

Article

Sustainable Connectivity—Integration of Mobile Roaming, WiFi4EU and Smart City Concept in the European Union

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Abstract: This article takes a comprehensive look at the integration of mobile roaming, WiFi4EU and the smart city concept within the European Union in the context of sustainability. These initiatives form key elements of the digital development and transformation of European cities. Starting with a brief look at the functioning of the European Union's internal market, the article briefly analyzes the objectives of these projects, highlighting their interplay and benefits for citizens. It focuses on the development of smart cities and the importance of digital connectivity in the process of building smart cities. It discusses the WiFi4EU initiative, which provides funding for free public WiFi networks and promotes digital inclusion. It also looks at the core pillars of smart cities, including digital connectivity, efficient transport, environmental protection, innovation and citizen participation. The article discusses the challenges associated with this integration, such as ensuring interoperability of different technological solutions and data privacy. It also highlights the importance of cooperation between city authorities, local communities and European institutions to achieve successful digital urban development. The research emphasizes the economic sustainability implications of these integrated technologies, considering the potential for innovation, job creation and economic growth within the digital and tech sectors. The main method used in the writing process was the analysis method, which was complemented by the comparison and synthesis methods. The final discussion assesses the benefits and challenges that this integration brings for the development of cities and the improvement of the quality of life of citizens. By critically examining the convergence of mobile roaming, WiFi4EU and smart cities in the European Union, this study aims to provide insights into the transformative potential of sustainable connectivity. The findings contribute to ongoing discussions on urban development strategies, emphasizing the need for a holistic approach that addresses both technological advancements and the imperative of sustainable practices for the benefit of current and future generations.

Keywords: sustainability; mobile roaming; WiFi4EU; smart cities; Digital Single Market; internal market; European Union; digital transformation



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1. Introduction

In an era marked by unprecedented technological advancements and a growing commitment to sustainable development, the European Union stands at the forefront of initiatives seeking to integrate digital connectivity with environmental responsibility. This study delves into the dynamic interplay between sustainability and the seamless integration of mobile roaming, WiFi4EU and the smart city concept within the European Union (hereinafter “EU” or “European Union”). According to Funta and Buttler (2023), in order to be at the forefront of this digital revolution, the European Union is committed to the development of a Digital Single Market and to promoting the concept of smart cities to help improve the quality of life of citizens and the sustainable development of urban areas [1]. In this sphere of modern innovation, mobile connectivity, data security and technological solutions are key elements that should support this digital development.

These elements are key to achieving one of the main pillars of the EU—the creation of a Digital Single Market. This article focuses on a complex issue that includes the sustainable integration of mobile roaming, WiFi4EU and the smart city concept in the context of the European Union [2].

The concept of “sustainable integration” in the context of mobile roaming, WiFi4EU and smart cities within the European Union refers to the harmonious and enduring combination of these three elements in a way that promotes long-term environmental, economic and societal benefits [3]. It is necessary to break down each component for clarity:

The mobile roaming (sustainable connectivity) component includes ensuring that mobile roaming services contribute to environmental sustainability by optimizing network efficiency, reducing carbon footprint and minimizing electronic waste. Economic viability involves promoting fair and cost-effective roaming agreements that support the financial sustainability of telecom operators, fostering healthy competition and innovation.

The WiFi4EU (environmental considerations) component includes implementing WiFi4EU initiatives with a focus on eco-friendly technologies, energy efficiency and responsible resource consumption to minimize the environmental impact of widespread connectivity. Inclusive access involves ensuring that WiFi4EU projects are designed to provide inclusive access to digital services, bridging the digital divide and promoting social sustainability.

The smart city concept (data-driven decision making) component includes leveraging data generated by modern technologies to enhance smart city functionalities, enabling informed and efficient decision making for urban planning and resource management. Citizen engagement involves fostering the integration of technology in a way that actively engages citizens, making them active participants in the smart city initiatives, ensuring the sustainability of community-driven projects.

The overall integration (interconnected sustainable infrastructure) of these components will establish interoperable infrastructure that allows for the integration of mobile roaming and WiFi4EU services into the broader framework of smart city initiatives.

In summary, “sustainable integration” emphasizes the need for a holistic approach that not only considers the environmental impact and economic viability of these technologies but also ensures that they contribute positively to social well-being and the long-term development goals of the European Union. The goal is to create a connected ecosystem that is environmentally responsible, economically viable, socially inclusive and technologically advanced [4].

The European Union is working to ensure quality and affordable internet connectivity for its citizens and businesses through initiatives such as the WiFi4EU program. At the same time, however, it needs to address issues related to data protection and network security in order to achieve the Digital Single Market. In this context, roaming, whether within a country or internationally, is of key importance for the free movement of citizens, goods and services and also has significant overlaps with the smart city concept [5].

In this article, we look at the effects of the integration of mobile roaming, WiFi4EU and the development of smart cities on economic growth, innovation, sustainability and data protection within the European Union. We will look at the opportunities these initiatives offer and the challenges that need to be overcome to succeed in the digital age. We will also identify how these elements can work together effectively to contribute to the creation of a Digital Single Market in the European Union and to the comprehensive development of smart cities. Last but not least, we will subject the elements that are subject to integration to a detailed legal and managerial analysis with concrete examples from practice. We will also try to present how the European Union will integrate these three elements in order to achieve a Digital Single Market [6].

Although all of the above initiatives have the potential to contribute to better connectivity and quality of life for citizens, this is not without challenges and issues related to data protection and network security. Data protection has become a priority for the EU, in particular with the entry into force of Regulation (EU) 2016/679 of the European Parliament

and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data and repealing Directive 95/46/EC (General Data Protection Regulation) [7].

Based on the above, we can therefore conclude that the main hypothesis of this article, which we will try to confirm or refute, is that the integration of mobile roaming, WiFi4EU and smart city concepts in the European Union fosters sustainable connectivity, leading to improved digital accessibility, enhanced urban services and heightened environmental consciousness among citizens and stakeholders.

This introduction sets the stage for an analysis of how these components synergize, envisioning a future where technology not only enhances the quality of life for EU citizens but also contributes to a more sustainable and resilient urban landscape. By exploring the intricate relationships between mobile roaming, WiFi4EU and the smart city concept, this study aims to unravel the concept of sustainable connectivity, shedding light on its implications for social equity, economic development and environmental stewardship within the European Union.

2. Literature Review

According to Benabed and Tudoran (2023), the European Union has long been trying to help us—the citizens of the European Union. It is trying to create a legal order that is parallel to the national one, but very often the national one has to adapt to the legal acts of the European Union [8].

There is a fairly large apparatus of officials within the European Union who are trying to develop markets within the European Union. The most general market, the idea of which dates back to the last millennium, is the market that ensures the free movement of goods, services, capital and people, in which European citizens have the freedom to live, work, study and do business [9]. The European Union, according to Groza (2022), calls this market the Internal Market of the European Union [10]. However, the internal market is not the subject of this thesis; the subject of this thesis is the Digital Single Market and the associated integration of the three core projects of the European Union, namely roaming without additional charges, the smart city concept and WiFi4EU. However, we would like to add that all of the above-mentioned services only work because there is an internal market and the associated free movement of goods, services, capital and people. Without these freedoms, the above projects would also have no practical meaning [11].

Before examining the issues of sustainable roaming, smart cities and WiFi4EU, it is necessary to define what the Digital Single Market is, what it does for us, how we benefit from it and why it is important for the European Union to keep working on this project. According to Dumitru (2020), we can help ourselves with what the European Union is doing in the area of the internal market. In the area of the internal market, the European Union is trying to create a single market for products and services throughout its territory [12]. And the Digital Single Market seeks to achieve a similar goal, namely to remove regulatory barriers and improve the standard of living of citizens and businesses. By regulatory barriers, we mean any obstacles that would hinder the use of digital and online technologies. The Digital Single Market covers a great many areas, from digital marketing to e-commerce. Smaller businesses and EU citizens in particular benefit from being able to cross national borders very quickly and at a very low cost, to use roaming services without charges, to use WiFi4EU and to participate in the building of smart cities [13]. Nowadays, it no longer matters where a business is based, because in a digitized Europe, it can cross national borders in a matter of minutes, without any additional bureaucratic burden and without high additional costs. The aim of the Digital Single Market is precisely to enable the use of modern technologies 100%. This freedom is expected to contribute over EUR 400 billion a year to the European economy and should create new jobs throughout the European Union. The basis for the creation of new jobs in the Union is the use of modern technology, which will enable businesses to expand to other countries, which will create more jobs in those countries. However, this is a corporate area, but the Digital Single Market

also brings many benefits to us, the citizens of the European Union. It will make it easier for us to access information and culture; as we said earlier, it will create new jobs; and, last but not least, it seeks to create a modern public administration [14]. In the early days of the Digital Single Market, we only had a declaration with a few promises, which was presented as a Digital Single Market strategy. We now know that 35 of the promises from that strategy have already been delivered and others are on their way to being delivered. Of course, this strategy will change over time, as we know that the field of information technology is changing day by day. Of all the promises that have been implemented, the following are certainly the most significant: the abolition of roaming charges, online platforms (protection on these platforms and the elimination of unfair competition), the WiFi4EU initiative, the smart city concept and the portability of online content [15].

According to Ene (2020), online platforms are the basis for the development of innovation and technological progress and are the foundation for the development of a digital society and economy within the European Union. Online platforms include online marketplaces, social media, creative content outlets, app stores, price comparison websites, collaborative economy platforms and search engines. All of these platforms increase consumer choice, improve the efficiency and competitiveness of the industry and also contribute to increasing citizen participation in public affairs [16]. As part of the European Union's efforts to protect all citizens of the Union who use these online platforms, a proposal for a Digital Services Act has been adopted. The Digital Markets Act, in conjunction with the Digital Services Act, will create a safer and more open digital space for all users. This legislation aims in particular to increase consumer protection; strengthen consumers' fundamental rights also in the online space; create a legal framework including clear liability conditions for breaches of obligations by online platforms; and, last but not least, foster innovation, growth and competitiveness within the Single Market [17].

According to Gracias, WiFi4EU is a European Union initiative to provide public wireless internet access in public spaces in cities and towns across the European Union. WiFi4EU aims to increase the availability of free public WiFi and to give citizens and visitors free access to the internet in local parks, libraries, municipal offices, cultural and public institutions and other public spaces [18]. EUR 120 million has been earmarked for this project and may be of interest to individual local authorities. However, once the amount needed to build the system has been awarded, the remaining operating costs will have to be borne by the public authorities concerned [19].

The concept of smart cities is a comprehensive approach to urbanization and urban governance that uses modern information and communication technologies (ICTs) and data to improve the quality of life of citizens and efficient city management and governance [20]. These technologies enable integrated solutions for areas such as transport, energy, environment, public safety, healthcare, education and more [21].

The term "sustainable connectivity" in the literature refers to the thoughtful integration of technological networks and digital infrastructures that align with principles of long-term environmental, social and economic sustainability. It encompasses the responsible deployment of connectivity solutions that seek to minimize adverse environmental impacts, ensure inclusive access to digital resources, contribute to economic growth and enhance overall societal well-being. Sustainable connectivity reflects a paradigm shift in the design, implementation and management of connected systems, emphasizing practices that are environmentally conscious, socially equitable, economically viable and resilient to future challenges. In the literature, discussions on sustainable connectivity often explore the intersection of technology, environmental stewardship and societal advancement, highlighting the importance of harmonizing technological progress with a commitment to lasting ecological, social and economic harmony [3]. Online content portability is a project that will ensure we can use our online subscriptions to films, sporting events, e-books, video games and music services anywhere in the EU, just as we do at home. Of course, this is followed by the modernization of EU copyright law and the expansion of the Union's mobile signal coverage, so that citizens will be able to use roaming services at no extra cost [22].

3. Aim, Materials and Methods

The aim of this paper is to comprehensively examine and understand how the seamless integration of mobile roaming services, the WiFi4EU initiative and the smart city concept collectively contribute to fostering sustainability within the European Union. The article relies on theoretical data, the method of analysis, synthesis, comparison and doctrinal interpretation. Statistical data and practical examples are also included within the article in order to clarify the mutual integration, synergies, opportunities and challenges that these elements bring to the European Union environment. Theoretical data involve information derived from existing theories, models or conceptual frameworks. This type of data lays the theoretical foundation for understanding a subject, providing a framework for analysis and interpretation. It is based on established principles and concepts within relevant academic or professional fields. The method of analysis refers to a systematic approach to examining and understanding information. It involves breaking down complex elements into smaller components, assessing their relationships and drawing conclusions. Various analytical tools, techniques or frameworks may be applied to explore patterns, trends and implications within the data or subject under consideration. Synthesis involves combining different elements or ideas to create a unified understanding. It is the process of integrating information from various sources to form a cohesive whole. Synthesis often goes beyond a simple summary, aiming to generate new insights or perspectives by bringing together diverse aspects of a topic. Comparison involves the examination of similarities and differences between elements or cases. This method is valuable for highlighting contrasts, identifying patterns and drawing meaningful distinctions. Comparative analysis is often used to gain a deeper understanding of a subject by exploring how it relates to or differs from other similar elements. Doctrinal interpretation involves analyzing and interpreting established principles, doctrines or guidelines relevant to a specific context. This method is often applied in legal or regulatory settings, where existing doctrines shape the interpretation and implementation of laws and policies. It provides a framework for understanding the normative aspects of a subject. Statistical data involve numerical information that quantifies various aspects of a subject. They provide a basis for empirical analysis and can support or challenge theoretical arguments. Practical examples are real-world instances or case studies that illustrate the application or consequences of theoretical concepts. These elements add a concrete and tangible dimension to theoretical discussions, helping to clarify and validate theories [23].

The main objective of this study is to analyze the integration of mobile roaming, WiFi4EU and the smart city concept in the European Union in the context of sustainable connectivity. Each of the above elements of sustainable connectivity is confronted with the issue of sustainability in the individual sections, and in these sections, we seek to describe the contribution to overall sustainability within the European Union. In the discussion and conclusion sections, we comprehensively describe how the mutual integration of these three elements contributes to the issue of sustainability. In addition to the issue of sustainability with regard to the main objective of the thesis, the article also discusses the theoretical basis of mobile roaming, smart cities and WiFi4EU, as this theoretical and legal basis provides us with an elementary basis for the subsequent analysis of the impact of the individual elements on the issue of sustainability.

Each of the elements—mobile roaming, WiFi4EU and the smart city concept—is the subject of a separate section, and these sections analyze the theoretical general basis as a starting point for further analysis. Within each of the sections, the link of the specific element to the issue of sustainability within the European Union is then presented. In order to achieve the main objective of the thesis, it is necessary to define the sub-objectives of the thesis [24]. By fulfilling the individual sub-objectives of the thesis, we will be able to fulfill the main objective of the thesis, which is stated above. Among the sub-objectives of the thesis, we include the creation of a rather extensive literature research as a basic theoretical starting point and the subsequent analysis of the sustainability and integration of the individual elements in the context of the European Union, a general analysis and

description of the current legal status of the issue of roaming without a fee, the collection of statistical data and data necessary to confirm our claims, creating relevant graphs and tables, obtaining information and then describing the complexities of the operation of the various roaming rules with a view to ensuring fairness for roaming users and operators alike, such as the fair use policy and sustainability mechanism. In order to give the readers a better understanding of this issue, it is necessary to apply the theoretical knowledge in practice, and therefore, a further sub-objective is the description of the different customer claims in different situations. In order to be able to fulfill the main objective of the thesis, which is to deal with the integration of these three elements in the context of sustainability, we have set as a further sub-objective the description of the integration of roaming with the concept of smart cities in which we highlight the mutual integration and the benefits of this integration for ordinary people. In order to be able to provide the reader with an insight into how roaming without charges contributes to overall sustainability within the European Union, it is also necessary to set as a sub-objective an analysis of the contribution of roaming to the overall issue of sustainability in the European Union. In relation to the issue of roaming, it is also necessary to include among the sub-objectives a description of the current theoretical background of the WiFi4EU concept and its objective and to support these claims with statistical data. WiFi4EU is closely linked to the issue of sustainability, and therefore, it is necessary to analyze extensively how the WiFi4EU concept contributes to a sustainable future within the European Union. The last element to be analyzed and a sub-objective is the smart city concept. Again, this is a concept that helps to achieve sustainability within the European Union in the long term. However, in order to analyze the contribution of smart cities to sustainability, it will be necessary to theoretically describe the concept itself in general terms with respect to international standards and also to define its individual elements such as smart people, smart economy, smart mobility, smart environment, smart housing and smart public administration. In order to be able to claim that smart cities themselves and their individual elements are sustainable, it was necessary to support our data with statistical data, and therefore, as another sub-objective of the thesis, we set out to support our claims with statistical data that will make our claims more transparent and support our claims. Another sub-objective is to analyze in detail the contribution of smart cities to the issue of sustainability and to describe how this concept actually contributes to overall sustainability within the European Union. In the discussion and conclusion sections, we describe how the integration of the different elements contributes to long-term sustainability within the Union. For the research and analysis conducted in this article, our primary sources encompassed a selection of reputable scientific articles, publications and official reports sourced from within the European Union environment. These materials were instrumental in grounding our exploration of the integration of mobile roaming, the WiFi4EU program and the smart city concept. By leveraging scientific literature and authoritative publications, we aimed to ensure the robustness and reliability of the information underpinning our investigation.

To delve into the legal dimensions of mobile roaming within the European Union, we extensively utilized legislative documents. This involved a comprehensive analysis of relevant EU legal standards and directives pertaining to roaming. By scrutinizing these legal frameworks, we sought to elucidate the regulatory landscape and provide a nuanced understanding of the legal parameters shaping the implementation and functioning of roaming practices within the EU [25].

In addition to theoretical and legal perspectives, the article incorporates a vital layer of empirical evidence through the inclusion of official statistical data. These data, meticulously gathered and analyzed, offer valuable insights into the current state of mobile roaming, the WiFi4EU program and the evolution of smart cities across the European Union and its individual Member States. The statistical information serves as a quantitative foundation, enabling a data-driven exploration of the multifaceted aspects associated with these interconnected elements.

Recognizing the need to bridge theory and practical understanding, the article integrates real-world examples throughout its discourse. These practical illustrations are strategically interwoven to elucidate the intricate functioning and mutual integration of mobile roaming, the WiFi4EU initiative and smart cities. By presenting tangible instances, we aim to enhance the reader's comprehension and facilitate a more intuitive grasp of the complexities inherent in the collaborative operation of these three elements.

In summary, our research methodology draws from a diverse array of sources, including scientific literature, legislative documents, official reports, statistical data and practical examples. This comprehensive approach ensures a well-rounded exploration of the sustainable connectivity landscape in the European Union, shedding light on the integration, synergies, opportunities and challenges arising from the convergence of mobile roaming, WiFi4EU and smart cities.

Above, we have listed the methods we worked with in the processing of this paper. As stated by Knapp, to gain knowledge about the legal order and about managerial practices, we will use the methods of logic. The methods of logic are universal and can be used in all sciences. The methods of logic determine the rules of human reasoning based on years of experience. Following them ensures the correctness of thinking and the truthfulness and orderliness of thought [26]. This involved analysis (detailed analysis of the theoretical concepts of mobile roaming, Wifi4EU and smart cities), synthesis (reconciling data and information from different sources to form a comprehensive view of the topic), comparison (comparing different approaches and implementations of mobile roaming, Wifi4EU and smart cities in European countries), legislative analysis (examining relevant EU legislative documents and their effect on the integration of the above elements), statistical analysis (analyzing statistical data related to roaming, Wifi4EU and smart cities) and the desk research method (to obtain relevant data and information, we used the desk research method, which consists in collecting and analyzing existing documents and data). In this way, we obtained relevant information and the background for this paper. The article is supplemented with graphs showing the sustainability index of individual smart cities in Europe and the world [27]. These materials and methods allowed us to gain a holistic view of the issues of the sustainable integration of mobile roaming, the WiFi4EU program and the smart city concept within the European Union and to identify the challenges and opportunities associated with these initiatives. These findings will be presented in detail in the following sections of this paper.

4. Results

4.1. Roaming without Charges—General

In the previous sections of this article, we have explained why the Digital Single Market is important, what it consists of and what its objective is and outlined the general background that we will analyze and flesh out in the following sections of the article. The subject of a more detailed legal, managerial and economic analysis will be roaming without charges, the smart city concept and WiFi4EU [21].

The general legal framework for roaming without charges is made up of six basic pieces of legislation. Of course, there are other acts linked to these regulations, but they are not so essential for this article. The six basic regulations are Regulation (EU) 2022/612 of the European Parliament and of the Council of 6 April 2022 on roaming on public mobile communications networks within the Union, Regulation (EU) 2015/2120 of the European Parliament and of the Council, Commission Implementing Regulation (EU) 2016/2286, Regulation (EU) 2018/1971 of the European Parliament and of the Council, Regulation (EU) 2017/920 of the European Parliament and of the Council and Regulation (EU) 531/2012 of the European Parliament and of the Council [28–33].

The citizens of the European Union have probably been most affected by the first and second regulations mentioned above, which have ensured that we have roaming without any charges. We have this in Article 6a of Regulation 2015/2120: 'With effect from 15 June 2017, provided that the legislative act to be adopted on the basis of the proposal

referred to in Article 19(2) is applicable on that date, and subject to Articles 6b and 6c, roaming providers shall not impose any surcharge on the domestic retail price on roaming customers in any Member State'. Thus, from 17 June 2017, we have not paid roaming charges. The regulation in question is followed by new legislation, Regulation 2022/612, which is *lex specialis* to the general regulation of Regulation 2015/2120 (*lex generalis*). The new regulation specifies the following in Article 4: "Roaming providers shall not charge roaming customers in any Member State any surcharge on top of the domestic retail price for any regulated roaming calls made or received, any regulated roaming SMS messages sent or any use of regulated data roaming services, nor shall they charge them any general charge for the use of a terminal equipment or service abroad." We can see the impact of the European Union Regulations in the following graph, which shows the price per minute of roaming calls (Figure 1). As can be seen in the chart, there is no longer any price cap on mobile voice calls as of 2017. This means that between 2017 and 2023, we no longer paid anything for calls received within the European Union, and telephone operators could not charge any fees for calls received within the EU. The price cap of EUR 0, in line with European Union regulations, will continue into the future [34].

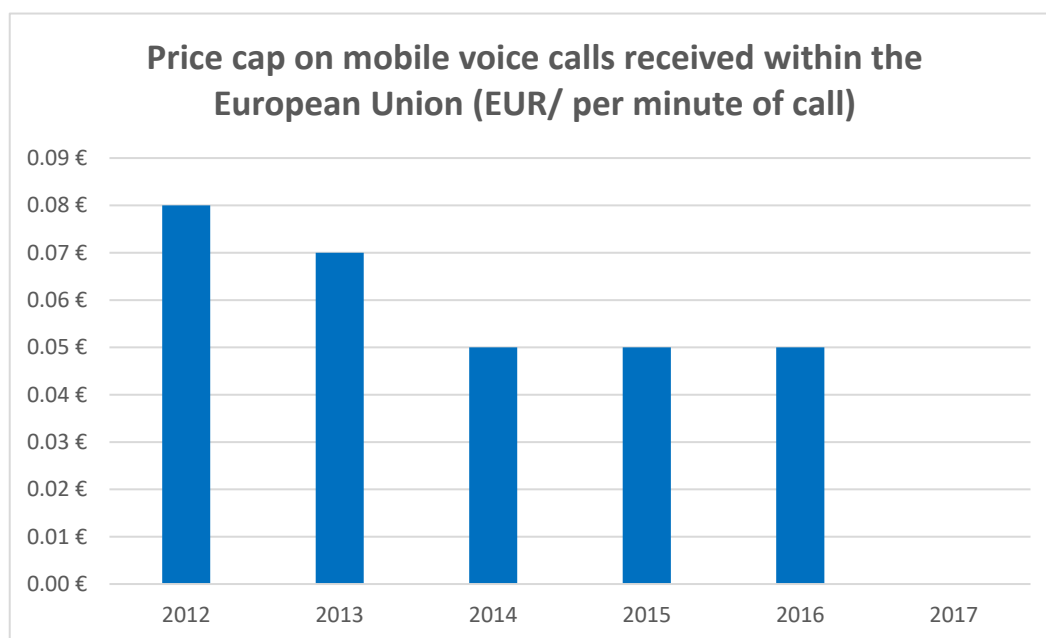


Figure 1. Price cap on mobile voice calls received within the European Union. Source: Own processing according to European Commission data.

There is a limitation on reasonable use, but for ordinary users, this is not a limitation [35]. We will analyze the issue of fair use of the service in later sections of this article. For ordinary consumers, this means that if you pay for a certain package of minutes, texts and data in your home country, any calls, texts and internet access with data searches you make while traveling abroad within the EU will be deducted from this volume as if you were at home, i.e., at no extra cost. This means higher costs for the operator, as it has to pay the operator abroad for using its networks. Some users mistakenly think that the only effect the abolition of roaming will have is to increase prices for flat-rate plans. This is logical, as the operator will incur costs and so this will be reflected in the prices paid by consumers. However, the European Union has also thought of this. Since 2007, it has been working to reduce consumer roaming and flat-rate prices in individual countries. Thanks to these efforts, it has managed to achieve what we use on a daily basis nowadays [36].

This assertion is supported by the chart below, which shows that in the long term (despite inflation and other macroeconomic factors) the price per GB of mobile data has been declining year-on-year in the European Union (Figure 2). This approach is there

thanks to the European Commission's drive for flat-rate pricing in individual countries. Although we cannot talk about harmonization of flat-rate prices at this stage since, as can be seen from the graph, the price per GB of data varies from one European Union country to another, we see a long-term decline, and in the future, it is possible that there will be harmonization at European Union level and, therefore, all national flat-rate prices will be the same. However, this must, of course, be preceded by an extensive analysis of the market and also of whether such a measure on the part of the European Union would be too disruptive to the freedom of enterprise as one of the fundamental freedoms in the Union [37].

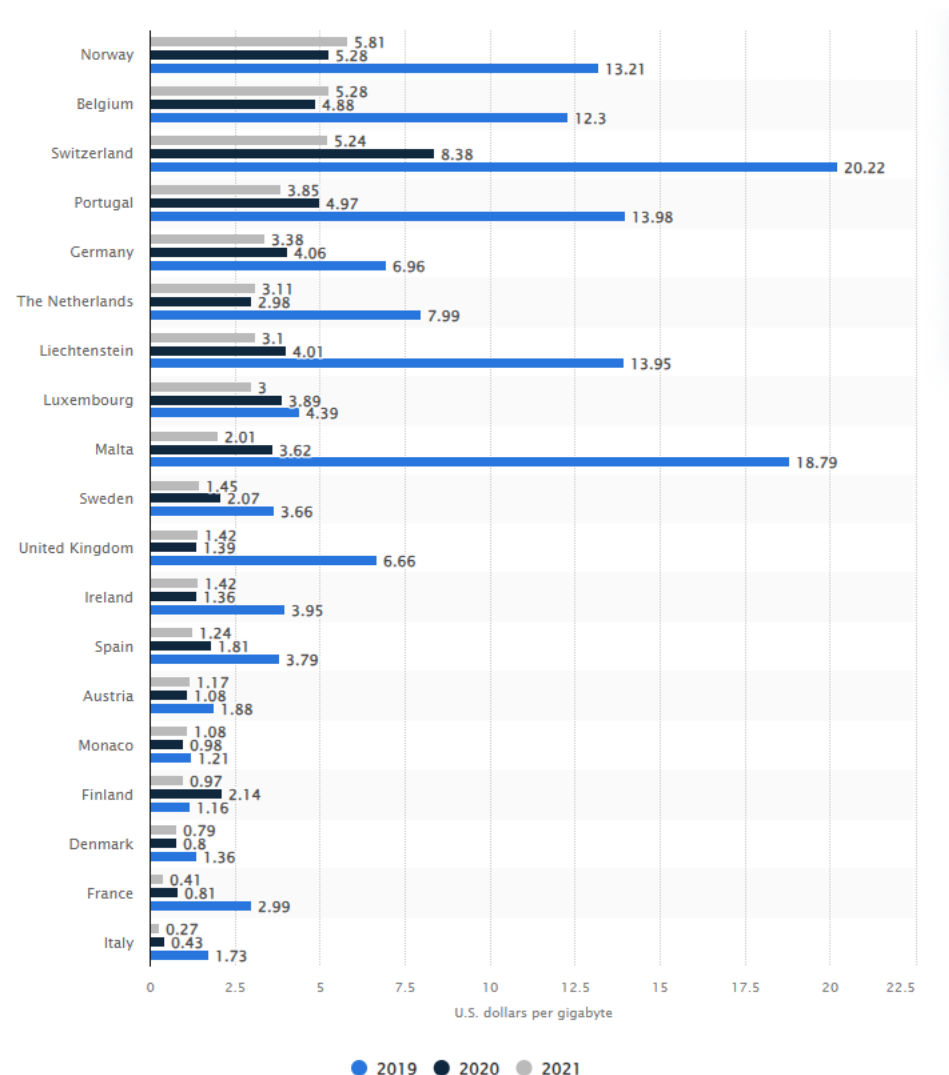


Figure 2. Source: Statista Statistics—average price of mobile data in selected Western European nations 2019–2021.

We have a flat rate or other services from the operator for the same price, with the advantage that we can use it free of charge anywhere in the European Union. This approach is also documented in Article 1 of Regulation 531/2012, where we learn the basic purpose of the Regulation, which has been amended by the above-mentioned Regulation 2017/920: “This Regulation establishes a common approach to ensure that users of public mobile communications networks travelling within the Union do not pay disproportionately high prices for roaming services within the Union compared to competing national prices”. That is to say, the basis is this regulation, but its purpose was only to ensure that roaming charges are not excessive. In 2012, we could not yet talk about roaming without charges [29].

It is clear that the European Union has been protecting the citizens of the Union even before the adoption of the regulation that has provided us with essentially free roaming. What is even more interesting in this regulation is Article 16, which provides us with an entity that oversees compliance with these regulations. This regulation delegates control to the national regulatory authorities. This approach has been maintained after the amendment of this regulation by Regulation 2015/2120 and also after the latest amendment by Regulation 2022/612, except that now the national regulatory authorities are obliged to publish reports on the monitoring of the situation in their national territory, and they must also forward any findings to BEREC and the Commission. As regards sanctions, these are left to the individual Member States by the European Union. The hallmarks of these sanctions are that they must be effective, proportionate and dissuasive. Article 21 of Regulation 2022/612 is called ‘review’ and specifies that the Commission, after consulting BEREC, will submit two reports to the European Parliament and the Council, followed, if appropriate, by a legislative proposal to amend the Regulation [33].

The European Commission therefore anticipates that modern technologies will evolve and that these regulations will need to be amended and modified. Thinking *de lege ferenda*, we can imagine that, following pressure from operators, for example, in places abroad where WiFi4EU connectivity is available, roaming without charges would not be available, as the consumer has a more efficient and cheaper option for connection. The aim would be to promote the business of smaller telecom operators and, at the same time, encourage people to use EU services in places where they are available and where there is more efficient use of these services [38].

4.2. Roaming without Additional Charges and Sustainability in the European Union

In recent years, the European Union has undergone a transformative shift in its approach to mobile communication services, particularly with the implementation of the “Roam Like at Home” initiative. This policy, which allows citizens to use their mobile phones across EU member states without incurring additional roaming charges, represents a significant leap toward fostering sustainable connectivity within the region. This part of the article explores the intersection of roaming without additional charges and sustainability, delving into the environmental, social and economic implications of this policy shift.

Environmental effect: The “Roam Like at Home” initiative has not only liberated European travelers from the burden of excessive roaming fees but has also contributed to environmental sustainability. By promoting the use of domestic mobile network providers abroad, the policy has potentially led to a reduction in the energy consumption associated with international roaming, as mobile devices connect to networks with lower latency and energy requirements. Reduction in energy consumption will come from the use of closer, well-serviced, networks.

In practical terms, the emphasis on utilizing domestic networks translates to reduced reliance on distant and energy-intensive infrastructure, resulting in a more sustainable use of resources. The lower energy consumption is particularly notable as it addresses concerns related to the environmental impact of global connectivity. Consequently, the “Roam Like at Home” initiative not only serves as a proponent of financial fairness for travelers but also aligns with contemporary efforts to minimize the ecological footprint associated with international mobile communications.

Promoting digital inclusivity: A key facet of sustainable development is inclusivity, and the elimination of roaming charges aligns with this principle by ensuring that citizens, regardless of their location within the EU, can seamlessly stay connected. This inclusivity is essential for bridging the digital divide, as individuals from diverse socio-economic backgrounds can now access digital services and information without facing financial barriers, thereby contributing to social sustainability.

Economic considerations: The economic sustainability of the “Roam Like at Home” initiative is two-fold. On one hand, it promotes economic growth by facilitating business communications across borders without the roaming charges. On the other hand, it sup-

ports the travel and tourism industry by enabling visitors to stay connected without the fear of bill shock, encouraging cross-border travel and economic activity.

According to data collected by Forbes Advisor, more than 27% of people use public WiFi because they need to use the internet when they travel abroad, but pay internet usage fees (roaming charges) when they are abroad. We would like to remind the reader that this survey was conducted on a global scale, meaning that it includes data from the US, Japan and other countries where there is no roaming policy without fees. Of course, as long as the base network has security certificates (as WiFi4EU networks have), then connecting to a public WiFi network is safe, but most WiFi networks abroad are random networks that do not have security certificates and can leak data and sensitive personal and banking information. This is why roaming without charges promotes digital inclusivity, as EU citizens, regardless of their socio-economic background, can connect to mobile data and do not have to look at the high fees they would pay abroad if they did not have this service. At the same time, roaming without charges also promotes economic sustainability. As the chart shows, over 23% of people use public WiFi to cut down on cellular data usage, and 27% use public WiFi when they travel abroad to save on roaming charges and still be able to stay connected (Figure 3). In the US, Japan and other countries outside the EU, these are relevant reasons to use a public WiFi network, but it should be stressed that using unsecured public WiFi networks poses a risk of leaking personal data, banking data and so on, and it is also highly impractical to connect to different WiFi networks everywhere. It should be stressed that if citizens of these countries are unable to connect to WiFi, they will have to pay for expensive mobile data roaming, which in no way promotes digital inclusivity and economic sustainability. In the context of fee-free roaming in the Union, all these problems are irrelevant, since it is possible to use mobile data, calls and texts in another Member State of the Union as in the home country, thereby promoting digital inclusiveness and economic sustainability [39].

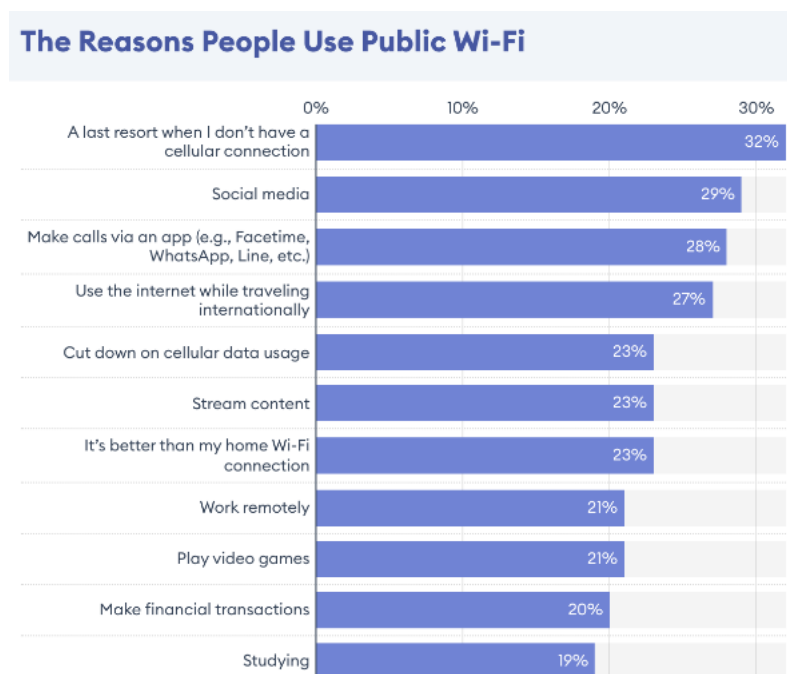


Figure 3. Source: Forbes Advisor—The Reasons People Use Public Wi-Fi.

Reducing electronic waste: Another facet of sustainability lies in reducing electronic waste. The elimination of roaming charges incentivizes consumers to retain and use their existing mobile devices across different EU countries, mitigating the environmental impact associated with the disposal of outdated devices and contributing to a more sustainable approach to consumer technology.

The “Roam Like at Home” initiative in the European Union stands as a testament to the intersection of progressive policies and sustainable connectivity. By eliminating additional charges for mobile roaming, the EU not only enhances the digital experience for its citizens but also makes strides toward a more environmentally conscious, socially inclusive and economically vibrant future.

4.3. Fair Use Policy

A fair use policy protects operators against abuse of the rules. The legal basis can be found in Article 5 of Regulation (EU) 2022/612 of the European Parliament and of the Council. This regulation is then followed by Commission Implementing Regulation (EU) 2016/2286, which gives us more detail on the fair usage policy. The aim of these rules is to create fair control mechanisms to prevent customers from abusing these rules. To ensure that these rules are not abused, the use of regulated retail roaming services at the applicable domestic prices is allowed, but only for the purpose of regular travel [34].

According to Kajanová et al., (2022), the concept of regular travel is too broad, and we do not know exactly what it means. A customer who travels regularly to another Member State within the European Union is a customer who is habitually resident in the Member State of the roaming provider in question or has stable ties in that State that obviously imply a presence in that territory [40]. Of course, that customer must, according to Gregusova et al., (2016), use retail roaming services in another Member State [41]. The definition of stable ties has become controversial over the years. Stable ties in a Member State, as defined by the legislation, mean the presence of a citizen in the territory of that Member State, which is determined by a permanent, full-time employment relationship. The same applies to cross-border workers. There is no limit to the number of calls and text messages that can be made while roaming. Any calls or messages not covered by the contract will be charged at the same rate as would be charged in the home country [42].

However, there are situations where an operator may charge you for calls, SMS and data while you are roaming. This is precisely when the policy on fair use of the service is breached. The operator will always warn customers when they enter another country of this policy, most often available in the form of an SMS message called the fair usage policy (FUP). This tells us that the consumption/availability in the EU during the last 4 months must be lower than the consumption/availability in the home network [1]. In practice, this means that roaming charges will be levied by the operator if more than 50% of the time has been spent in EU countries in the last 4 months and at the same time more than 50% of the minutes of calls, SMS, MMS or data have been consumed in these countries. The second condition stipulates that no more data may be transferred abroad than the fair usage threshold. The following formula is used to calculate the maximum possible data transfer: $(\text{flat-rate price excluding VAT}/4.5) \times 2 = \text{GB volume}$. If this principle is violated, roaming charges will be levied by the operator. However, before the charges start, the operator must inform the consumer that if he/she continues to be abroad, charges may apply. If, within two weeks of receiving the notice, he or she starts using the phone more frequently in his or her home country, the charges will not apply. Otherwise, the mobile operator will start charging service fees. These charges are also regulated [43].

The operator may not arbitrarily determine the amount of the surcharge. Regulation (EU) 2017/920 of the European Parliament and of the Council has given us a legal framework and also set a cap on the fees that can be charged for individual services. The cited regulation sets the upper limit of charges for calls, SMS and overdrawn data for us. In the case of calls, this limit is set at EUR 0.032 per minute. For text messages, the limit is set at EUR 0,01 per message. Data are the most interesting from the point of view of legal regulation, because the European Union, in this regulation, provides for the annual reduction in the maximum limit of charges. From 2017 onwards, this amount will fall every year until we reach a limit of EUR 2.16 per GB of data. In the following graph, we see a curve showing us the direction in which charges for mobile data in roaming are going within the European Union [42] (Figure 4).

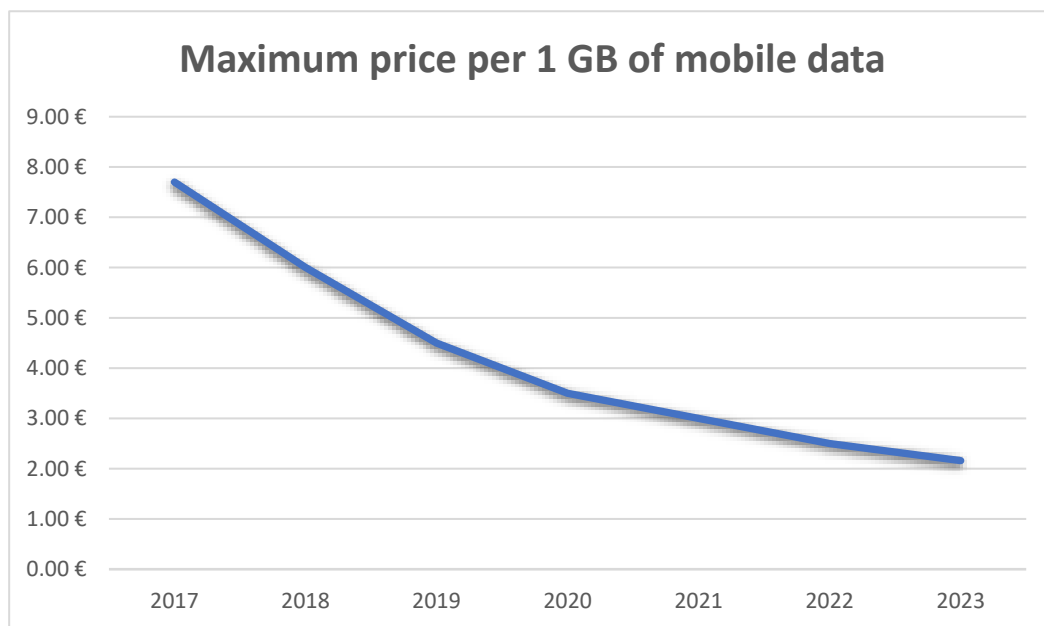


Figure 4. Maximum price per 1 GB of mobile data. Source: Own processing according to European Commission data.

This reduction in charges per GB of data transferred abroad is also supporting the development of the Digital Single Market within the European Union, but the European Union faces further challenges in setting a single rate for all operators in the Member States. It is perfect that we are reducing the charges for possible roaming, but as long as national charges are very high, people will not use these services even within their own country, let alone abroad.

4.4. Sustainability Mechanism

Article 6 of Regulation 2022/612 also defines an exemption from the obligation to abolish roaming charges. This exception is called the sustainability exception. The literal wording of that article is as follows: “In specific and exceptional circumstances and in order to ensure the sustainability of its domestic charging model, where a roaming provider is unable to recover its total actual and foreseeable costs of providing regulated roaming services in accordance with Articles 4 and 5 from its total actual and foreseeable revenues from the provision of such services, that roaming provider may apply for authorisation to apply a surcharge. That surcharge shall be applied only to the extent necessary to recover the costs of providing regulated retail roaming services.” It is understood that this exemption will only apply if the costs necessary to abolish roaming charges exceed the revenues from these services. According to statistics and analyses, the introduction of roaming without charge has reduced the operators’ revenues by 9.1%, which is several billion euros, and not every country can ensure the competitiveness of the companies; therefore, if the operator cannot cover the costs, it can apply for and be granted an exemption [44]. This request will be addressed to the national regulatory authority, which will assess whether this request is justified. The national regulatory authority examines whether the sustainability of the domestic charging model would be compromised. Thereafter, every 12 months, the applicant must submit a report disclosing their actual cost–benefit situation [45].

An operator may charge roaming charges only to the extent necessary to cover costs. This exception is of course only applied in exceptional cases, where the abolition of roaming charges could also lead to an overall economic threat and cause too high a loss for individual providers. This could lead to individual operators subsequently leaving the country due to the unprofitability of continuing to operate. Therefore, the European Union had to think about this possibility as well. To date, only four countries have made use of this option,

namely Lithuania, Finland, Poland and Estonia (Figure 5). Of course, several states could have applied for this option, or any state could have applied, but it has only been approved for these four to date. This does not preclude the possibility that others may join them in the future [46,47].

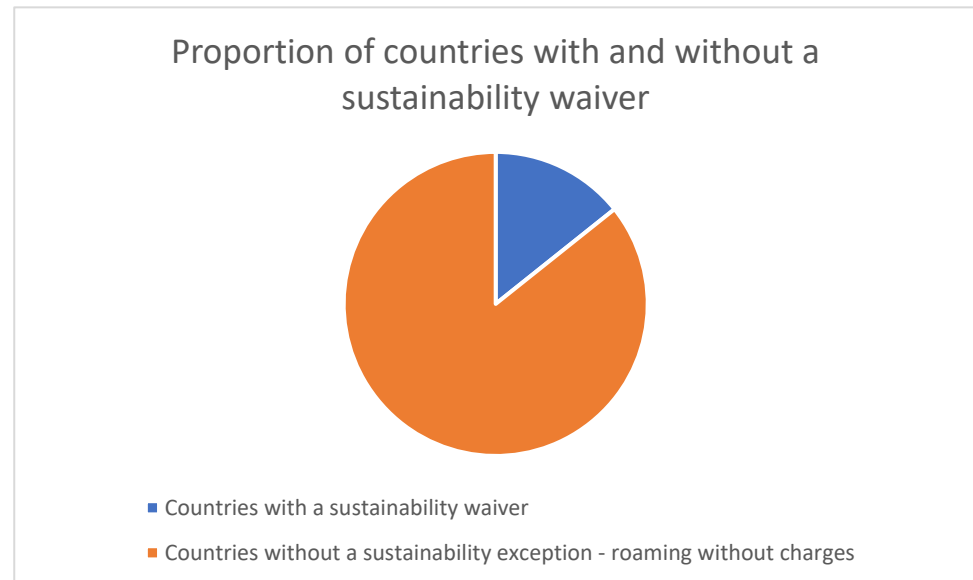


Figure 5. Proportion of countries with and without a sustainability waiver. Source: Own processing according to European Commission data.

4.5. Consumer Demands in Different Situations

In this section, we would like to focus on individual practical cases that may arise and set out the answers to how roaming without additional charges resolves them or what the consumer's rights are in specific cases. Quite a large number of Union citizens still make use of the prepaid card option. The rules on flat-rate tariffs also apply *mutatis mutandis* to prepaid cards, which in practice means that the consumer can also use the phone in other countries of the European Union without additional charges. However, if the consumer pays a unit price and at the same time the domestic unit price for data is less than EUR 4.5 per GB of data, the mobile operator has the option to limit the amount of data. However, even the mobile operator cannot limit these data at its discretion, the principle being that dividing the current credit balance by 4.5 will give us the minimum number of GB of data that the operator must guarantee. In the case of a EUR 25 credit at the time of going abroad, the operator must guarantee us $25/4.5 = 5.55$ GB of data.

Another case can occur in the case of unlimited data, which most users already have nowadays. In this case, the minimum amount of data that the operator has to provide us with will depend on the monthly fee paid for the flat rate. If we divide the price of the monthly flat-rate fee by EUR 4.5 and multiply by 2, we get the minimum amount of data that we can use in a given country. So, for example, in the case of a EUR 50 flat rate, the following will apply: $2 \times 50/4.5 = 22.22$ GB. That is, a minimum of 22 GB of data can be overdrawn.

The last common situation that can arise is that we have limited data included in the contract. Here, the subject can use the data as they would at home at no extra charge and is limited by the amount of data they have in the contract. Also in this case, the operator can set a data limit that is lower than what we have "at home", but only in one case, i.e., if the price per GB is lower than EUR 2.25. The principle of fair use of the service is therefore clear; if a citizen spends more time abroad and uses more data or other services there than at home, he or she must pay roaming charges.

But there are also situations where people do not want to break these rules but still break them through no fault of their own. An example is people living in border areas. It

often happens to people living in border areas that their mobile operator connects to foreign operators, and so they could very easily break the fair use of service rule. In this case, if the phone logs on to the domestic network at least once a day, this is considered as using domestic services and not as roaming. According to Matúšová and Nováček (2022), the operator should be contacted to inform them of this fact and, if necessary, to agree with them on how to deal with these matters. However, as is generally known, this regulation applies only within the European Union. This means that roaming charges outside the European Union can be high. Operators also provide the same no-fee roaming scheme in other countries. These countries include, for example, Norway, Iceland, Liechtenstein, Monaco and Andorra. In these countries, most operators provide fee-free roaming. However, not all operators provide it [48].

4.6. Roaming without Additional Charges and Smart City: Transforming Mobility and the Way We Live in the City

Roaming without additional charges and the smart city concept are two technological and social innovations that are revolutionizing the way we live and work in major cities around the world. The combination of these two concepts brings new possibilities to our lives that improve our mobility, comfort and quality of life.

Roaming without additional charges is the result of the efforts of European countries and regulators to unify telecommunications services and allow citizens to communicate freely in all European Union Member States without fear of high roaming charges. Since 2017, EU citizens have been able to make calls, send messages and use data under the same conditions as if they were in their home country thanks to this initiative. This revolution in mobile communications has boosted travel, business and people-to-people relations, not only in big cities but also in the countryside [16].

Within the smart city concept, roaming without additional charges is even more important as it provides citizens and visitors with access to smart solutions and real-time information. Tourists can easily obtain information about local attractions, public transport, cultural events and even health services, which contributes to a convenient and hassle-free exploration of the city. For smart city residents, roaming at no additional cost becomes an important tool for quick communication and access to important information in their daily lives [49].

The smart city concept seeks to use technology and data to improve the lives of residents in large cities. City authorities, together with technology companies, implement various smart systems and applications to ensure efficient management of traffic, security, public services, energy and the environment. Under the smart city concept, technology is becoming part of everyday life. Smart lighting tracks people's movements and adapts to the needs of the city, thus saving energy. Traffic systems inform drivers about traffic conditions and guide them to the optimal route, reducing congestion and emissions. Rapid response by emergency services is enabled through connected devices and sensors. Mobile apps are available for residents to monitor air quality, vote on city decisions and communicate with city authorities [18].

These technological innovations are even more powerful when combined with roaming at no extra cost. Citizens and visitors can benefit from smart, real-time solutions without worrying about high data costs. Fast access to information on transport, health services, culture and all aspects of urban life enables better navigation in the city and contributes to a better quality of life.

Roaming without additional charges and smart cities are two concepts that together are changing the way we live in cities. Roaming enables easy and affordable communication within the EU, while a smart city provides smart solutions and services that improve the quality of life of citizens and contribute to the sustainability and efficiency of cities. The combination of these two concepts is creating a new era of mobility and urban life that allows us to live in the city with greater comfort and efficiency and seamless communication [50].

4.7. WiFi4EU: Supporting Free Public Internet Access in Smart Cities

The WiFi4EU program is a major European Union initiative that plays a key role in promoting free public internet access in cities and towns across the EU. It aims to ensure the availability of wireless connectivity for citizens and visitors in public spaces, promoting inclusive access to digital services and making cities more competitive in the digital age [51].

WiFi4EU was introduced in 2018 by the European Commission in response to the growing importance of digital connectivity across the world. This claim is supported by the graph below, which shows the increase in internet users globally [52] (Figure 6).

Individuals using the Internet

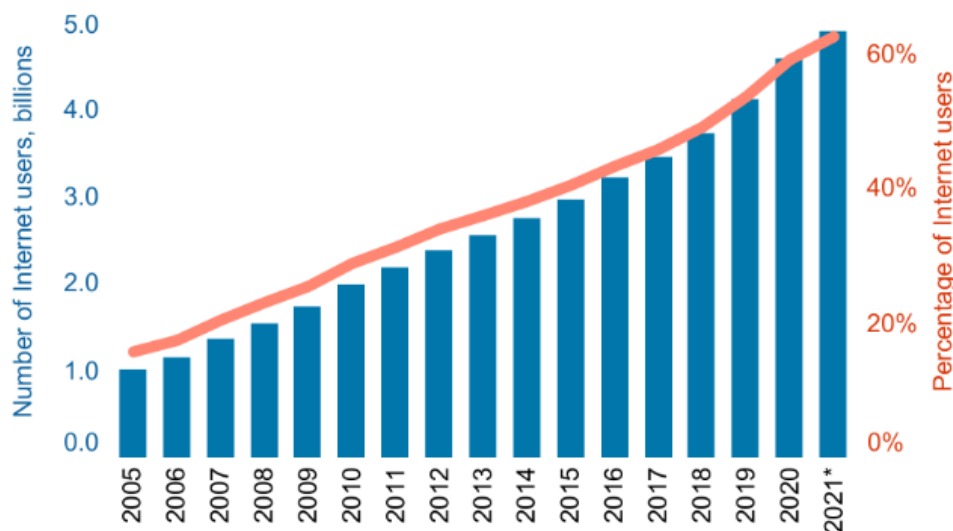


Figure 6. Individuals using the Internet. Source: The World Bank—Digital Regulation Platform. * The value in 2021 is an approximate value, as even today there are not yet fully accurate figures due to a number of external factors.

The key objectives of the WiFi4EU initiative are as follows:

1. Ensure internet access for all: The program seeks to ensure that citizens and visitors have the opportunity to use free WiFi in areas where they move and spend their time, such as parks, squares, public buildings and other public spaces.
2. Promoting digital inclusion: WiFi4EU aims to make the internet and information accessible to those who would otherwise not have access to the internet, thereby promoting digital inclusion and equal opportunities for all citizens [53].

As this is one of the main projects in delivering the smart city concept, the funding is under the auspices of the European Union. Funding from the WiFi4EU program is available to municipalities and cities in the European Union through regular calls for proposals launched by the European Commission. The calls are open to all public local authorities and are part of a wider EU effort to promote digital connectivity and the development of smart cities (Figure 7). Funding is provided to cover the costs of building and operating wireless connections, including the installation of access points and their maintenance [54].



Figure 7. WiFi4EU in numbers. Source: European Commission statistics.

In the previous section of this article, we noted that the introduction of free roaming has ensured that European Union citizens have a mobile data connection in any European Union country, without additional charges. There has also been a fairly significant reduction in the prices for flat-rate tariffs. This has undoubtedly raised the standard of living of all citizens, but additional analysis by experts from the European Union has shown that not all citizens have access to mobile data connections. That is why the European Union has introduced the WiFi4EU project, which aims to ensure that everyone has access to the internet in public places. So, if we have a citizen of the European Union who is away from his or her home at the time of an election or other important vote, first of all, he or she has the opportunity to use a mobile data connection in another Member State of the European Union without any roaming charges [55]. In case he or she does not have a prepaid mobile data connection and still wants to participate in the vote in question, he or she only needs to go to a public place in the city where he or she is currently and connect to WiFi4EU, and in this way, he or she would be able to vote [45].

4.8. WiFi4EU towards a Sustainable Future in the EU

In the pursuit of a sustainable future, the European Union has taken significant strides by introducing initiatives that not only redefine connectivity but also contribute to environmental and social sustainability. One such initiative is the WiFi4EU program, an ambitious project aimed at providing free, high-quality WiFi in public spaces across EU member states. WiFi4EU is definitely shaping a sustainable future by fostering digital inclusivity, reducing digital divides and aligning with the broader goals of environmentally responsible urban development.

WiFi4EU plays a pivotal role in promoting social sustainability by ensuring that every EU citizen, regardless of their location or economic status, has access to free and reliable WiFi in public areas. This initiative effectively addresses digital divides, creating a more inclusive

digital landscape where individuals can participate in the digital economy, access educational resources and engage in civic activities, irrespective of socio-economic backgrounds.

The above thesis is also supported by the following graph (Figure 8). As can be seen from the graph, WiFi4EU as a public secure WiFi network solves a large number of problems and supports long-term sustainability. Over 20% of people use public WiFi networks to be able to work remotely, which supports the long-term sustainability of employment in the region. Nineteen percent of respondents even study using public WiFi networks, which again helps to raise the standard of living of the population and increase their education. Without a public WiFi network, they would not have access to education, and thus, these networks also break down socio-economic disparities. In addition, public WiFi networks save money, as approximately 25% of respondents use public WiFi networks as a substitute or to save mobile data. As an example, consider a US citizen who comes on a trip to the European Union and wants to use the internet. If he or she had to pay for a cellular connection, he or she would not avoid high fees, but thanks to WiFi4EU, he or she can connect to the internet in almost every city. At the same time, the chart shows that 32% of respondents use public WiFi as a substitute for mobile data when they are not available. It is worth noting that WiFi4EU is available free of charge to all those within range of this WiFi, regardless of socio-economic background, which ensures social and economic sustainability in the long term. It is also preferable from an energy-saving point of view for residents to connect to a public WiFi network, as it requires less energy compared to operator networks, which are much more energy-intensive to operate. This achieves the environmental sustainability of WiFi4EU [39].

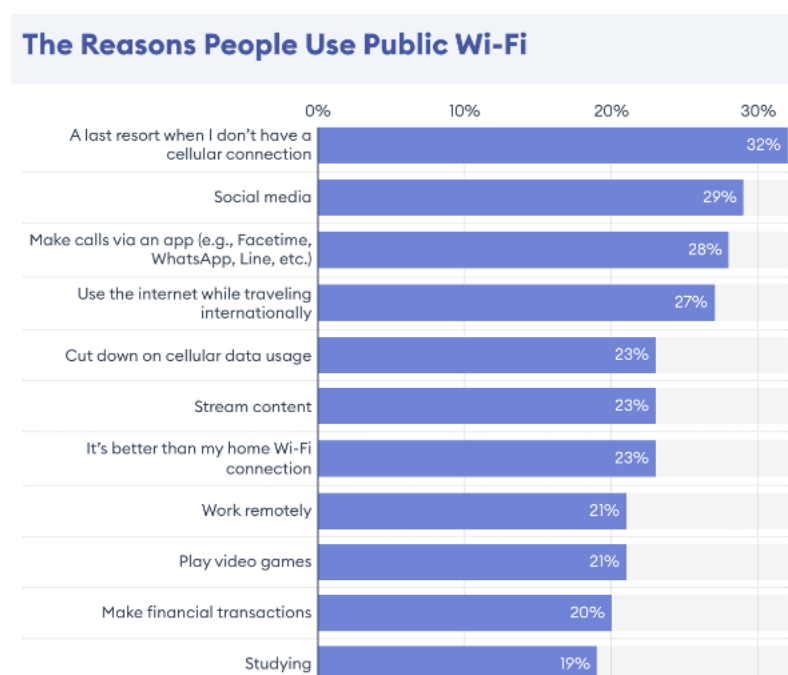


Figure 8. Source: Forbes Advisor—The Reasons People Use Public Wi-Fi.

The WiFi4EU program is a key component of the broader smart city concept within the European Union. By providing ubiquitous WiFi access, it contributes to the realization of smart cities, where data-driven technologies are harnessed to optimize urban services, energy consumption and transportation networks. This technological integration not only enhances the efficiency of urban systems but also fosters a sustainable urban environment by minimizing resource wastage and improving overall quality of life.

WiFi4EU serves as a catalyst for economic sustainability by stimulating innovation and entrepreneurship. The provision of free WiFi in public spaces creates opportunities for businesses, startups and individuals to leverage connectivity for economic activities. This,

in turn, contributes to economic growth, job creation and the development of a dynamic digital ecosystem within the European Union.

The implementation of WiFi4EU also aligns with the principles of environmental responsibility. By facilitating connectivity in public spaces, the program reduces the need for individuals to rely on their mobile data networks, potentially leading to energy savings and decreased carbon emissions associated with data transmission. This approach supports the EU's commitment to greener, more sustainable urban living.

WiFi4EU stands as a beacon guiding the European Union toward a sustainable future where connectivity is not just a convenience but a fundamental enabler of progress. By promoting digital inclusivity, supporting smart cities, fostering economic growth and embracing environmental responsibility, WiFi4EU exemplifies how technology can be harnessed to create a more sustainable and interconnected European community. Investing in WiFi4EU will pay off in the long run, as statistics show that public WiFi networks in the European Union are among the fastest in the world [56] (Figure 9).

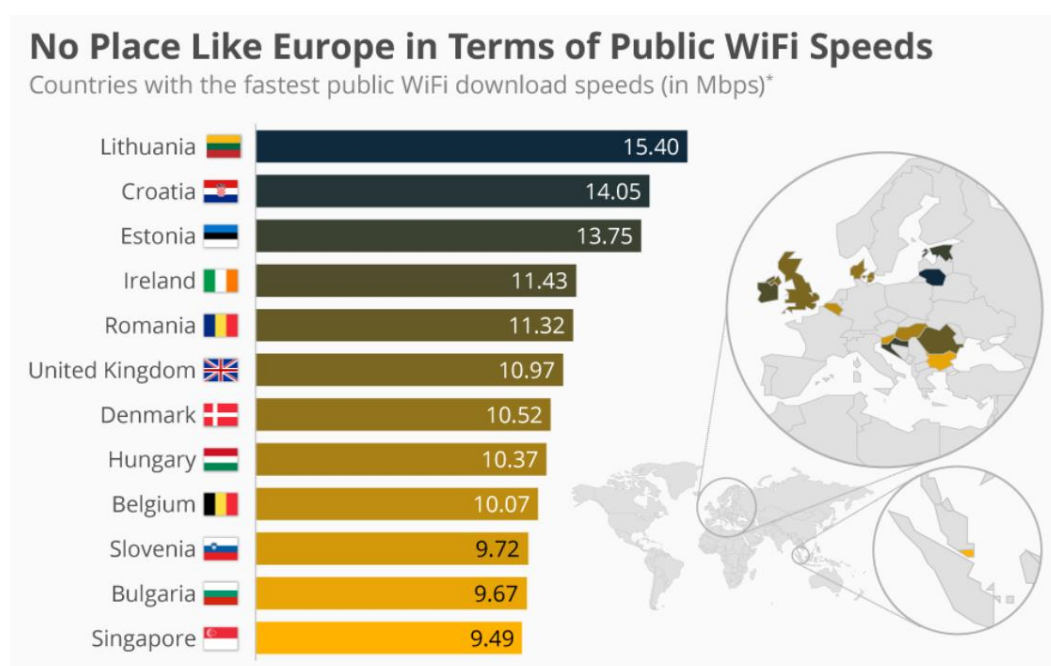


Figure 9. Source: Forbes–Statista–Rotten WiFi – No place like Europe in terms of public WiFi Speeds.

4.9. Smart Cities

Smart cities are one of a number of European Union programs through which the EU seeks to ensure that cities and towns are transformed to a higher level by modern technology. Smart cities have several dimensions, which we will analyze below, but each of these aspects significantly promotes technological development in urban areas and, as a result, improves the quality of life of citizens to a very significant extent. The European Union considers a smart city, or in other words, an intelligent city, to be a city where traditional networks and services are created and used in a more efficient way using information and communication technologies to the benefit of the city's residents and businesses. ICT networks are interconnected, which means that data are shared, for example via the internet. Through such data forwarding, technologies are enabled to collect, analyze and then distribute these data, thus optimizing processes within the city, increasing the city's efficiency, sustainability and, last but not least, competitiveness compared to other cities. As mentioned above, smart cities are characterized in particular by the efficient use of information and communication technologies. Thanks to these technologies, they transform traditional networks and services into more modern, comprehensive and sustainable ones, the benefits of which are enjoyed mainly by residents, public administrations and local

entrepreneurs. Thanks to smart cities, the quality of life of a large number of citizens and entrepreneurs has already improved today [13].

According to the latest standard issued by the International Organization for Standardization 23 indicators have been defined to measure the performance and success of smart city implementation in individual countries. These include, for example, economic performance, education, energy use, environmental change, climate change, finance, decision-making bodies within cities and municipalities, health, accommodation, social conditions, security, solid waste, development of sports in municipalities, development of culture in municipalities, telecommunications–internet accessibility/WiFi4EU, transport, local agriculture, urban design, wastewater, water and many more [57].

These indicators therefore set the level of cities and are intended for all those who are in some way interested in the functioning of cities and municipalities. These are, in particular, local government managers, activists, entrepreneurs, developers, researchers or designers. These indicators were the basis for the establishment of the six main dimensions of the smart city system. These are smart people, smart economy, smart mobility, smart environment, smart housing and smart public administration [58].

The first of the above categories is the so-called Smart People category. This category assumes that citizens will be involved in decision-making processes, they will cooperate with local communities and their participation in governance will have real impacts on the ground. Thus, citizens have the opportunity to influence decisions that affect their cities. People, as one of the many elements of smart cities, are also considered one of the most important building blocks, especially because it is people who can program and then use the various technologies that are inextricably linked to the smart city concept. The basic prerequisites for successfully building a smart city are people who excel in their professions, are university graduates, are flexible, can use online learning tools, can adapt to change, excel in creativity, have a healthy lifestyle, accept diversity and multiculturalism and much more. It is such people in symbiosis with a smart city that can create a high standard of living in a given city, which will ultimately mean that they will attract highly skilled human capital to that city [59].

A simple example of why people are important in smart cities is as follows: There will be an election for the mayor of a given city. Everyone has the right to vote, so some will exercise that right personally, but if someone is away and would like to vote and thus influence the course of public affairs, the smart city makes it possible for them to do so thanks to smart governance, where electronic voting via ID card is commonplace. And so even someone who is currently on holiday in Greece can, thanks to the free roaming connection, connect to the internet, verify their ID card and vote in this way. This option ensures that the votes of people who are not in their place of residence at the time are not lost, and it also increases voter turnout, as it is much easier for many people to vote from the comfort of their own homes. This was one example of the integration of smart cities and free roaming within the European Union. Another example could be the same situation as described above, except that a citizen does not have paid mobile data and would still like to vote, so he or she connects to one of the publicly available WiFi networks called WiFi4EU and thus has the right to exercise his or her right to vote. As we can see, the integration of free roaming internet connection, WiFi4EU and the smart city concept can be seen even in very simple examples. It is precisely through the integration of these pillars that the citizens of the European Union are significantly improving their standard of living and more easily functioning within the state and the city [60].

Another element of the smart city is the so-called smart economy. The smart economy seeks to create an environment where information technology plays an important role in creating a prosperous and sustainable city, where a stable and efficient economy, a high standard of living for residents and quality business conditions are ensured. Only a symbiosis of the above aspects of the smart economy will ensure that entrepreneurs will be motivated to employ people and do business in the area, while at the same time, thanks to incentives from the city/state, they will be encouraged to strive to do business in a

so-called low-carbon and sustainable way, i.e., with the smallest possible environmental footprint. The main features of the smart economy are therefore, as already mentioned several times, digitalization and innovation, with which we can imagine cities that use digital technologies to support local entrepreneurship and to develop economic sectors. This can include, for example, the promotion of startups, the creation of incubation centers and the promotion of research and development. Another feature is the development of technological infrastructure. This means building high-speed internet connections, WiFi4EU wireless networks and data centers and making sure that cities and towns are covered as widely as possible with mobile signals without interruptions, to ensure that citizens from other EU countries who use free roaming can also be connected to the internet anywhere and anytime without interruptions. The smart economy also includes the principle of open data and transparency, which can be imagined in practice as citizens and entrepreneurs having access to virtually all data (except classified and similarly restricted data), thus ensuring transparency and fighting corruption; in addition, citizens will better understand the functioning of the city and the processes in the city and can use the data to develop new products and services. At the same time, there is also a strong focus on promoting economic sustainability and development, which means that the smart city promotes eco-friendly industries and ensures energy efficiency. Ultimately, the smart economy should ensure a better quality of life for city residents by providing them with better job opportunities, reducing pollution and increasing access to services [61].

Smart mobility involves not only the smart movement of vehicles but also the smart movement of people. In cities where the smart city concept is at a very high level, it is possible to reach everywhere on foot or by bicycle along a cycle path. The key is, therefore, to use bicycles, scooters, public transport or, if necessary, shared vehicles as much as possible to travel around the city. But the aim is to use cars as little as possible. Getting around the city should be as fast, efficient and sustainable as possible. Another aspect of smart mobility is the use of traffic lights at traffic intersections to the benefit of cyclists, public transport and pedestrians and, therefore, ultimately to the detriment of vehicles. A basic idea of a smart city is the renewable and sustainable movement of the population. Smart parking lots are set up for cars, which directly guide drivers to park in a different parking lot or show them where to park, thus relieving the burden and, to a significant extent, speeding up traffic in cities. In practice, this may involve the introduction of sensors that show drivers whether a parking space is available or not. If these sensors are also synchronized with mobile applications, the driver can see directly on the map the available parking spaces via the application and at the same time check the price for parking. In the wake of smart mobility, we cannot leave out smart vehicles either. These vehicles are interconnected via the internet and cloud services, allowing information about their movements to be shared. This greatly helps cities; because they know which roads are congested and also see which roads are free, they can redirect traffic to those roads via traffic lights. Smart mobility has an essentially unlimited range of project implementation, and it is therefore up to the mayors of individual cities and municipalities to see if they can meet this challenge. However, as long as they follow the recommendations of the European Union and the experts, they will certainly succeed [62].

In order for a city to declare that it has a smart environment, it must meet several conditions. The first one is that the city does not eliminate nature, but just tries to incorporate as much greenery as possible into its streets. So, the bottom line is that it conserves and preserves the ecosystem of the urban region and maintains biodiversity within it. It tries to use natural resources, is green and clean and has a large number of natural public spaces. The smart environment also includes a component of smart waste disposal. The city should have an integrated efficient system of waste collection, transportation, recycling and disposal with the utmost consideration for the efficient use of renewable energy [63].

According to Skora et al., (2022), smart public administration is the last determining factor of a smart city. Smart public administration is a concept that seeks to use modern technology and digital transformation to improve the efficiency, transparency and quality of

public administration. The concept is often associated with city and municipal innovation and efforts to leverage technology to support better service to citizens [64]. The key elements of smart government include the following:

1. Digitalization: Moving from traditional paper-based processes to electronic and digital solutions, enabling faster and more efficient processing of official business.
2. Open Data: Making data and information publicly available on the internet to make it easier for citizens to monitor and analyze the performance of the government.
3. E-Government (E-City-Government): Creating online platforms on which citizens can carry out various administrative tasks and interact with municipal authorities without the need to be physically present in the offices.
4. Citizen Participation: Providing tools and channels that enable citizens to actively participate in policy making, decision making and monitoring of public projects.
5. Improving Efficiency: Using technology to reduce bureaucracy, eliminate duplication of processes and increase the efficiency of public administration.
6. Security and Data Protection: Securing citizens' data and information is a key element of smart government to prevent misuse of information and privacy breaches.
7. Innovation and Experimentation: Actively seeking to innovate and experiment with new technologies and approaches to improve public administration [60].

Smart public administration seeks to create efficient and open urban systems that contribute to a better-functioning society and meet the needs of citizens. The concept may vary depending on the country and local conditions, but the aim is always to use technology to improve public administration and provide better services to citizens. Investing in smart cities is certainly important, because the amount of capital allocated to these projects is growing worldwide, and therefore, if the European Union wants to catch the trend, it is necessary to further allocate funds to this area. It is assumed that revenues from smart cities will be at the level of more than USD 2500 billion in 2025, and therefore, such investments by the European Union will have a high return. The opinion presented before is also confirmed by the statistical research presented below in the table and graph (Figure 10).

Year	2018	2019	2020	2021	2022	2023	2024	2025
Revenues (in bln. \$)	\$737	\$858	\$1007	\$1194	\$1428	\$1721	\$2094	\$2577

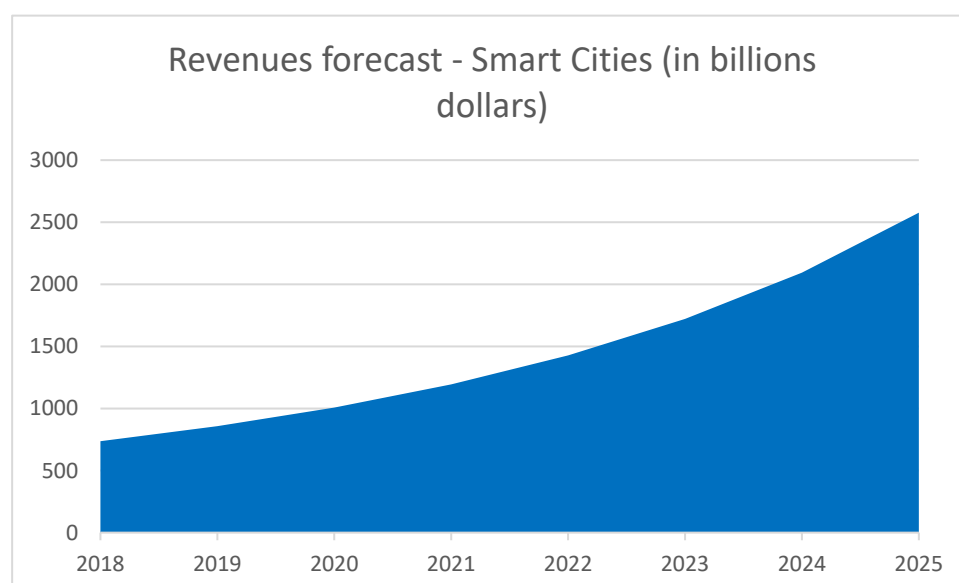


Figure 10. Source: Smart Cities Market Analysis & Segment Forecasts to 2025, Grand View Research.

The concept of smart cities represents a holistic approach to urbanization and urban governance that focuses on the use of information and communication technologies (ICTs) to achieve more efficient, sustainable and inclusive urban development. Smart cities are becoming an important part of the digital transformation in the European Union and play a key role in achieving the objectives of the Digital Single Market. Within the European Union, the smart city concept is supported and funded by various programs and initiatives. One major initiative is the WiFi4EU program, which provides funding for the deployment of public WiFi networks in urban areas. These networks contribute to the availability of digital services for citizens and visitors. The development of smart cities is also ensured by free roaming connections, as smart cities count on the fact that even when citizens are not at home, they can still participate in governance. Digital connectivity, efficient transport, a quality environment, sustainability, innovation and open data are just the basic pillars through which we can reach the level of a smart city as the European Union envisages it. However, free roaming and WiFi4EU are essential prerequisites for the effective functioning of such a city.

4.10. Sustainable Smart Cities

In the 21st century, urban landscapes are undergoing a profound transformation as cities embrace the concept of smart cities to address the challenges of rapid urbanization, resource constraints and environmental degradation. It is necessary to discuss the multifaceted relationship between sustainability and smart cities, delving into how innovative technologies and data-driven solutions are shaping urban environments to foster ecological resilience, social inclusivity and economic vitality. Smart cities represent an evolution in urban development, where advanced technologies such as the Internet of Things and data analytics converge to create intelligent urban ecosystems. At the core of sustainable smart cities lies a commitment to environmental responsibility [65].

Environmental stewardship in urban development: In this context, the integration of advanced technologies is leveraged to optimize resource usage, enhance energy efficiency and revolutionize waste management practices. Sustainable smart cities are characterized by their ability to monitor and manage environmental impact through data-driven insights, ensuring a balance between urban development and ecological preservation [66].

Examples of smart city sustainability are the Slovenian smart cities, where waste recovery rates have increased from under 30% to over 76.7%, which is an absolute leader in the world (Figure 11). This graph demonstrates the direct link between environmental sustainability and the smart city concept [67].

Case studies showcasing successful implementations of sustainable practices underscore the transformative potential of these technological interventions in fostering environmentally conscious urban growth.

Inclusive urbanism: Moreover, sustainable smart cities prioritize social inclusivity. By harnessing technology to address social inequalities in healthcare, education and public services, these cities strive to create environments that offer equal opportunities for diverse urban populations. The role of digital connectivity becomes pivotal in bridging the digital divide, ensuring that the benefits of smart city initiatives are accessible to all, irrespective of socio-economic backgrounds.

Technological innovations for sustainable mobility: A critical aspect of sustainable smart cities lies in redefining urban mobility. This involves integrating smart transportation systems, embracing electric mobility and implementing data-driven traffic management strategies to reduce congestion and lower carbon emissions. These advancements not only contribute to environmental sustainability but also enhance the overall quality of life for city residents.

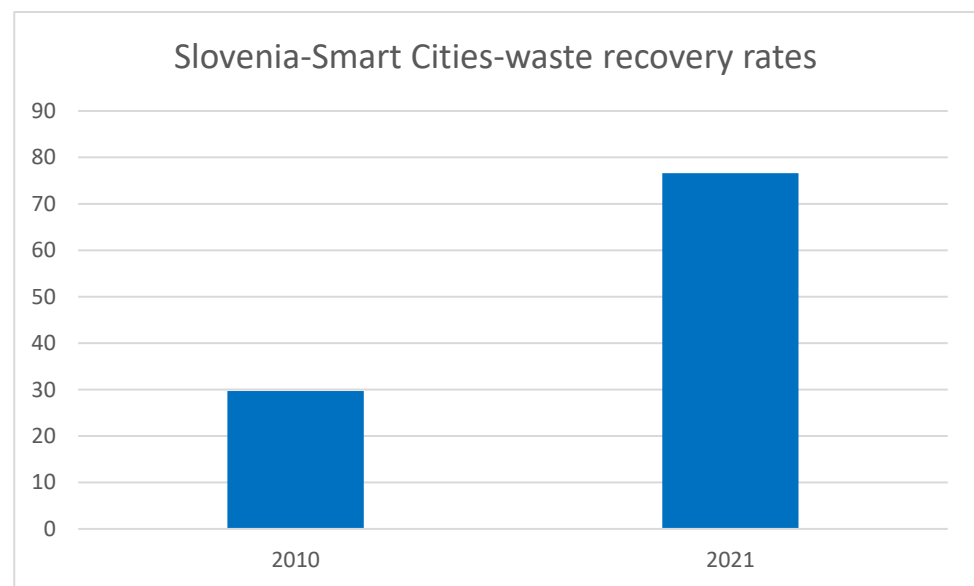


Figure 11. Statista: Global municipal waste recovery rates 2010–2021, by select country.

The statistics below show the total number of electric bus registrations from 2016 to 2022 by region (Figure 12). Clearly, China has the highest number of registrations, and it should be said that a large number of modern smart cities are springing up in China as well. However, from a sustainability perspective in the Union, we can see a long-term increase in the purchase of sustainable modes of transport in order to reduce the carbon footprint [68].

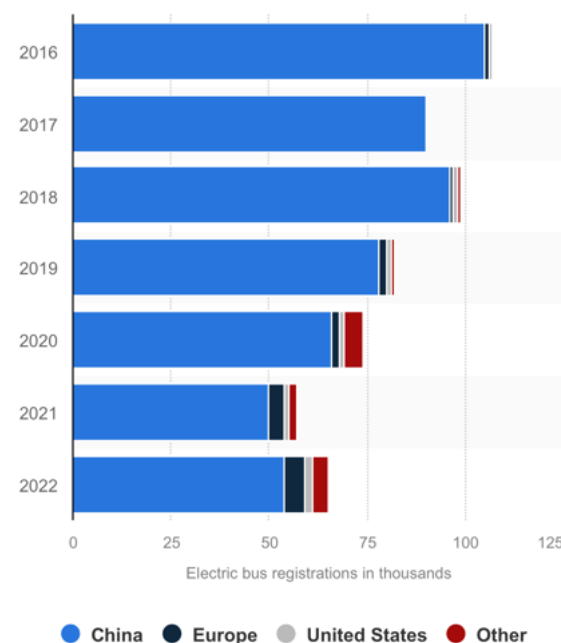


Figure 12. Source: Statista, Total number of electric bus registrations from 2016 to 2022, by region.

Economic resilience and innovation: smart cities are not only hubs of technological innovation but also drivers of economic resilience. By fostering innovation hubs, supporting startups and attracting investments in technology and sustainability, these cities stimulate economic growth. The emergence of job opportunities in sectors aligned with the principles of sustainable smart cities further reinforces the economic benefits of embracing smart infrastructure.

According to market research, smart cities are one of the main and most lucrative segments that should ensure economic growth and sustainability in the future. If economies are able to adapt to smart cities and build more of them, they will also grow economically and thus be able to find a balance between economic growth and long-term environmental sustainability in their regions. The charts only confirm that the smart city market and its individual elements will only grow by 2030, and it is therefore important that all cities are able to capture this trend and move towards long-term sustainability [69] (Figure 13).

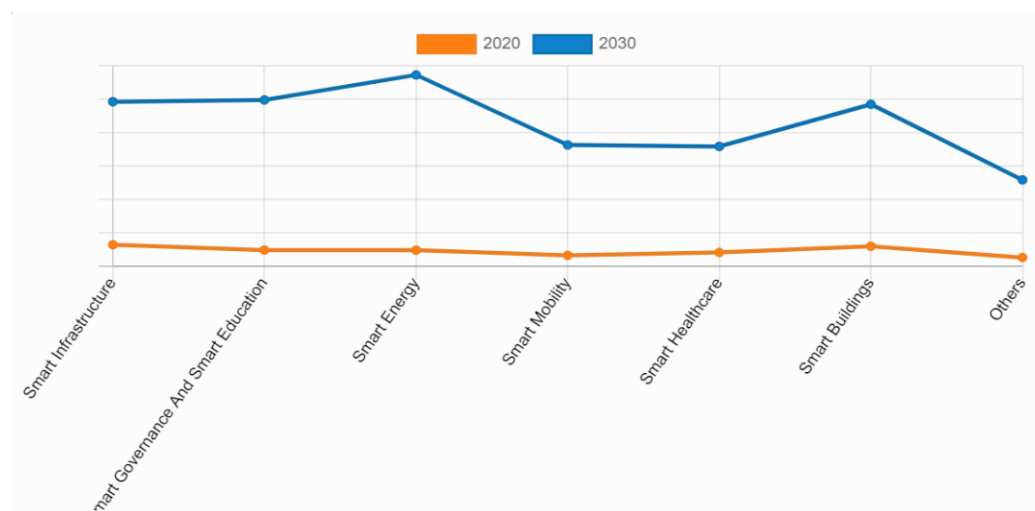


Figure 13. Source: Allied Market Research, Smart Cities Market Statistics: 2030.

Community engagement and governance: The success of sustainable smart cities is closely tied to citizen participation. These cities prioritize transparent, accountable and collaborative governance models, ensuring that the community plays an active role in shaping the sustainability agenda. By fostering a sense of collective responsibility, smart cities can enhance the effectiveness and sustainability of their urban development initiatives.

Challenges and future perspectives: While the potential benefits of sustainable smart cities are vast, challenges exist in their implementation. This includes issues related to data privacy, security and the equitable distribution of technological benefits. Navigating these challenges will be crucial for the continued success and sustainability of smart city initiatives. Looking forward, emerging technologies and future trends hold promise for further advancing the sustainability agenda in urban environments, paving the way for even more resilient and innovative cityscapes.

This exploration into the realm of sustainable smart cities aims to unravel the intricate balance between technological innovation and environmental responsibility. By navigating through the various dimensions of sustainability within smart cities, we strive to understand how these urban ecosystems can evolve into models of resilience, inclusivity and innovation for the benefit of present and future generations.

The sustainability of smart cities itself is also regularly measured by experts who process the data into clear graphs and interesting statistics. The Sustainable Smart Cities Index 2022 presented below ranks 100 of the world's cities based on 51 metrics, across 26 indicator themes, arrayed under the three pillars of sustainability: planet, people and profit [70]. The numbers next to the city names indicate only the order in the chart. They have no other additional meaning (Figure 14).

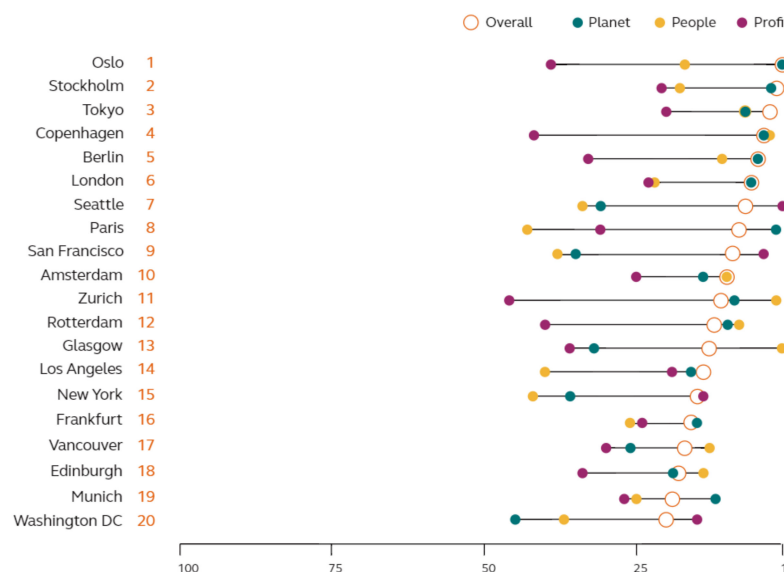


Figure 14. Source: The Arcadis Sustainable Smart Cities Index 2022.

5. Discussion

The sustainable integration of mobile roaming, WiFi4EU and the smart city concept within the European Union represents a comprehensive approach to creating a modern, simpler and smarter life in the European Union. This integration is key to improving mobile connectivity, the provision of public WiFi services and the efficient management of urban infrastructure. In the following discussion and conclusion, we will look at how these initiatives relate to each other, what benefits they bring and what the challenges and opportunities are in their implementation.

Mobile roaming, the WiFi4EU program and the smart city concept share the common goal of providing citizens and visitors with fast and reliable internet access, smart public administration and transforming the living standards of citizens to a higher level. Mobile roaming ensures that people can use their mobile data in different EU countries without additional charges, making it easier to travel and communicate in different cities within the European Union [71], and is a basic prerequisite for a smart city to work, as a smart city collects data about its citizens, evaluates these data and tries to make the citizens' lives as easy as possible (e.g., sending automated notifications over the internet, with the citizen being able to read the notification anywhere thanks to the roaming at no additional cost and being able to reply to it, so the citizen does not have to come home, go to the post office and pick up the letter and then send another letter in reply to that letter; roaming and smart cities save time and money for citizens). The WiFi4EU program supports the installation of public wireless networks in cities that are free to the public, increasing internet accessibility [72]. The smart city concept focuses on the use of digital technologies and data to improve the quality of life of citizens and efficient city management, which often includes the provision of public WiFi networks and working with the coverage of a city or municipality with a mobile internet connection, ensuring that citizens from other Member States can also take advantage of roaming services or WiFi4EU.

The main contributions of the work are as follows: Theoretical foundations and conceptual frameworks: At its core, this paper establishes a robust theoretical foundation by drawing upon relevant scientific articles, publications and official reports sourced from the European Union. This literature review not only elucidates the existing theories surrounding sustainable connectivity but also lays the groundwork for subsequent analyses. By synthesizing theoretical perspectives, this paper offers a conceptual framework that facilitates a deeper understanding of the three elements—mobile roaming, WiFi4EU and smart cities.

Legislative scrutiny and doctrinal interpretation: One notable contribution lies in the meticulous examination of legislative documents governing mobile roaming within the EU. This paper engages in a nuanced analysis of relevant EU legal standards and directives, providing readers with a detailed insight into the regulatory landscape that shapes the implementation of roaming practices. This not only adds a legal dimension to the discussion but also contributes to the broader discourse on how policy frameworks influence sustainable connectivity in the European context.

Empirical foundation through statistical data: A key strength of this paper is its reliance on official statistical data, offering a quantitative basis for its arguments. By incorporating data on mobile roaming, the WiFi4EU program and the development of smart cities, this paper provides empirical evidence to support its claims. The statistical analysis serves to underscore the current situation in the EU and its individual Member States, thereby enhancing the credibility and relevance of the findings.

Real-world context with practical examples: To bridge the gap between theory and practice, this paper enriches its narrative with practical examples. These real-world instances serve as illustrative case studies, making the functioning of different institutes and the mutual integration of mobile roaming, WiFi4EU and smart cities more tangible for the reader [73].

This pedagogical approach not only enhances comprehension but also positions this paper as a valuable resource for policymakers, industry professionals and scholars seeking to navigate the complexities of sustainable connectivity.

Highlighting synergies, opportunities and challenges: This paper makes a noteworthy contribution in the discussion and conclusion part by not only identifying synergies between mobile roaming, WiFi4EU and smart cities but also by shedding light on the opportunities and challenges that arise from their integration. This nuanced exploration goes beyond a mere description of the elements involved; it critically assesses the implications and potential benefits, offering valuable insights for future developments in the realm of connectivity and urban innovation.

Implications for economic growth and environmental consciousness: Furthermore, this paper implies that the integration of these elements is not merely a technological endeavor but holds profound implications for economic growth and environmental consciousness. By unpacking the multifaceted dimensions of sustainable connectivity, the article contributes to a holistic understanding of how these advancements can positively impact societal and environmental well-being [74].

- (a) **Summary of the effects of the concepts outlined within specific smart city services:** Smart public administration: Mobile roaming and WiFi4EU contribute to streamlined communication and connectivity within smart public administration systems. Improved connectivity enhances the efficiency of administrative processes, enabling real-time data exchange, collaborative working environments and enhanced citizen services.
- (b) **Smart mobility:** The integration of mobile roaming and WiFi4EU plays a pivotal role in enhancing smart mobility solutions. These technologies support real-time traffic monitoring, navigation services and seamless connectivity for smart transportation systems, ultimately reducing traffic congestion and improving overall transportation efficiency.
- (c) **Smart lighting:** Through robust connectivity provided by mobile roaming and WiFi4EU, smart lighting solutions can be better managed and optimized. This allows for adaptive lighting systems that respond to environmental conditions, increasing energy efficiency and contributing to a more sustainable urban environment.
- (d) **Smart transportation:** Efficient transportation systems are facilitated by the integration of mobile roaming and WiFi4EU, enabling smart traffic management, intelligent logistics and enhanced connectivity for public transportation. These elements collectively contribute to reduced traffic congestion and improved transportation services.

- (e) **Smart tourism:** Mobile roaming and WiFi4EU enhance the tourist experience by providing seamless connectivity, location-based services and real-time information. This contributes to smart tourism initiatives, supporting tourists in navigation, cultural exploration and access to local services.
- (f) **Smart people:** Improved connectivity positively impacts the daily lives of citizens. Smart city initiatives empowered by mobile roaming and WiFi4EU contribute to citizen engagement, education and access to information, fostering a more connected and informed population.
- (g) **Smart economy:** In the realm of the smart economy, the integration of these technologies facilitates digital innovation, e-commerce and business connectivity. This creates a conducive environment for entrepreneurship, economic growth and the establishment of a thriving digital economy. The resulting economic growth contributes to the overall prosperity of the smart city [75].
- (h) **Smart environment:** Mobile roaming and WiFi4EU contribute to environmental sustainability by enabling smart environmental monitoring systems. These technologies support data collection, analysis and decision-making processes related to air quality, waste management and green initiatives.
- (i) **Smart housing:** Connectivity is a fundamental aspect of smart housing solutions. Mobile roaming and WiFi4EU support smart home technologies, enhancing energy management, security systems and overall quality of life for residents.
- (j) **Smart education:** Enhanced connectivity benefits educational institutions through improved access to online resources, virtual learning environments and collaborative platforms. This facilitates smart education initiatives, fostering a technologically advanced learning environment.
- (k) **Smart energy use:** Efficient energy use is promoted through the integration of mobile roaming and WiFi4EU in smart city infrastructure. Smart grids, energy monitoring and conservation initiatives are facilitated, contributing to sustainable energy practices.
- (l) **Environmental change and climate change:** The technologies under consideration support initiatives addressing environmental and climate change concerns. Real-time data collection and analysis contribute to informed decision making for climate adaptation and mitigation strategies.
- (m) **Smart finance and decision-making bodies:** Smart financial systems benefit from improved connectivity, enabling efficient transactions, digital banking and transparent financial processes. Decision-making bodies within cities and municipalities are empowered by real-time data, enhancing their ability to make informed, data-driven decisions.
- (n) **Smart health:** The integration of mobile roaming and WiFi4EU significantly influences smart health initiatives. Enhanced connectivity enables real-time health monitoring, telemedicine solutions and seamless communication between healthcare professionals and patients. This facilitates quicker response times, remote diagnostics and improved overall healthcare delivery, contributing to a more efficient and responsive healthcare system within the smart city framework.
- (o) **Smart accommodation:** In the realm of smart accommodation, the integration of mobile roaming and WiFi4EU enhances the overall experience for residents and visitors. Seamless connectivity supports smart home technologies, enabling automated systems for climate control, security and energy management. Residents can enjoy a more comfortable and connected living environment, while visitors benefit from intelligent accommodation options that offer enhanced services through robust connectivity.
- (p) **Smart security:** The impact of mobile roaming and WiFi4EU on smart security is profound. These technologies enable the deployment of advanced surveillance systems, access control and real-time monitoring. Improved connectivity ensures swift communication between security devices and central control systems, enhancing the overall effectiveness of smart security solutions. This contributes to a safer urban environment with proactive measures against potential threats.

- (q) **Smart waste management:** In the context of smart waste management, the integration of mobile roaming and WiFi4EU plays a crucial role in optimizing waste collection and disposal processes. Connected sensors on waste bins can transmit real-time data on fill levels, enabling more efficient route planning for waste collection vehicles. This not only reduces operational costs but also enhances environmental sustainability by minimizing unnecessary vehicle emissions.
- (r) **Smart culture:** Mobile roaming and WiFi4EU contribute significantly to the enrichment of cultural experiences within the smart city framework. Connectivity facilitates the digitization of cultural assets, virtual exhibitions and interactive cultural events. Visitors and residents alike can access information about historical sites, museums and cultural events in real time, fostering a vibrant and connected cultural ecosystem within the city. This not only promotes cultural appreciation but also contributes to the economic and social vitality of the community.

The integration of mobile roaming, WiFi4EU and smart cities marks a transformative nexus in the urban landscape, where connectivity, technology and sustainable living converge. The seamless interplay of these elements presents a dynamic framework for urban development, fostering synergies that extend across diverse smart city services [76].

The integration of mobile roaming and WiFi4EU into the fabric of smart cities is a pivotal driver for enhanced connectivity, efficiency and citizen services. Mobile roaming facilitates ubiquitous connectivity, allowing residents and visitors to stay connected seamlessly, irrespective of geographical boundaries. WiFi4EU, with its focus on free WiFi access in public spaces, complements mobile roaming by extending high-speed connectivity to key urban areas, contributing to a more inclusive and digitally connected city [77]. This integration manifests in various smart city services, influencing healthcare, accommodation, security, waste management and cultural experiences. For instance, in smart health, the convergence allows for real-time health monitoring and telemedicine, while in smart accommodation, it enables smart home technologies for enhanced living experiences.

The synergies between these elements amplify their individual impacts, creating a networked ecosystem that transcends traditional city boundaries. The ubiquitous connectivity enabled by mobile roaming and WiFi4EU becomes the backbone of smart city services, fostering a more responsive and data-driven urban environment.

The integration of mobile roaming and WiFi4EU enhances communication channels, fostering collaboration between citizens, businesses and administrative bodies. This synergy facilitates efficient public administration, enabling responsive and transparent governance.

The connectivity afforded by mobile roaming and WiFi4EU contributes to optimized transportation systems. Real-time traffic monitoring, smart navigation and seamless connectivity for public transportation are synergistically supported, leading to reduced congestion and enhanced mobility services.

The integration enhances smart city initiatives related to environmental sustainability. Real-time data collection from connected devices aids in smart waste management, energy conservation and environmental monitoring, contributing to a more sustainable and resilient urban ecosystem.

Synergies between mobile roaming, WiFi4EU and smart cities result in cultural enrichment and tourism enhancement. Seamless connectivity fosters virtual cultural experiences, while tourists benefit from location-based services and real-time information, creating a more engaging and connected cultural landscape.

The integration and synergies presented underscore the potential for holistic urban development. Smart cities, powered by mobile roaming and WiFi4EU, become vibrant hubs where technological advancements align with citizen needs, economic growth and environmental sustainability. This integration paves the way for a more connected, efficient and livable urban future.

Synergies between initiatives: There are many benefits to integrating these initiatives. Cities can use the WiFi4EU infrastructure to implement smart city solutions such as traffic monitoring, air quality monitoring or citizen information portals. At the same time, city

authorities can use data from these systems to improve public services. Mobile roaming allows citizens and visitors to the city to stay online regardless of their location, which promotes interaction with smart applications and solutions.

The integration of mobile roaming, WiFi4EU and smart city technologies has the potential to drive substantial efficiency gains. As smart cities leverage data-driven insights to optimize energy usage, transportation and resource management, the seamless connectivity provided by mobile roaming and WiFi4EU contributes to a more connected and responsive urban environment. This symbiosis could result in reduced energy consumption, lowered carbon emissions and overall positive environmental impact.

One of the central objectives of WiFi4EU is to bridge digital divides by providing free and accessible WiFi in public spaces. The integration of mobile roaming further supports this inclusivity by ensuring that citizens can stay connected seamlessly even when traveling across EU borders. However, it is essential to address potential disparities in access to mobile devices and the internet to fully realize the social benefits of these initiatives.

The integration of these connectivity elements holds significant promise for economic sustainability. Smart cities, fueled by robust connectivity, create fertile ground for innovation and entrepreneurship. The facilitation of seamless mobile connectivity and WiFi accessibility enhances the attractiveness of urban environments for businesses, startups and digital nomads, potentially stimulating economic growth and job creation.

However, the integration of these initiatives is not without problems and challenges.

1. Accessibility and investment: WiFi4EU and smart city programs require financial investment in infrastructure, which can be a challenge for some smaller cities. There is a need to ensure that financial resources are available for all cities, not just large metropolises. Mobile roaming availability should be ensured throughout the city, not just in the central area.
2. Data security and privacy: When integrating smart city technologies, it is important to ensure the data security and privacy of citizens. The misuse of personal data or lack of privacy protection can cause mistrust between citizens and city authorities.
3. Technical challenges: Integration of these initiatives requires technical competence and expertise. Cities need staff and contractors with the ability to design, implement and maintain these systems.
4. The combination of sustainability and connectivity development is not always possible. As we know that the actual construction of networks and the associated operations consume a lot of electricity and at the same time destroy nature, it is essential that the European Union invests resources in sustainable ways of building networks and ensuring connectivity [78].

This paper makes a significant contribution to the scholarly discourse on the intersection of mobile roaming, WiFi4EU and smart cities within the European Union. By systematically exploring the integration and synergies among these three elements, this paper unveils multifaceted impacts across various smart city services. The noteworthy contributions of this paper include the following: This paper offers a holistic understanding of the dynamics shaping connectivity within smart cities. By dissecting the integration of mobile roaming and WiFi4EU, it provides insights into how these elements collectively influence diverse urban services. One of the key contributions lies in identifying and elucidating synergies that arise from the convergence of mobile roaming, WiFi4EU and smart cities. These synergies amplify the impact of individual elements, leading to more efficient and responsive urban services. This paper extends beyond a broad overview and delves into specific impacts on smart city services such as health, accommodation, security, waste management and culture. This application-specific analysis enhances the practical relevance of the study. By incorporating practical examples, this paper bridges the gap between theory and application, providing readers with tangible instances that illustrate the functioning and integration of these elements in real-world urban environments. The insights generated from this exploration are valuable for policymakers, urban planners and industry professionals involved in shaping smart city strategies. The nuanced under-

standing of connectivity dynamics and synergies offers actionable knowledge for informed decision making. Through its analysis of connectivity's impacts on smart cities, this paper contributes to the broader discourse on sustainable urban development. It emphasizes the potential for technology to drive positive change in urban living, fostering efficiency, inclusivity and environmental consciousness.

In essence, this paper serves as a foundational resource for academics, practitioners and policymakers interested in the evolving landscape of connectivity within smart cities. It not only enhances our theoretical understanding of the subject but also provides practical insights that can inform strategic decisions for the future development of connected and sustainable urban environments within the European Union.

6. Conclusions

The journey toward sustainable connectivity through the integration of mobile roaming, WiFi4EU and the smart city concept within the European Union reflects both promise and complexity. As we navigate the intricate web of technological advancement, environmental responsibility and societal transformation, it becomes evident that the pursuit of a connected and sustainable urban future is nuanced and multifaceted. These initiatives are intertwined and together create a new model for delivering public services and improving the quality of life in cities. From reducing digital divides and fostering innovation to enhancing environmental sustainability, the interconnectedness of these elements holds the potential to reshape the urban landscape of the European Union positively. However, despite the enormous potential of these elements, there are some challenges that we need to overcome to achieve successful integration.

One of the main challenges is financial investment. Developing and maintaining reliable mobile connectivity and smart city infrastructure requires huge financial resources. It is therefore important for the EU and local authorities to work together to develop appropriate financial models and encourage investment to ensure the long-term sustainability of these projects. This may include public–private partnerships and the use of EU funds. As we can see from the chart below, the cost of smart cities is rising in the billions of dollars every year, so one of the main challenges will be to manage the funds wisely (Figure 15). It is the wise management of funds that is essential for the long-term financial and economic sustainability of the concept [79].

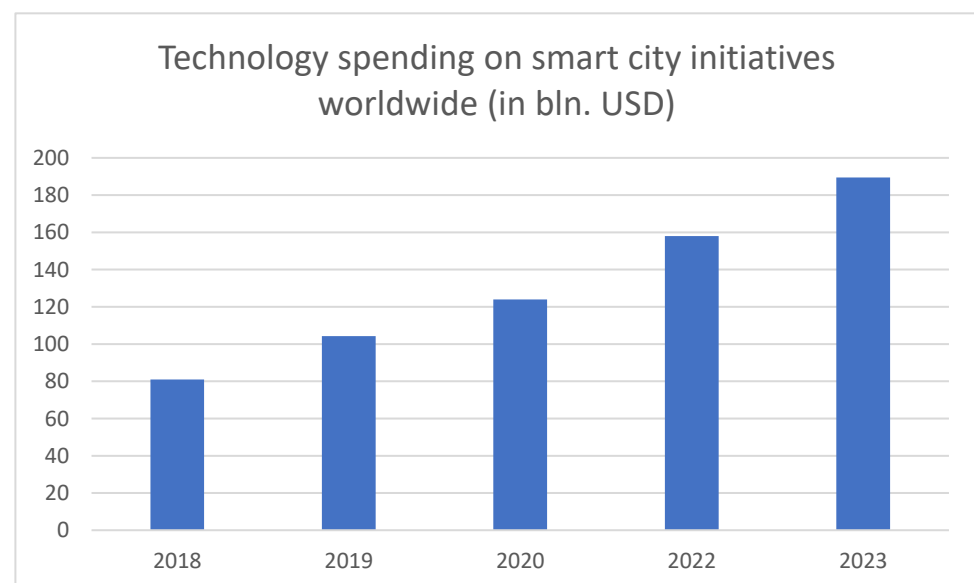


Figure 15. Source: Statista—Technology spending on smart city initiatives worldwide.

Another important consideration is data security [80]. Mobile data and connected devices are constantly on the move, which poses a risk to data privacy. It is essential

that the EU and local authorities put in place strict security measures and rules regarding the collection, storage and processing of data. In this area, educating citizens about data security and their privacy rights should also be a priority [81]. The importance of data protection in the integration of smart cities, mobile roaming and WiFi4EU is also confirmed by statistical data according to which in 2010, regarding the issue of personal data and data protection within smart cities, WiFi4EU was addressed minimally, as only one book on personal data and data protection was published in this period. In 2019, there were 23 such publications, which underlines the need for the protection of these data and also represents one of the main challenges in this area [82] (Figure 16).

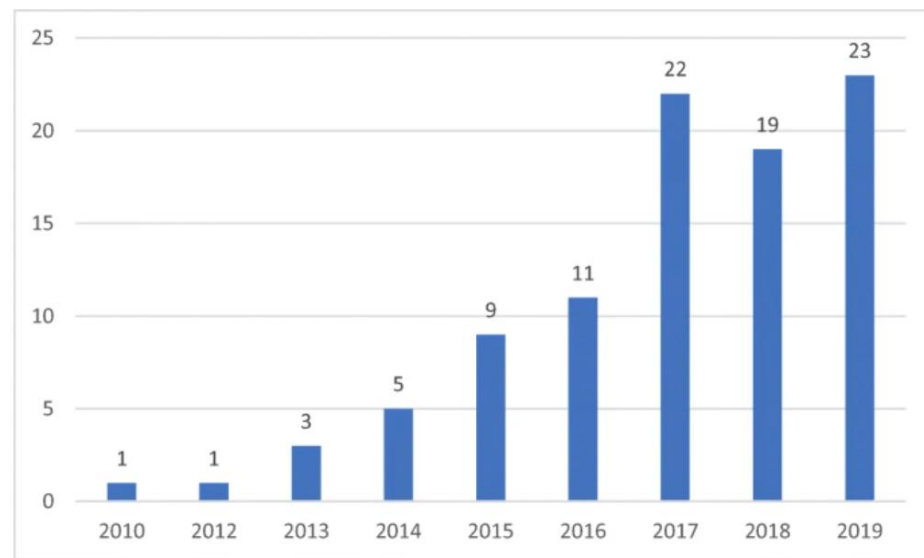


Figure 16. Number of books published with topic related to Security, Privacy and Risks within Smart Cities. Source: Security, Privacy and Risks Within Smart Cities [83].

The technical aspects are another challenge that we need to address. The integration of different technologies and systems into a single ecosystem requires careful study and planning. Interoperability is a key factor so that all these elements can work together effectively. This means that different devices and applications should be able to communicate with each other and create synergy. Ensuring interoperability requires technical expertise and collaboration between different technology companies and service providers.

Policymakers, industry leaders and communities must collaborate to address digital inequalities, strengthen data privacy measures and navigate the regulatory complexities inherent in implementing smart city initiatives. Public engagement, transparent communication and a commitment to environmental responsibility are essential components of a sustainable and connected future. In the chart below, we present the most frequently discussed issues associated with smart cities and ultimately with the integration of mobile roaming, the smart city concept and WiFi4EU, as these elements are interrelated (Figure 17). For example, for a secure WiFi4EU network, we need to solve the privacy and security of mobile devices and services; for a smart city to be sufficiently covered by mobile signal, we need to invest in smart city infrastructure. The key elements and challenges in integrating these few elements are summarized in the diagram below [83].

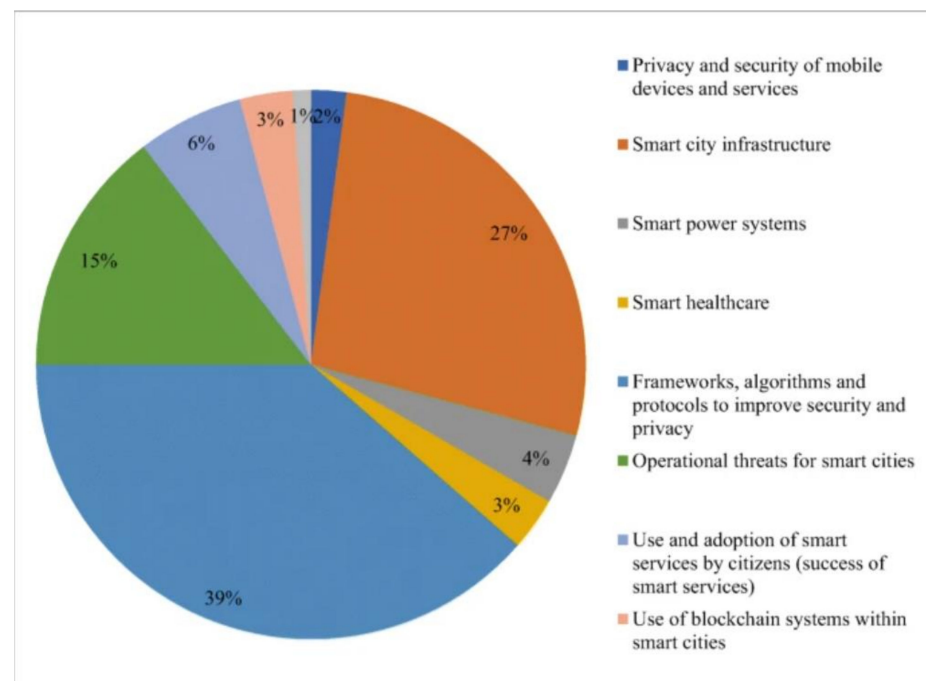


Figure 17. Most frequently discussed issues associated with smart cities and with the integration of mobile roaming, the smart city concept and WiFi4EU Source: Security, Privacy and Risks Within Smart Cities [83].

Despite these challenges, it is important to recognize that there are huge benefits to be gained from the integration of mobile roaming, WiFi4EU and smart cities. We can imagine citizens being able to travel across the European Union and have easy access to reliable mobile connectivity without worrying about high roaming charges [84]. The WiFi4EU program will enable public places and communities to provide free WiFi, promoting digital inclusion and internet access for all. Smart cities can contribute to better traffic management, a more efficient use of energy, improved safety and many other aspects of urban life.

In addition, the integration of these initiatives can contribute to sustainability. The use of technology to improve the management of urban infrastructure can lead to a more efficient use of resources and a lower ecological footprint. Smart cities can promote renewable energy and reduce the amount of waste produced by cities, as shown by the statistical data in the relevant section.

The sustainable integration of mobile roaming, WiFi4EU and smart cities is a key factor in the European Union's drive for sustainable digital development and improved quality of life for citizens and businesses. These initiatives create opportunities but require complex solutions in terms of finance, security and technology. With regular collaboration between city authorities, regulators and technology companies, we can achieve the vision of smart, connected and sustainable cities across the European Union. These steps will enable us to create thriving and competitive cities that will serve as a model for the world.

The European Union is making progress towards its goals of integrating roaming, WiFi4EU and smart cities. These projects are constantly on the move, and their integration is increasingly visible. Roaming has become an indispensable tool for mobility within the EU, and citizens can enjoy seamless access to mobile internet in any Member State without restrictions and excessive costs. The WiFi4EU program is being actively expanded, ensuring that more public places will have free internet access and thereby improving citizens' access to digital services.

In the area of smart cities, we see that many cities in Europe are committed to developing smart solutions for a better quality of life for citizens. These cities are implementing various technological innovations that increase the efficiency of public services and reduce

their ecological footprint. These cities are becoming greener, more energy-efficient and safer for their citizens.

Going forward, we can confidently expect these initiatives to continue to develop and grow in success. As technology continues to evolve and awareness of these concepts increases, so too will citizens' interest in these services, which will ultimately mean that the European Union will continue to invest in these projects. The aim is to create even more connected and sustainable cities where citizens have access to efficient and reliable digital services that improve their quality of life.

Countless opportunities for innovation and growth await the companies that focus on the technology sector and the governments that support these projects [85]. With technology advancing ever faster and infrastructure improving, we can expect roaming mobile connectivity, free WiFi and smart cities to become increasingly important parts of our daily lives in the near future [86].

As the European Union advances toward its vision of sustainable smart cities, the integration of mobile roaming, WiFi4EU and smart city initiatives serves as a testament to the region's commitment to innovation, inclusivity and environmental stewardship. By overcoming challenges and building on the positive potential of these initiatives, the EU can forge a path toward a more resilient, equitable and sustainable urban future, where connectivity serves as a catalyst for positive societal and environmental change. The European Union is well on its way to achieving its goals in this area and to realizing the full potential of these initiatives to improve the lives of all its citizens.

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