A Preliminary Survey on Smart Specialization Platforms: Evaluation of European Best Practices

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Abstract. In July 2021, the World Economic Forum, in collaboration with the G20 Global Smart Cities Alliance, presented a study on the status of technology governance in cities, outlining the fundamental conditions that all smart cities, regardless of their strategic aims, must achieve. A decision support system based on a model that enables interoperability across multiple urban sectors should ensure these requirements, which serve as the foundation for effective technological governance. To accomplish this, many European cities have based their urban strategies on smart specialisation on open web platforms that systematise different sectors to create smart cities. From these premises, the purpose of this paper is threefold: (i) investigate the relationship between smart urban development and the use of open data platforms; (ii) understand how these are useful for defining actions and strategies that facilitate the planning of a smart city, and (iii) understand, if it is possible, to find platform's common characteristics that allow cooperation of intentions between European Union cities. To this goal, the authors make a systematic and cross-reading of some European platforms' good practices in smart city solutions and projects, highlighting the scope of the smart city and sustainability/financing, the open data exploitation and the technical characteristics. In this regard, an analytical approach is proposed, underlining the originality and value of this research to strengthen the smart Governance model based on open web platforms.

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1 Introduction

Over the last decades, cities have invested in smart applications to provide better services to citizens and businesses. Concepts such as smart mobility, smart waste management, smart water, smart building, smart energy have evolved to signify the extensive use of IoT (Internet of Thing) in better managing city assets [1]. Connected sensors that collect data can help cities optimise their physical infrastructure's performance and are a key part of what it takes to build a smart city [2–4].

Implementing these solutions has helped the cities become more efficient and open but not yet smart. A key trend is moving to the next generation of smart cities where the focus is no anymore on the infrastructure but on sharing and managing data to enable better decision-making for all stakeholders' government, business, and residents [5–9]. Smart cities of tomorrow are evolving as intelligent, connected ecosystems that involve not just government but citizens, visitors, and businesses. This new information-sharing partnership between the city, residents and businesses can be considered a '*city-as-a-platform*'. In this context, smart cities enable more innovative things and smarter decisions. A truly smart city uses technology to promote better decision-making for city officials and its residents. The use of open web platforms allows cities to (i) manage data in an organised and systematic way, (ii) to advance as ecosystems of technological transformation and (iii) to be part of a network of cities of different maturity levels which can act as a catalyst for the motivation and engagement of their decision-makers and ambassadors of transformation.

However, in the past years, various pioneering cities in the use of platforms have been involved in (partially) sponsored city initiatives by a large tech company to promote their proprietary digital city platforms [10]. This has provoked a lot of longer-term consequences. Indeed, as initial platforms are proprietary and do not follow any standards, it becomes more difficult at a later stage to switch to different urban data platform providers as existing applications and systems have to be adapted or redeveloped. This situation is often referred to as '*vendor lock-in*'. Local authorities soon find themselves restricted to one company's IT system and products for many years. This also forms a significant barrier to entry for smaller technology providers excluded from these opportunities. Additional barriers also exist for small technology providers trying to engage in this market. Small technology providers must adapt and integrate their solutions if a local authority presents a specific technical system. This adds high cost and complexity to each implementation and limits the company's ability to expand and scale its solutions to other similar cities and communities. In recent years, to solve these problems, more and more cities have selected standards-based platforms for which multiple vendor implementations exist. This makes it easier in future to switch to a different vendor without breaking many existing dependencies. Standards-based ecosystems are often richer in terms of what they offer as market opportunities for a participating product, service and solution providers increase.

Open standards for urban data platforms have also been recently emerging. Key aspects that are currently standardised include data models and Application Programming Interfaces (APIs) for integrating IoT data sources and developing smart city services on the platforms. Examples of such emerging standards are NGSI-LD (Next Generation Service Interfaces-Linked Data) by the European Telecommunications Standards Institute (ETSI) for context information management [11], FIWARE data models also in NGSI [12], and the TM Forum business ecosystem APIs for ecosystem transaction management [13]. Multiple vendor implementations of urban data platforms around the aforementioned standards are now available. This also includes open-source implementation such as that supported by the FIWARE Foundation. An interesting aspect is that funding support is now available for public sector organisations to adopt such standards-compliant data platform components through the Connecting Europe Facility (CEF) [14]. Open technologies do not stop at urban data platforms but can also extend to the necessary connectivity layer in a future city. Recently emerging low-power, wide-area network technologies such as LoRaWAN [15] have made IoT connectivity affordable for cities, with some limitations with respect to the more expensive emerging 5G solutions. While they previously had to rely on network operators or external organisations to provide wide-area connectivity services, they can now own their network at a fraction of the average cost. In this way, cities are rapidly transforming their services to address current societal, environmental and economic challenges. Vertical smart solutions are being progressively replaced by solutions capable of exploiting a considerable range of data channels. This significantly reduces the barrier to smart city experimentation. In addition, accessible community-provided networks, such as The Things Network (TTN), enable cities to benefit from connectivity services provided by their citizens and tech communities, at relevant costs, which lead in most cases the cities to create their own network.

For these reasons, the authors will focus on digital platforms by answering the question, 'Which aspects of open web platforms can help a city move towards a smart city?' Secondly, the authors deepen this theme by analysing, in more detail, the platforms of European cities that have been useful for improving their urban strategies by answering the questions 'Why are open web platforms useful for defining actions and strategies that facilitate the planning of a smart city?' and 'Are there common features of the platforms that allow the cooperation of intentions between cities?'

To accomplish this, the paper begins with a theoretical study on open data platform EU legislation in Artificial Intelligence (AI) and smart city (Sect. 2). Subsequently, the paper focuses on European best practices (Sect. 3) through a content analysis between Smart Specialization Platforms (Sect. 3.1). In Sect. 3.2 the scope of the smart city and sustainability/financing, the open data exploitation and the technical characteristics are shown as a result. Finally, the results are discussed and the research's future directions (Sect. 4).

2 The Role of EU in Open Data Platforms: Legislation on Smart City and Artificial Intelligence

Today, each city/area still has its smart specialisation criteria requiring a highly tailored solution. Only a flexible and dynamic platform can put a city in complete control of

its operational objectives. Cities are abandoning an approach based on data sources and becoming aware of actual data channels where information and actions flow in multiple directions. Multi-directional flows are vital in implementing city operating systems involving daily tuning to deal with current challenges. Cities are becoming smarter also due to regulatory pushes from international bodies and organisations such as the European Commission (Table 1).

As Table 1 shows, connectivity and interoperability are considered the most fundamental building block of digital transformation. It enables data to flow, people to collaborate wherever they are, and connects more objects to the Internet, transforming manufacturing, mobility and logistic chains.

However, the digital landscape is becoming more diverse, challenging cross-border interoperability and interconnectivity. As a result, Europeans still face barriers when using (cross-border) online tools and services. This means that citizens miss out on goods and services and businesses miss out on market potential, while governments cannot fully benefit from digital technologies. The EU's Digital Single Market aims to overcome these challenges by creating the right environment for flourishing digital networks and services. This is not only achieved by setting the right regulatory conditions, but also by providing cross-border digital infrastructures and services. Furthermore, a sense of belonging to a European Commission initiative (see Table 1) and corresponding network helps to activate local initiatives, enabling cities to progress towards meeting their objectives. It also stimulates a pan-European culture of working together to solve the 'European way' challenges, thereby putting the citizen at the centre as the ultimate beneficiary. A key trend in the smart cities sector is working beyond and across organisational boundaries and joining initiatives and networks at the European and international levels. The basic reason behind this trend is that: a city is smart when it acquires the capacity to evolve, learn, adapt and innovate continuously. A key challenge, which emerged as fragmented smart cities initiatives were implemented worldwide, was the realisation that in most cases, innovation resulting from publicly-funded projects usually hit a dead-end soon after the funding stopped, with frustration on both the demand and supply side. In this context, no system can scale and spread because there are no standards, and there are no standards because there is no widespread deployment. In this regard a growing trend is observed towards establishing of a global market that makes it possible to share solutions among cities that are facing similar challenges, while respecting their different cultural, economic, social, and technical structures. In order for this to happen, each smart city should develop based on a foundation that enables seamless sharing and reusing of digital, data-driven solutions, thereby reducing the cost of innovation, increasing the return on investment, and – thanks to the use of open standards and APIs – avoiding vendor lock-in. About that, in July 2021 the World Economic Forum, in cooperation with of the G20 Global Smart Cities Alliance, released a report on the state of technology governance in cities title "Governing Smart Cities: Policy Benchmarks for Ethical and Responsible Smart City Development" [24]. The report provides a benchmark in defining ethical and responsible governance policies for smart city programmes, based on findings coming from interviews and surveys with city government officials and policy experts of 36 Pioneer Cities across 22 Countries. The G20 Global Smart Cities Alliance proposes a political roadmap organized around five fundamental

Table 1. EU legislation in smart solutions and artificial intelligence (AI)

Name and Link	Synthetic description
2021 Artificial intelligence ACT [16]	The European Commission proposes a regulation laying down harmonised rules on Artificial Intelligence and amending certain union legislative acts
2021 European interoperability framework for smart cities and communities (EIF4SCC) [17]	The EIF4SCC aims to provide the local administration with definitions, principles, recommendations, and examples from all over Europe and beyond. It is a standard model to facilitate common public services in all cities and regions
2020 Shaping Europe's digital future [18]	Shaping Europe's Digital Future sets out as a key action to develop a 'reinforced EU governments' interoperability strategy' by 2021, aiming to foster coordination and the adoption of common standards for public services and data flows
2020 Smart cities marketplace [19]	It is a platform that aims to bring cities, industries, SMEs, investors, researchers and other smart city actors together. The goal is to have access to knowledge on Smart Cities to shape an idea of a bankable project, suitable for attracting public and private investors and which allows for an individual exchange between project promoters and community members for financial agreements and projects
2019 Join, boost, sustain [20]	The 'Join, Boost, Sustain' movement aims to support the scaling up of open, interoperable, cross-sector and cross-border digital platforms and digital solutions across the EU
2016 ISA^2 - Interoperability solutions for public administrations, businesses and citizens [21]	In January 2016, the five-year ISA2 programme on interoperability solutions and common frameworks for European public administrations, businesses and citizens was launched to promote the ICT-based modernisation of the public sector in Europe and to facilitate addressing the needs of businesses and citizens via improved interoperability of European public administrations
2015 A digital single market strategy for Europe [22]	Section 4.1 (Building a data economy) of the Communication 'A Digital Single Market Strategy for Europe' states that the Commission 'will encourage access to public data to help drive innovation

(*continued*)

Table 1. (*continued*)

Name and Link	Synthetic description
2014 Connecting europe facility [23]	The CEF building blocks offer basic capabilities that can be used in any European project to facilitate the delivery of digital public services across borders. The CEF building blocks are interoperability agreements between European Union member states. The aim of the building blocks is thus to ensure interoperability between IT systems so that citizens, businesses and administrations can benefit from seamless digital public services wherever they may be in Europe

principles, as a baseline for robust technology governance: equity, inclusivity and social impact; security and resilience; privacy and transparency; openness and interoperability; operational and financial sustainability. These principles encompass basic requirements that all smart cities should meet, no matter about their strategic objectives. In other words, if a city considering environmental sustainability as strategic invests in smart lighting to reduce its carbon footprint, it must also ensure security for citizens with street lights on when needed. According to the proposed roadmap, good models embody policies such as: "*Building accessibility standards into procurement to ensure digital-related services are accessible to those with disabilities; defining processes to assess privacy implications of new urban technology deployments; defining key accountability measures to be taken in order to protect the assets of cities and their citizens; setting out planning policies that improve coordination among city stakeholders and reduce the cost and complexity of digital infrastructure roll-out; developing a model policy for open data strategy in a city*". At the same time, the European Telecommunications Standards Institute published the standard ETSI TS 103 463 V1.1.1, Access, Terminals, Transmission and Multiplexing (ATTM) [25]. Key Performance Indicators for Sustainable Digital Multiservice Cities) define smart cities indicators in Europe. The set of indicators is based on the work delivered by the EU-funded project CITYkeys (http://www.citykeys-project.eu/). It expresses smart development in terms of people (social sustainability), planet (environmental sustainability), prosperity (economic sustainability), governance (developing and implementing) and propagation (potential for up-scaling and application in another context). According to the project results, such a performance measurement framework can be useful in cities as a support system during the agenda-setting process, for identifying tasks that could be performed better and more efficiently, for benchmarking differences and similarities in particular when it is necessary to establish a connection between district development and individual projects. European cities involved in the CITYkeys project revealed that they use city-level performance measurement to support decision-making, upscale and progress from experimental projects towards large-scale

implementation, and manage resources. Furthermore, municipalities can use a performance measurement system to provide requirements for procurement procedures based on the actual situation and the need to meet city targets.

From the indications of the EU, the drive towards a connective smart city based on interoperability that starts from the guided and standardised use of Artificial Intelligence will lead cities to more investment in new technologies. For that reason, in planning platforms architecture, the basic level includes and integrates all existing networks, infrastructure and functions of the city that will be interconnected: urban transport, waste, municipal energy consumption, municipal/public parking spaces, green/urban areas, water supply networks, utilities networks. To understand the importance of open data platforms in the active management of smart cities, the authors, in the next section, analyse four successful European examples.

3 European Best Practices: Research Methodology for the Analysis of Smart Specialization Platforms

3.1 Methodological Approach and Application to Case Studies

This section examines some good European practices in smart city solutions and projects, trying to (i) investigate the relationship between smart urban development and the use of open data platforms; (ii) understand how these are useful for defining actions and strategies that facilitate the planning of a smart city and (iii) understand if it is possible to find platform's common characteristics that allow cooperation of intentions between European Union cities. To do this, the authors analyse the contents of the open web platforms of four European cities: Amsterdam, Helsinki, Copenhagen and Florence (Fig. 1), which have demonstrated interoperability and connectivity across multiple urban sectors and have implemented urban strategies on smart specialisation through their platforms. This will be done through a specific analysis of the contents that highlights the scope of the smart city and sustainability/financing, the open data exploitation and the technical characteristics.

3.1.1 Amsterdam Smart City (ASC)

The Amsterdam Smart City programme is a public-private initiative consisting of twenty permanent partners, including governments, academic institutions, social organisations and innovative companies active in the metropolitan area of Amsterdam [26–28]. It involves 32 territorial projects focused on the energy transition and connectivity [29]. Amsterdam was the first European municipality to launch a Smart City programme based on a model that enables bottom-up projects in various sectors, including circular economy, digital connectivity, energy, health, mobility and jobs of the future [30–32]. ASC also won several awards as the most successful smart city in the world (Chief Digital Officer Club in 2014, World Smart Cities Awards in 2012 and the European City Star Award in 2011). One of the main aspects of ASC is the role of governance, which, when combined with the aim of efficiency, environmental performance and quality of life, has the potential to promote public engagement [29]. As Jameson et al. (2019) underline,

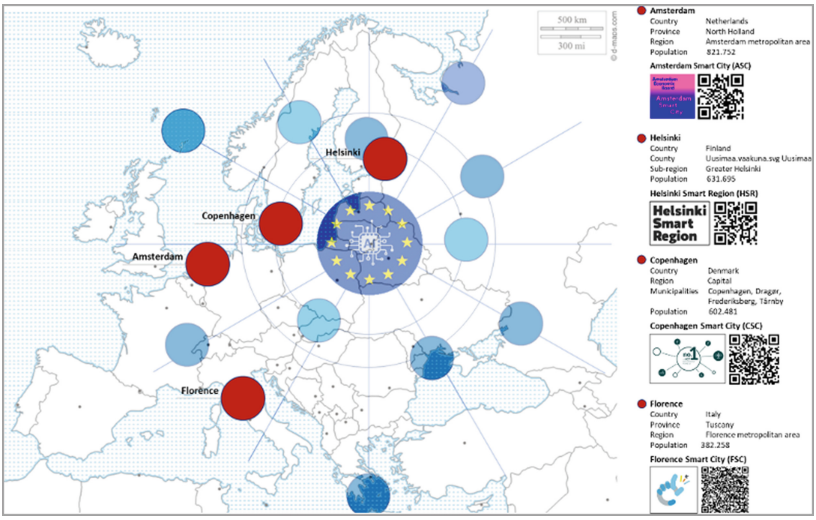

Fig. 1. Map of the cities analysed and links of smart initiatives

this aspect epitomises the split "between 'smart city' policies in urban planning and governance, where datafication is framed as a purely economic and technical phenomenon, and social policy, which frames problems as social and political" [30, p. 1].

ASC launched an open web platform in 2016 to expand its scope and professionalise the programme. Using a website as an online platform [24], ASC hopes to reach a broader audience and facilitate cooperation between the various partners to increase exchanges of ideas and opportunities, sharing projects and best practices, highlighting the most current issues and updates on the subject and organising multidisciplinary events and workshops [24, 33]. The open web platform has two roles: a "connector and an information exchanger. Firstly, the website as a connector means that it helps people, not only in the city of Amsterdam but also around the world, to get in touch with others, to contribute to urban innovation, and to gather related information about projects that are currently going on". Secondly, "the website as an information exchanger indicates that it facilitates suppliers and demanders to share their ideas, information, knowledge, and projects" [33, p. 246).

The platform is divided into six channels [24]: (i) Circular City. Amsterdam has established a circular economy innovation program to implement material reuse strategies by converting waste into electricity, urban heating and building materials; (ii) Energy. The city of Amsterdam has the ambition to provide every citizen with a solar panel in the next few years; (iii) Mobility. Amsterdam is considered the cycling capital of the world; 32% of traffic movement in Amsterdam takes place by bicycle, and 63% of its inhabitants use bicycles daily. Since 2008, car sharing has increased by 376%; (iv) Citizens & Living. To keep Amsterdam liveable and to find innovative tourism initiatives, the municipality works with its citizens; (v) Digital City. People are more connected, and technology has become part of the daily life of the citizens of Amsterdam; (vi) Smart City Academy provides available knowledge on smart city projects and helps with project development.

Professors, teachers and students study starting, managing, collaborating and scaling smart city projects. Through this system of channels, ASC open platform has made information more transparent for all actors by moderating all data entered by all people who join the platform. In this way, everyone can easily access information and "all actors should be able to choose a wide range of information that can support their decisions and further interact with other actors in several projects" [33, p. 247).

3.1.2 Helsinki Smart Region (HSR)

Helsinki Smart Region is a regional strategy of smart specialisation that promotes the participation of different actors in the European Union's international networks and cooperation projects. Indeed, HSR is linked to the EU initiative "Smart Specialization Platform" [34], which assists EU countries and regions in developing and implementing their smart specialisation strategies. The purpose is to improve regional innovation potential and to foster international collaborations by prioritising sustainable growth via the effective use of the Region's economic, environmental and social resources [35, 36]. The strategy is not limited to the Finnish capital of Helsinki (over 650,000 inhabitants). Still, it expands to the entire Helsinki-Uusimaa region, with 26 rapidly growing municipalities, even very small ones of about 2,000 inhabitants [40]. Hielkema et al. (2013), in "Developing the Helsinki Smart City", argue that "removing boundaries between municipalities and municipal organisations helps to create new integrated services" [37 p. 191]. This creates strength for the HSR project because it allows, on the one hand, to test smart and digital pilot solutions for cities and municipalities of different sizes and, on the other hand, to create a network of co-utility between territories with different socio-economic characteristics (urban, agricultural, pastoral ones).

HSR's smart specialisation is based on the close connection of different actors (large companies and start-ups, public sector, research and education centres) that create smart innovations together and in continuous contact with the population [41]. This strategy is based on innovative ecosystems [38] based on regional strengths where actors play a central role. HSR focuses "on the regional innovation ecosystem and the use of ecosystem thinking to consider which actor groups are relevant in societal change processes" [39, p. 9]. These ecosystems address three main themes [40]: (i) Citizens' City: citizens creating agile and user-centred solutions together with companies and institutions. The region provides real-time open data that citizens use to create new businesses. This was made systemic by the HSR project, which facilitated the development of significant technologies and social innovations. This theme covers areas such as transportation, housing, urban planning and healthcare; (ii) Climate neutrality; the region, by developing new infrastructure and construction service models, has set the goal of carbon-neutral by 2035. The issue of climate neutrality covers areas such as circular economy solutions, new forms of energy, bioeconomy innovations and new materials; (iii) Industrial modernisation: Helsinki-Uusimaa produces various products using, for example, industrial IoT and mobile technologies. HSR, through various innovation activities in different fields, develops cutting-edge technologies for the industry and future processes. Areas covered by the theme include, for example, new industrial processes, health technologies, robotics and travel.

Through these smart development themes, the Region has applied the concept of European Union Smart Specialization in territorial development. This produced, in recent years, the rapid growth of the innovation, digitality and technological security industries as the main support points of the entire HSR system. In conjunction, "knowledge creation takes place in the region's universities and research institutes, public administration, third sector and private companies. The expertise of the people working for these actors gives birth to a strong science and research base, new technology and skill" [40, p. 2]. Finally, this system is put into practice by the implementation of pilot projects in each theme (Citizens' City, Climate neutrality and Industrial modernisation).

3.1.3 Copenhagen Smart City (CSC)

Copenhagen, the capital of Denmark, situated on the east coast of Zealand, aims to become the world's first carbon-neutral capital by 2025 and is achieving the ambitious goal through smart city initiatives. It is one of the 20 cities included in the Nordic Smart City Network, a collaboration initiative joining five countries with the aim to explore the Nordic way to create smart, sustainable, and liveable cities.

In 2014 Copenhagen won the World Smart Cities Award [41] for its Copenhagen Connecting (CC), a project based on the intelligent use of data (wireless data from mobile phones, GPS in buses and sensors in sewers and garbage cans, etc.) to create a greener city, a better quality of life and a better business climate. This plan assists Copenhagen politicians in achieving the city's goals of reducing congestion, air pollution and CO_2 emissions. The concept is scalable and replicable and designed to avoid vendor lock-in and includes as key benefits a better use of resources, reliable and cost-effective services that meet the needs of citizens, engage businesses and open up new business opportunities.

The City has provided itself with a smart plan (CC Plan, in cooperation with private companies such as Rambøll and the University of Copenhagen, the University of Aalborg, the Technical University of Denmark (DTU) and the IT University of Copenhagen), and investments to implement it. For example, it has invested 34 million euros in new street lamps and over 13 million euros in new traffic lights and intelligent traffic management. A unique starting point for the implementation of the smart strategy in Copenhagen and for the development of smart solutions was the political decision to define a new government program, the Danish Basic Data Program, that included free access to public data sources (high-quality basic data: https://www.opendata.dk/city-of-copenhagen) collected and archived by the Danish authorities in order to promote innovation and address the challenges of urbanisation and climate change, such as traffic congestion and flooding in urban areas.

Copenhagen's smart city approach is firmly anchored in the three main objectives of achieving carbon neutrality by 2025; creating a greener, more sustainable, and the more liveable capital city; and supporting economic growth. Among the various projects launched to achieve its targets, one prominent example is the Strategic Climate Action Plan, which encompasses many diversified initiatives. Climate action and traffic systems receive the most significant share of funds.

The leadership role that Copenhagen has earned worldwide in smart innovation has contributed to the creation of Greater Copenhagen, a collaborative organisation

founded in 2015, including Region Skåne, Region Halland, Region Hovedstaden, Region Sjælland and all 85 Danish and Swedish municipalities in the region (encompassing 4.4 million citizens in Southern Sweden and Eastern Denmark). Greater Copenhagen's efforts are directed at five key areas, which are essential to the framework for future growth and welfare: Green Transition, Labour market, Infrastructure, Digitalisation, and Life Science.

3.1.4 Florence Smart City (FSC)

Florence is a medium-sized Italian city (about 380,000 inhabitants, metro area of 1.5 million) with an intense tourist and commercial vocation (14 million of tourists per year). In 2020, it got the first place in the ranking of smart Italian cities according to the ICityRank report, research conducted by the Public Administration Forum, resulting in decades of policy and governance actions [42].

Together with San Sebastian (ES) and Bristol (UK), it is one of the three leading cities in the European project Replicate, which allowed an exchange of experiences and a sharing of problems and solutions with geographically different realities, thanks to the former STEEP EC project [43]. The three partner cities of Replicate project agreed on the need to adopt a comprehensive Smart City Plan [44], which includes the whole set of necessary actions following a holistic approach. Key factors were detected: a) strong collaboration of all the stakeholders across the value chain: public administrations, technology experts, companies, end-users, etc.; b) the city must be considered a complex system of processes strictly interconnected; c) building up a Smart City requires time, resources, clear vision and strong leadership.

Open Innovation for engaging the stakeholders, open standards to ensure interoperability, and open-source to maximise uptake and impact is another component of the Florence Smart City strategy. Open data is an opportunity for growth and support in decision-making, not only for statistical purposes but because it makes a city responsive, placing knowledge at the heart of the city government and sharing it with all the players (if you can measure it, you can manage it). To date, about 1,900 open datasets are published on the official website of the municipality of Florence [45].

That of Florence is the result of an ongoing process that has involved public administrations at various levels of governance, universities and research centres, private investors and stakeholders. A significant step along this path was the creation, in the context of the Replicate EU project of the first SCCR (Smart City Control Room) by collecting a relevant amount of data, performing big data analytics, and elaborating What-If scenarios to provide a vast set of dashboards starting from the main panel that is 24/7 accessible to city operators, where each tile/widget is autonomously updated and interactive to bring the user to a set of more detailed views on data and maps. This first SCCR taken advantage of other important open-source solutions (see the national projects Sii-Mobility, Km4City and European RESOLUTE H2020) up to the release of Snap4City framework [46, 47]. This solution is fully GDPR compliant and supports Living Lab implementation and management of IoT Applications, community and Multi Organization solutions, resources, heatmaps, AI and predictive models, traffic flow reconstruction (from Sii-Mobility), routing algorithms (from Sii-Mobility), What-IF simulation models, knowledge base and federated Smart City API, scalable processes,

scalable data analytics, user profiles, Mobile Apps, IoT MultiBroker and MultiProtocol, Digital Twin local and global, BIM, etc. Being completely open-source, modular and scalable, this solution has had the advantage of growing with the needs of the city by adding components, reconfiguring and exploiting the components already present on the territory, without any Vendor-lock-in, protocol-lock-in, technology-lock-in and solution lock-in.

These premises highlight a vital connection between open data platforms and smart urban development. Made through artificial intelligence, these platforms can be connected with the reality of the city. Furthermore, using different data, the platforms manage to interpret the needs of citizens in other fields. By combining them, they create a dynamic interoperability capable of giving the city networks a real connection. To go into the details of the connectivity of the platforms, the following paragraph describes the results of the research with more focus on the smart city and sustainability/financing, the open data exploitation and the technical characteristics.

3.2 Results

To evaluate the positive outcomes of open web platform in smart urban development, this section defines three benefits that emerged from the study of the platforms in Amsterdam, Helsinki, Copenhagen and Florence: (i) the scope of the smart city and sustainability/financing, (ii) the open data exploitation and (iii) the technical characteristics. This section, reads these results in the context of Smart Cities. In fact, not all cities/areas are becoming smart in the same manner and are smart at the same level, because platforms services are typically different. However, as seen in the previous section, in most cases, the selected cities are deciding on addressing a selection of smart services, for example smart parking, smart waste management, smart lighting, etc., according to their needs and strategies.

3.2.1 Scope of the Smart City and Sustainability/Financing

Smart cities projects have demonstrated a positive impact on improving the environmental conditions and liveability of cities and the economic returns for citizens and public administrations. A key aspect of selected smart cities projects is to rely on revenue streams for economic sustainability coming from different sources. Deloitte, a network of companies in audit, consulting, financial advisory, risk advisory, tax and legal fields, [48] tries to list them as follows: (i) Financing model payments: payments received that match agreed cost (including finance) amounts, allowing full coverage of expenditure and agreed on returns; (ii) Availability payments: payments received that are linked with the performance of the private sector operator and availability of the service/asset in line with agreed performance standards. (iii) Savings sharing: certain services will generate savings for the public sector. If quantifiable and accountable, those savings can generate a budget to help fund the associated assets/service; (iv) Shadow tolls: the public sector makes payments to the private sector based on usage of the service/asset. In some cases, recurring payments may reduce risk; (v) User fees/charges: users pay directly for services (e.g., road tolls). This tends to be riskier than public sector payments as it is more difficult to quantify in advance with any certainty; (vi) Rate type payments: the public

sector collects revenues from the public and utilises these to pay the private sector for specific services/assets (e.g., power generation/water utilities); (vii) "Pay-as-you-go": users are charged for each use of the service. Can be collected using the billing system of mobile operators; (viii) Subscription: user pays a fixed amount for service irrespective of the level of usage; (ix) Advertising-based: revenue streams are generated by selling advertising on asset space, rather than collecting from individual users. This allows service providers to provide service free (or inexpensively) to users; the above issues have been investigated during the elaboration of the feasibility study for the Cyprus Smart City platform [49].

3.2.2 Open Data Exploitation

Considering the different domains (government service, health service, security-safety issues, mobility, energy, waste, etc.) in which a smart city can generate revenues, an important impact on results is related to smartening public services like lighting, parking, waste management without forgetting the relevance of accessible Data storage. In fact, Open Data and citizens' engagement in their use can improve the quality of public services and bring to develop new applications and digital services that exploit the reuse of public data.

Due to this huge amount of data coming from different domains, the risk is to create separate data silos that do not allow to correctly evaluate project returns and exploit the full potential of smart city applications. Recently, cities are becoming more aware of multiple directions data channels and are abandoning an approach based on simply connecting data sources. Efficient management and exploitation of multi-directional flows are becoming key points to optimising results and dealing with current challenges. Thus, cities operating systems must be able to work with them.

A well-designed smart city platform allows collecting, aggregating, and analysing data to support decision-making with effective advice considering all the dimensions involved. For instance, resulting benefits from smart light, waste management and smart parking can be traced back to better environmental conditions due to traffic reduction, reduction of time spent in commuting and routing (public services as ambulances, fire brigade, services, logistic), reduction of energy resources and therefore a reduction of costs for citizens and for city administrators.

The key trends in smart waste management solutions leverage IoT technologies to monitor trash bins or just monitoring the collected waste from bins, collect data such as level of filling, data and time of latest waste collection and generate alerts in case of fire, vandalism or unauthorized bin movements. This data allows us to predict when the bin will be full and allows an efficient truck routing for the waste collection. This solution can improve city services with relevant savings on fuel expenses and maintenance costs, optimising the trips for waste collection dynamically.

Many cities are implementing smart street lights due to more tangible and instant cost reductions. Smart street lights (e.g., Copenhagen Smart City) save energy and make public spaces safer at night and provide helpful support for additional IoT tools like air quality sensors, surveillance cameras, smart light management for police and critical conditions, and Wi-Fi hotspots. Data collected by smart street lamps (such as people and

traffic flows) can be marketed to recover costs for installation. Additionally, light remote control and activations by motion-sensing could save up to 20% in energy consumption.

3.2.3 Technical Characteristics

In the context of Smart City applications (web and mobile), most of the early solutions have been based on GIS (Geographical Information Systems) which provide standard solutions for managing geolocalised entities such as maps, shapes, etc., by using protocols such as WFS (Web Feature Service), WMS (Web Map Service). GIS-based solutions are discharging the complexity on the client side since the GIS servers are typically not capable of satisfying a huge number of requests simultaneously and neither to provide smart services. Other solutions are providing data via Open Data platforms such as CKAN (Comprehensive Knowledge Archive Network), which presents API to access the single data set file as well as a collection of APIs provided by multiple stakeholders in the city/area, and the possibility of exchanging these descriptions via harvesting protocols. IoT solutions based on IoT brokers for the smart city have also been proposed; for example, FIWARE based-solutions, which expose NGSI REST API, are provided to the Web and mobile clients to access at the data, typically last values and not historical values, directly accessing to IoT sensor data and not too sophisticated data structures neither via semantic queries [50].

In selected cities, there is a strong push on data and services aggregation to exploit higher-level machine learning business intelligence tools and control room dashboards, also provide smarter mobile apps that offer smarter services using a wider range of data. Therefore, it is pretty frequent to use Smart City API to provide and create services and data for web and mobile applications. Examples of Smart City APIs are Km4City (Knowledge Model for the City) API, and E015 (Digital Ecosystem E015: this name was given for expo 2015, then this changed as API distribution/sharing environments). Therefore, to develop smart city solutions, the usage of Smart City API can be the way to provide smarter applications that can take into account multiple aggregated data sources and data analytics, such as reasoning and predictions on parking, traffic flow, and people flow, weather, etc. On the other hand, most of the Smart City API services are focused on a single city/area and expose a limited number of services contextualised on the same geographic area, for example info-mobility, point of interest (POI), routing, smart light, smart parking, etc. This means that in most cases, passing from one city/area to another, the users have to get other applications to get the same services. This also happens for the lack of interoperability among the Smart City API, SCAPI, at the semantic level.

4 Discussion and Conclusions

This paper presented a detailed review of four open web platforms through an analysis that analysed the scope of the smart city and sustainability/financing, open data exploitation and technical characteristics.

In general, the paper investigated the relationship between smart urban development and the use of open data platforms. The results obtained reveal that the cities that use open data platforms to accelerate their intelligent growth, rely on Artificial Intelligence (AI),

seen as a fast-evolving family of technologies that can bring a wide array of economic and societal benefits across the entire spectrum of industries and social activities.

This study and the related analyses demonstrate that this approach aims to enhance urban living by integrating more sustainable solutions and addressing city-specific challenges across various policy sectors, including energy, mobility and transport, and ICT. It builds on the engagement of the public, industry and other interested groups to develop innovative solutions and participate in city governance.

Subsequently, the research has shown that for a controlled and dynamic management, the smart city requires planned planning actions that connect, at the same time, several sectors. This characteristic, typical of the platforms analysed in Sect. 2, allows for defining actions and strategies that facilitate city management. In fact, the platforms allow a functional connection between different sectors that helps administrations to make planned decisions in the urban ecosystem.

Moreover, the analyses have shown that there are different characteristics that the platforms can implement to allow cooperation of intentions between different European cities. This is highlighted by the European Union, which defines standards and regulations that serve to standardise these platforms as much as possible. Furthermore, to ensuring that public and private organisations can work together, the research shows that a key feature for the use of these open data platforms is interoperability (e.g. interconnection ser-vices, data integration services, controlled vocabularies and common code lists to de-scribe data exchanges, organisational interoperability).

Furthermore, this analysis has been included in the broader discourse of Smart Cities, which, through the EU regulatory guidelines, increasingly use Artificial Intelligence to implement open data platforms. The analysis highlighted that Smart Cities are more and more understood as innovation ecosystems in which, if adopted across Europe and beyond, the open source-open data framework could set the foundations for a new digital single market, where local authorities and technology providers of all sizes can easily exchange data and digital goods and services in a fair data economy. With this digital market in place, local authorities will have access to a catalogue of digital services, quickly testing and procuring the best solutions for their citizens' needs and placing demands on the market based on their strategic goals.

But the benefits of this single digital market will only be realised if the minimal interoperability and connectivity mechanisms are adopted at scale. For this to happen, national governments are more and more prioritising the digital transformation of local authorities and creating an environment that rewards participation and minimises innovation risks. Funding, policies, legal frameworks and licensing models must also be in place to increase market confidence and trust between buyers and sellers.

This study provided a detailed framework for the use of Smart Specialization Platforms in cities. However, the next step in this theoretical research is to build a platform architecture model that should be implemented to meet the needs of different cities across Europe. Second, a preliminary analysis should be implemented to a single EU platform's social, urban, economic, and political gain. These new evaluations are welcome in further studies.

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