vehicles for Smart Cities and Communities (EV4SCC);
- Intelligent Mobility for Energy Transition (IMET);
- New Mobility Services (NMS);
- Urban Air Mobility (UAM).

All the initiatives developed by AC SUM work on *door-to-door multi-modal real-time urban mobility* for contributing to the increasing of sustainability and, more in general, the quality of life of citizen and competitiveness of business. By focusing on the NMS, in 2014 European Commission embedded the "New Mobility Services partnership" into AC SUM. Since 2021 the partnership involves 174 partners including public authorities, industry, researchers and citizens working for deployment and market NMS in the urban context (Fig. 4).

Cooperative Intelligent Transport Systems (C-ITS), Cooperative, Connected and Automated Mobility (CCAM) and Mobility as a Service (MaaS) are the main goals of the NMS partnership for increasing sustainability in urban mobility (EU CIVITAS 2023). One of the main challenges pertains to the transformation process from theory to European rules and best practices; among these, the recent theoretical concept of seamless mobility translated into Mobility as a Service (MaaS), which is an emerging paradigm enabled by sharing

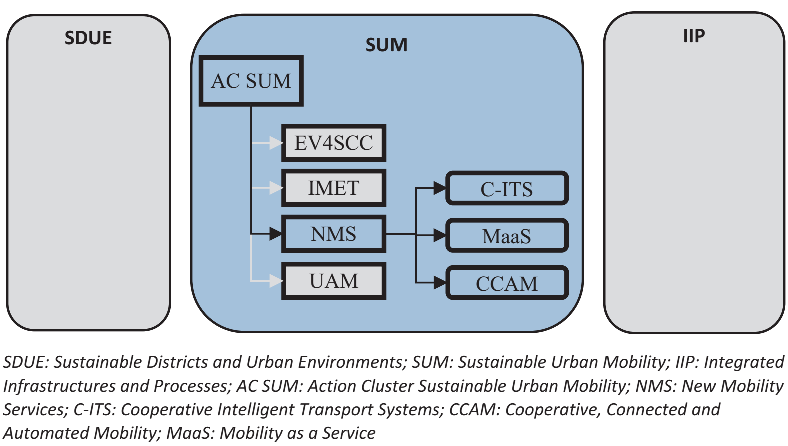

Fig. 4 Action cluster Sustainable Urban Mobility (SUM) and initiatives. SDUE: Sustainable Districts and Urban Environments; SUM: Sustainable Urban Mobility; IIP: Integrated Infrastructures and Processes; AC SUM: Action Cluster Sustainable Urban Mobility; NMS: New Mobility Services; C-ITS: Cooperative Intelligent Transport Systems; CCAM: Cooperative, Connected and Automated Mobility; MaaS: Mobility as a Service

mobility and developments of emerging ICT (Kamargianni et al. 2016). MaaS is a user-centred form of mobility that combines information and potentialities of ICT tools, Transport System Models (TSM) inside public or private Decision Support System (DSS), with the aim of offering an alternative to unsustainable mobility, often based on the use of private cars (Matyas 2020; Vitetta 2022). MaaS represents an opportunity to promote sustainable urban mobility. Over the last few years, also thanks to the development of technologies and field experiences developed in funded projects in the smart city field, the paradigm does not only address the integration between ICT and transport but also the issue of energy resources and environmental impacts (Russo 2022; Russo and Rindone 2023).

The literature on the scientific advancements regarding the Mobility as a Service (MaaS) paradigm is the subject of Sect. 3.1.

2.3 European Smart City Initiatives

The M-EIP-SCC platform collects in a database the information about each EU-funded Smart Cities (EUSC) project in relation with the specific thematic fields, concerning three different territorial scales: urban area portion (energy of an urban area) or a single building (energy of a single building), either existing or new. Table 1 summarizes the smart city thematic fields present in the M-EIP-SCC platform in relation to the territorial extension.

The advancement of the European smart city process are analyzed by performing a desk survey conducted starting from the information offered by the M-EIP-SCC platform. The period considered in the investigation goes from 2012 to 2022. The projects concerning the "Mobility and transport" field were investigated. The cities involved in the projects constitute experimental sites to verify the feasibility of the smart city concept.

The total list of EUSC projects amounts to 89, involving 48 lighthouse cities and 72 fellow cities. A great part of total projects (75%) has been completed. Among the total list of projects, 18 are named "lighthouse". Of these, 12 projects regard the thematic field "Mobility and Transport". The total number of cities interested in the thematic field "Mobility and Transport" is 34, of which: 23 cities are working on the subthematic field "vehicle and infrastructures"; 8 cities are working on the thematic field "vehicles"; 3 are working on the thematic field "infrastructures" (Figs. 4, 5).

By considering the 48 cities involved in the 18 lighthouse projects, it is possible to identify the group of thematic fields addressed in a project. Note that the majority of cities worked on ICT, Mobility and Transport (UT) and Energy with reference to single buildings. Figure 6 depicts different sets and their intersections relative to the three pillars: Transport, Energy and ICT. The figure reports the number of projects and the corresponding involved lighthouse cities.

Table 1 EU-funded smart cities (EUSC) projects: thematic field and territorial extension

Thematic field	Territorial extension		
	Urban area portion	Single building	
		Existing	New
"Energy system(s) integration"	X		
"Mobility and transport"—"vehicle"	X		
"Mobility and transport"—"infrastructures"	X		
"Information and communication technologies"	X	X	
"Positive energy district (PED)"	X		
"Refurbished building(s)"	X	X	
"New building(s)"	X		X

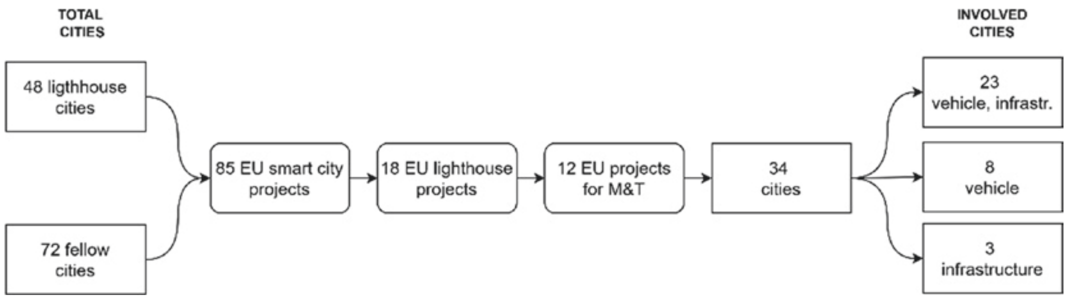

Fig. 5 Summary of EU smart city projects and cities in mobility and transport (M&T) projects

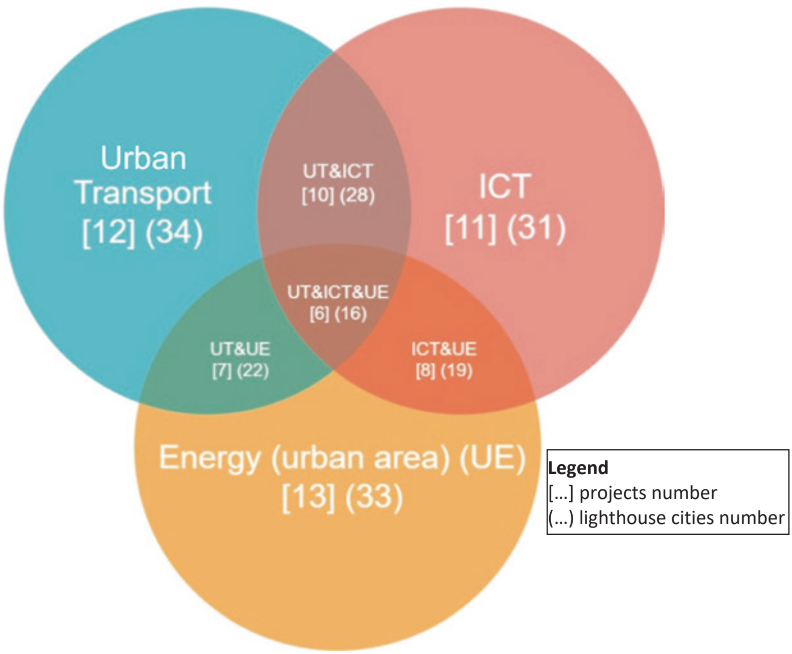

Fig. 6 Thematic fields of smart city projects and mutual intersections (UT: Urban Transport; UE: Urban Energy)

Figure 6 shows that there is a relevant part of smart city projects that have two common pillars. The greatest overlap is recorded between ICT and transport, with 10 projects involving 28 lighthouse cities. Six smart city projects are fully compliant with the European smart city paradigm, developing all the three pillars.

3 European Smart City: Bottom-Up Approach

This section analyzes the European smart city initiatives following a bottom-up approach to investigate if the three pillars are used in an integrated way. The focus is on the Mobility as a Service (MaaS) paradigm (Sect. 3.1); according to the European smart city approach, MaaS interacts with the ICT and energy pillars (Sect. 3.2); some European cities are implementing the paradigm with specific initiatives that consider one or more pillars (Sect. 3.3).

3.1 Mobility as a Service (MaaS): Basic Paradigm

The Mobility as a Service paradigm puts into practice a set of consolidated theories about mobility (Banister 2008; Cascetta 2013; Hensher et al. 2020). MaaS moves from the traditional transport approach based on physical infrastructures, isolated operators and limited set of information, to a new concept of smart mobility in which user needs are at the center of a transport system. This is possible through the achievement of interoperability between different actors involved in the urban transport ecosystem (operators of traditional transport services, ICT operators, public administrations). Interoperability is not just about data and immaterial platforms; in order for the MaaS paradigm to become a reality, it is necessary to integrate the material transport infrastructures and services that operate on them, with ICT tools for monitoring, ticketing and payment information systems. New MaaS operators integrate data, information deriving from traditional Transport Service Providers (TSPs) and MaaS Operators (MOs) in order to supply more services as unique travel option. This implies advancements on transport design network methodologies (Musolino et al. 2022) based on user's need (Musolino 2022). The output is a transport system that integrates material and immaterial, governance, institutions and equipment supply components (Rindone 2022).

In the transport sector, the focus shifts from the physical aspects, connected with the infrastructure construction and management processes, to the management and immaterial factors. The final aim is to increase the user's perception that the different transport components (infrastructures and services) are part of an integrated transport system. Using emerging ICT technologies and the provided services (e.g., spatial and temporal, historical and real-time positioning services, mobile hardware and software), it is possible to design and implement an integrated transport system where different travel options are possible deriving from the combination of one or more transport services. The combination among ICT platforms, Internet of Things (IoT), Artificial Intelligence (AI), and blockchain, create travel options tailored on individual mobility needs (Atzori et al. 2010; Russo 2022). MaaS is thus more than a single app or technology. This is a new way of organizing transportation network in terms of infrastructures, services, management and rules for increasing travel users' benefits and social, economic and environmental sustainability or, in a more general way, the goals of Agenda 2030. In this context, the role of public administrators is to facilitate innovation processes of TSPs and MOs.

Smart urban mobility includes the following applied processes regarding the different demand components:

- People mobility and Mobility as a Service (MaaS) concept (Hensher et al. 2020);
- Freight mobility and Logistics as a Service (LaaS) (Klingebiel and Wagenitz 2013), Freight as a Service (FaaS) (Comi and Russo 2022; MIMS, 2022) and Self-Organizing Logistics (SoL) (Schroten et al. 2020; Campisi et al. 2021) concepts.

3.2 Mobility as a Service: Advanced Paradigm

The MaaS paradigm is evolving from a configuration, characterized by the use of ICT tools for monitoring mobility, to a more complex ecosystem where the transport system is designed with the support of Transport System Models (TSMs). The final goal is the equilibrium among all sustainability components.

People and freight mobility are observed with ICT tools that collects information about transport supply (Rindone 2022), demand (Senikidou et al. 2022; Musolino 2022) and their interactions (Vitetta 2022). Data and information feed Transport System Models (TSM) that reproduce traveler choices allowing the simulation of transport systems in current and future configurations. The evolving MaaS ecosystem integrates:

- material urban transport infrastructures and services, including 'hard' (e.g., mass urban transit) and 'soft' modes (especially walking and cycling);
- immaterial urban Information and Communication Technologies (ICT) and related services (information, ticketing and payment) for mobility;
- infrastructures for energy production, distribution (e.g., urban grid) and consumption.

The final goal is to achieve an urban sustainable transport system through successive steps of advancement on different MaaS levels (Fig. 7), corresponding to increasing levels of sustainability (Vitetta 2022; Russo 2022):

1. N-MaaS (No MaaS) features no integration because each transport mode operates in a separate way;
2. MaaS 1.0 or I-MaaS only integrates transport system with an ICT platform used by operators and users (ICT MaaS);
3. MaaS 2.0 or T-MaaS enhances MaaS 1.0 with TSM for designing and managing transport system;
4. MaaS 3.0 or S-MaaS (Sustainable, TSM and ICT MaaS) enhances MaaS 2.0 with Environmental Impact Functions (EIFs) for verifying sustainability goals and targets.

3.3 MaaS Initiatives in European Cities

Table 2 reports the list of the 12 smart city projects focused on the "Mobility and Transport" thematic field (see Sect. 2.3). These projects are developed by 29 lighthouse cities, out of the total 48.

A web survey has been done by the authors, to check the status of the MaaS paradigm advancements in these lighthouse cities. The survey has two objectives: (1) to verify whether the lighthouse city has launched a MaaS initiative, even at an initial stage (e.g., a pilot); (2) to verify if the initiatives integrate ICT, TSM and Energy issues.

The first objective yielded the results reported in Table 2. 69% of lighthouse cities have started a MaaS initiative.

The second objective is described by the results shown in Fig. 8. Each MaaS initiative has been classified in relation with the three smart city pillars and their mutual interactions. The figure shows the number and the percentage of the 48 lighthouse cities involved in a smart city project (see Sect. 2). The greatest share of initiatives regards only the ICT issue (18 cities, 37.5%). Some of these integrates ICT with TSM (6 cities, 12.5%) and Energy (7 cities, 14.6%)

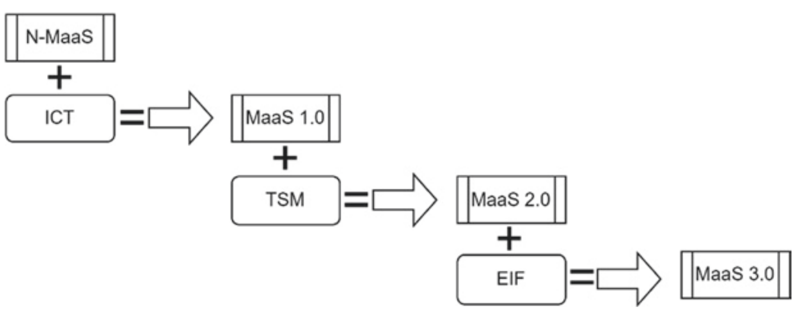

Fig. 7 MaaS levels (TSM: Transport System Models; EIF: Environmental Impact Function)

Table 2 MaaS initiatives in lighthouse cities

City	Population[a]	Smart city project	MaaS initiative
Limerick, Ireland	94,132	+CityxChange	NA
Trondheim, Norway	205,332	+CityxChange	Yes
Bilbao, Spain	1,048,966	ATELIER	NA
Amsterdam, Netherlands	2,881,048	CITY-ZEN	Yes
Barcelona, Spain	5,111,749	GrowSmarter	Yes
Hamburg, Germany	3,341,649	mySMARTLife	Yes
Helsinki, Finland	1,540,002	mySMARTLife	Yes
Nantes, France	320,732	mySMARTLife	NA
Tepebasi/Eskisehir, Turkey	305,632	REMOURBAN	NA
Valladolid, Spain	425,008	REMOURBAN	Yes
Nottingham, United Kingdom	337,100	REMOURBAN	Yes
Bristol, United Kingdom	472,400	REPLICATE	Yes
Florence, Italy	383,083	REPLICATE	NA
San Sebastián, Spain	405,089	REPLICATE	NA
Glasgow, United Kingdom	635,640	RUGGEDISED	NA
Umeå, Sweden	130,224	RUGGEDISED	NA
Rotterdam, Netherlands	1,883,116	RUGGEDISED	Yes
London, United Kingdom	9,002,488	Sharing Cities	Yes
Milan, Italy	4,985,668	Sharing Cities	Yes
Lisbon, Portugal	3,008,000	Sharing Cities	Yes
Lyon, France	2,280,845	SMARTER TOGETHER	Yes
Munich, Germany	2,927,716	SMARTER TOGETHER	Yes
Vienna, Austria	1,951,354	SMARTER TOGETHER	Yes
Tampere, Finland	334,112	STARDUST	Yes
Trento, Italy	241,386	STARDUST	Yes
Pamplona, Spain	209,672	STARDUST	NA
Eindhoven, Netherlands	767,499	Triangulum	Yes
Stavanger, Norway	237,369	Triangulum	Yes
Manchester, United Kingdom	556	Triangulum	Yes

NA information not available
[A]*Source* Eurostat 2023

issues. A limited number of initiatives integrates the three smart city pillars (4 cities, 8.3%).

The case of Helsinki is emblematic. It is the first city in the world that has experimented the MaaS paradigm. In Helsinki, the MaaS implementation produced implications for ICT tools, transport infrastructures and services, as well as for the forms of management and payment of the different transport operators. The role of the rules was decisive because it provided an impulse for all public and private actors involved in the mobility sector so that they could integrate from different points of view, starting from information. Three drivers have been fundamental for the MaaS implementation:

- the public administration commitment, which produced relevant changes in transport regulations, starting from the data and information sharing of different transport operators, and the promotion of public–private partnerships;
- the roles of ICT, essential for integrating and sharing information, TSM implemented on open source or commercial DSS (eg., google API or openstreetmap); an example is the

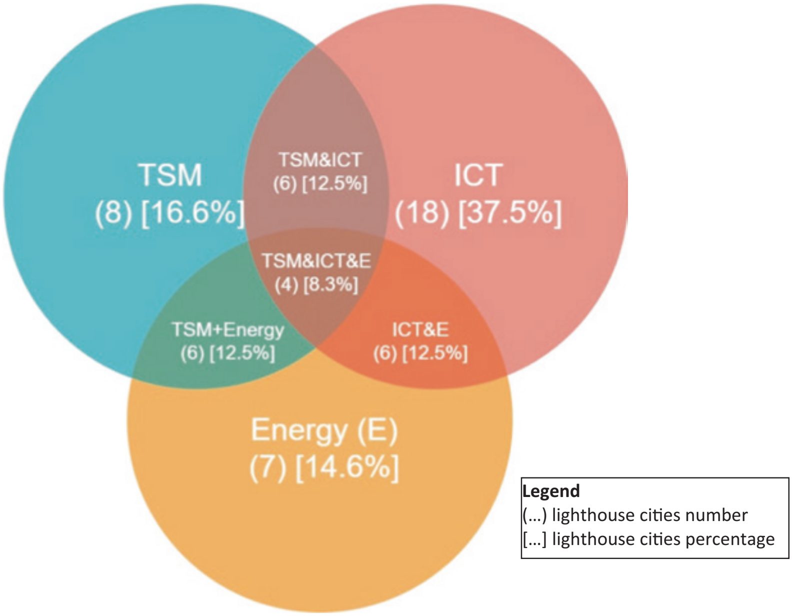

Fig. 8 Thematic fields of MaaS initiatives and mutual intersections

Helsinki Region Transport's platform (HSL 2023), which collects data, TSM for supporting TSPs and MOs;

- the role of transport infrastructures and services operators; with the PA commitment, they pursue:
  - physical integration among different infrastructures,
  - modal integration among individual and collective transport,
  - fare integration among financial services of single operators for bundle commerce.

Some European smart city projects are representative of mutual intersections among thematic fields. For instance, the STARDUST project proposes technical solutions implemented in the three lighthouse cities (Pamplona, Spain, Tampere, Finland, and Trento, Italy) regarding the energy, mobility and ICT sectors. A real example is the experimentation of the "e-car sharing" in the Municipality of Trento, consisting in the design and installation of charging stations for electrical vehicles used by private and public operators; among the expected impacts are the reduction of greenhouse gas emissions (about 63% less than in 2021) and energy savings (about 58% less than in 2021). Another example is the "Grow Smarter" project: the city of Barcelona experimented traffic management actions through Macroscopic Fundamental Diagram (MFD); a set of models is built for simulating effects produced by smart traffic light optimization: application of these models is expected to have positive impact in terms of reduction of traffic density and travel time, together with 15–16% reduction in CO_2 and NO_x emissions.

4 Discussion and Conclusions

4.1 Discussion

Smart City is a paradigm for facing current and future urban challenges with the aim of improving sustainability. The European Commission is working to implement the paradigm in European cities, to pursue balanced and integrated development of transport, ICT and energy sectors. This paper investigates the level of advancement of the integration between the three pillars of the city paradigm at the European level.

Specific focus is on the urban transport smart city pillar, which interacts with the other two (ICT and energy). From the results obtained from a survey of funded smart city projects, it emerges that integration among the three smart city pillars is limited. Four European smart city projects are fully compliant with the European paradigm because they addressed all three pillars (ICT, transportation, and energy). In the smart mobility sector, this is even more apparent. The great part of the MaaS initiatives pays attention to ICT issues, but requires more attention to Transport System Models (TSM) and energy production and consumption. There are only four cities implementing the MaaS paradigm including all three European smart city pillars: Espoo, Helsinki, Manchester, Rotterdam. Note that two cities belong to the same country; this confirms the need for commitment at the national level. The final aim is improving the process of planning and designing for improved urban sustainability.

4.2 Conclusive Remarks

Most of the analyzed European cities have started smart city and MaaS initiatives. This confirms the attention of cities to the Smart City paradigm and the need to integrate transport with ICT and energy. There is a limited number of real experiences integrating all the sectors related with the three pillars. The main limit of this research is connected with the reliability of the database produced by EIP-SCC.

This research can have further developments following different research directions. It is possible to analyze the impact produced by smart city projects breaking it into sustainability components. Another direction concerns the state of advancement of transportation planning processes. It would be interesting to increase the knowledge about how the three pillars will be implemented in real urban contexts, in this way addressing other lines of research.

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References

V. Akuraju, P. Pradhan, D. Haase, J.P. Kropp, D. Rybski, Relating SDG11 indicators and urban scaling—an exploratory study. Sustain Cities Soc **52** (2020). https://doi.org/10.1016/j.scs.2019.101853

L. Atzori, A. Iera, G. Morabito, The Internet of Things: a survey. Comput. Netw. **54**, 2787–2805 (2010)

D. Banister, The sustainable mobility paradigm. Transp. Policy **15**(2), 73–80 (2008)

P. Batty, R. Palacin, A. González-Gil, Challenges and opportunities in developing urban modal shift. Travel Behav. Soc. **2**(2), 109–123 (2015). https://doi.org/10.1016/j.tbs.2014.12.001

T. Campisi, A. Russo, G. Tesoriere, E. Bouhouras, S. Basbas, COVID-19's effects over e-commerce: a preliminary statistical assessment for some European countries, in *International Conference on Computational Science and Its Applications* (Springer, Cham, 2021, pp 370–385)

T. Campisi, A. Russo, G. Tesoriere, M. A. Al-Rashid, *A two-steps analysis of the accessibility of the local public transport service by university students residing in Enna*, In *International Conference on Computational Science and Its Applications* (Springer Nature Switzerland, Cham, 2023), pp. 147–159.

E. Cascetta, *Transportation Systems Engineering: Theory and Methods*, 1st ed. (Springer Science & Business Media, Berlin/Heidelberg, Germany, vol. 49) (2013)

A. Comi, A. Russo, Emerging information and communication technologies: the challenges for the dynamic freight management in city logistics. Front. Future Transp. Sec. Transp. Syst. Model. (2022). https://doi.org/10.3389/ffutr.2022.8873079

D. Correia, J.L. Marques, L. Teixeira, CITY@PATH: a collaborative smart city planning and assessment tool. Int. J. Transp. Dev. Integr. **6**(1), 66–80 (2022). https://doi.org/10.2495/TDI-V6-N1-66-80

EC, European Commission, *Communication from the Commission Smart Cities and Communities European Innovation Partnership* (2012), Retrieved at: https://ec.europa.eu/transparency/documents-register/detail?ref=C(2012)4701&lang=en. Last Access 07 Jan 2023

EU CIVITAS (2023) *The New Mobility Services Partnership*. Retrieved at: https://civitas.eu/NMS. Last Access 31 Jan 2023

European Commission. EC, *Strategic Implementation Plan (SIP)* (2013). Retrieved at: https://smart-cities-marketplace.ec.europa.eu/media/2261. Last Access 07 Jan 2023

European Commission. EC, *Operational Implementation Plan (OIP): First Public Draft* (2014). Retrieved at: https://smartcities.at/wp-content/uploads/sites/3/operational-implementation-plan-oip-v2-en2.pdf. Last Access 07 Jan 2023

European Commission. EC, *Smart city market place*. EXPLORE, SHAPE & DEAL. An interactive guide to the smart cities marketplace (2022a). Retrieved at: https://smart-cities-marketplace-brochure.eu/.2021/#page=1. Last Access 07 Jan 2023

European Commission. EC, *Smart Cities Marketplace: Projects and Sites Overview* (2022b). Retrieved at: https://smart-cities-marketplace.ec.europa.eu/projects-and-sites/projects. Last Access 07 Jan 2023

European Commission. EC, *Smart Cities Marketplace: Action Clusters* (2023). Retrieved at: https://smart-cities-marketplace.ec.europa.eu/action-clusters-and-initiatives/action-clusters. Last Access 30 Jan 2023

European Commission. EC, *Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan*, 2nd edn (2019). Available Online: https://www.eltis.org/guidelines/sump-guidelines. Last Access 30 Jan 2023

European Court of Auditors. ECA, Sustainable Urban Mobility in the EU: no substantial improvement is possible without Member States' commitment (2020). Retrieved at: https://www.eca.europa.eu/lists/eca-documents/sr20_06/sr_sustainable_urban_mobility_en.pdf. Last Access 24 Jan 2023)

Garcia-Ayllon, S., Hontoria, E., & Munier, N. (2022). The contribution of MCDM to SUMP: The case of Spanish cities during 2006–2021. International Journal of Environmental Research and Public Health, 19(1) doi:https://doi.org/10.3390/ijerph19010294

Helsinki Region Transport (HSL) (2023). Open data. https://www.hsl.fi/en/hsl/open-data (Last access, 20/02/2023)

Hensher, D. A., Mulley C., Ho C., Wong Y., Smith G., and Nelson, J. D., *Understanding Mobility as a Service (MaaS): Past, present and future*. Elsevier, 2020.

R. Hickman, P. Hall, D. Banister, Planning more for sustainable mobility. J. Transp. Geogr. **33**, 210–219 (2013). https://doi.org/10.1016/j.jtrangeo.2013.07.004

M. Kamargianni, W. Li, M. Matyas, A. Schäfer, A Critical Review of New Mobility Services for Urban Transport. Transportation Research Procedia **14**, 3294–3303 (2016)

K. Klingebiel, A. Wagenitz, An Introduction to Logistics as a Service, in *Efficiency and Logistics. Lecture Notes in Logistics*, ed. by U. Clausen, M. ten Hompel, M. Klumpp. Springer, Berlin, Heidelberg (2013). https://doi.org/10.1007/978-3-642-32838-1_22

R. Macrorie, S. Marvin, A. Smith, A. While, A common management framework for European smart cities? the case of the European innovation partnership for smart cities and communities six nations forum. J. Urban Technol. (2022). https://doi.org/10.1080/10630732.2022.2121558

C.J. Martin, J. Evans, A. Karvonen, Smart and sustainable? five tensions in the visions and practices of the smart-sustainable city in Europe and north America. Technol. Forecast. Soc. Chang. **133**, 269–278 (2018). https://doi.org/10.1016/j.techfore.2018.01.005

C.J. Martin, J. Evans, A. Karvonen, K. Paskaleva, D. Yang, T. Linjordet, Smart-sustainability: A new urban fix? Sustain. Cities Soc. **45**, 640–648 (2019). https://doi.org/10.1016/j.scs.2018.11.028

Ministero delle Infrastrutture e della Mobilità Sostenibili. MIMS. Mobilità e Logistica Sostenibili. Analisi e indirizzi strategici per il futuro (2022). https://www.mit.gov.it/nfsmitgov/files/media/notizia/2022-10/Mims_Mobilit%C3%A0%20e%20logistica%20sostenibili_pag%20singola%20r3_0.pdf. Last Access 07 Jan 2023

M. Matyas, Opportunities and barriers to multimodal cities: lessons learned from in-depth interviews about attitudes towards mobility as a service. Eur. Transp. Res. Rev. **12**, 7 (2020)

G. Musolino, Sustainable mobility as a service: demand analysis and case studies. Information **13**(8), 376 (2022)

G. Musolino, C. Rindone, A. Vitetta, Models for supporting mobility as a service (MaaS) design. Smart Cities **5**(1), 206–222 (2022)

C. Rindone, Sustainable mobility as a service: supply analysis and test cases. Information **13**(7), 351 (2022)

F. Russo, Which high-speed rail? LARG approach between plan and design. Future Transp. **1**(2), 202–226 (2021)

F. Russo, Sustainable mobility as a service: dynamic models for agenda 2030 policies. Information **13**(8), 355 (2022)

F. Russo, C. Rindone, Regional transport plans: from direction role denied to common rules identified. Sustainability **13**(16), 9052 (2021)

F. Russo, C. Rindone, TPL—strumenti di Piano, in *Sistemi di trasporto pubblico locale. Risorse, pianificazione, esercizio*, ed. by D. Festa, G. Corona. EGAF, Italy (2022)

F. Russo, C. Rindone, Smart city for sustainable development: applied processes from SUMP to MaaS at European level. Appl. Sci. 2023, **13**(3), 1773 (2023). https://doi.org/10.3390/app13031773

F. Russo, C. Rindone, P. Panuccio, The process of smart city definition at an EU level. WIT Trans. Ecol. Environ. **191**, 979–989 (2014)

F. Russo, C. Rindone, P. Panuccio, European plans for the smart city: from theories and rules to logistics test

case. Eur. Plan. Stud. (2016). https://doi.org/10.1080/09654313.2016.1182120
F. Russo, P. Panuccio, C. Rindone, Structural factors for a third-generation port: between hinterland regeneration and smart town in Gioia Tauro, Italy. Urban Maritime Transp. **27**(204), 79–90 (2021)
F. Russo, C. Rindone, P. Panuccio, External interactions for a third-generation port: from urban sustainable planning to research developments. Int. J. Transp. Devel. Integrat. **6**(3), 253–270 (2022)
A. Schroten, A. Van Grinsven, E. Tol, L.Leestemaker, P.P. Schackmann, D. Vonk-Noordegraaf, J. Van Meijeren, S. Kalisvaart, Research for TRAN Committee—The impact of emerging technologies on the transport system, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels (2020)
N. Senikidou, S. Basbas, G. Georgiadis, T. Campisi, The role of personal identity attributes in transport mode choice: the case study of Thessaloniki, Greece. Soc. Sci. **11**(12) (2022). https://doi.org/10.3390/socsci11120564
UN, United Nation: SDG Indicators. Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development (2018). Retrieved at: https://unstats.un.org/sdgs/indicators/indicators-list/. Last Access 20 Feb 2023
UN, United Nation. Sustainable Development Goals (SDG) (2015). Retrieved at: https://sdgs.un.org/goals. Last Access 20 Feb 2023
A. Vitetta, Sustainable mobility as a service: framework and transport system models. Information **13**(7), 346 (2022)
F. Zhao, O.I. Fashola, T.I. Olarewaju, I. Onwumere, Smart city research: a holistic and state-of-the-art literature review. Cities **119** (2021). https://doi.org/10.1016/j.cities.2021.103406