

European Union Capitals in the Face of Smart City and Age-Friendly Challenges – Analysis and Ranking of Cities*

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*Presented at the 47th IBIMA International Conference, 29-30 June 2026, Madrid, Spain

Abstract

Research objective: The aim of the paper is to analyze the capitals of European Union countries in terms of implementing and improving solutions that promote a dignified life for older people, in the context of developing smart and age-friendly cities.

Methodology: A comparative analysis and ranking of EU capitals were conducted, taking into account social, technological, and information and communication solutions supporting ageing societies.

Main findings and their significance: The results made it possible to identify good practices and determine directions for the development of age-friendly cities. The conclusions provide important guidance for planning the development of other cities both within the European Union and globally.

Keywords: smart cities, senior-friendly destinations, capitals of EU countries, comparative analysis, ranking of capital.

Introduction

As predicted by the United Nations, by 2050, 66% of the world's population will live in cities (Bibri S.E., Krogeste J., 2017). The increasing population of urban areas affects not only the countries of North and South America and Asia, but in particular Europe, which is the third most populous continent on Earth. Europe is one of the most urbanized continents in the world. The development of cities will determine the future development of the European Union in economic, social, and territorial terms. In EU countries, more than two-thirds of the population already live in cities, and this percentage is constantly growing (it is projected that by 2030, the share of urban residents in the total population in these countries will be between 75% and 80%), and by 2050, it may even reach approximately 83–84% (Albino V., Berardi U., Dangelico R.M., 2015). In Poland, according to Statistics Poland (GUS) data, urban residents account for over 60% of the total population. The largest cities in terms of population in the European Union are Berlin and Madrid (3.7 million and 3.3 million inhabitants respectively) (Statistisches Bundesamt, www.destatis.de, Instituto Nacional de Estadística – www.ine.es). The growing population means that cities consume 60-80% of global energy resources (Albino V., Berardi U., Dangelico R.M., 2015), and their share in greenhouse gas emissions is increasing year by year (Bibri S.E., Krogeste J., 2017).

Cities are significant driving forces of the economy, serving as places of meeting, creativity, and innovation, as well as centers for services provided to the surrounding areas. Due to population density, cities have enormous potential for energy savings and transformation towards a low-carbon economy. However, cities are also places where problems such as unemployment, segregation, and poverty are concentrated. Along with the dynamic expansion of urban areas, effective urban development becomes a priority both for technologically advanced countries and for countries remaining outside the global leaders. Sustainable and modern cities in terms of infrastructure and management, ecological cities, are perceived as key foundations of the future. The answer to contemporary emerging problems (related to the implementation of sustainable development goals) and the advocated direction for the development of modern cities is the concept of smart cities, which is increasingly

popular both in Polish literature (Stawasz D., Sikora-Fernandez D., Turala M., 2012; Czupich M., Kola-Bezka, Ignasiak-Szulc A., 2016; Zakrzewska-Półtorak A., 2016) and in foreign literature (Letaifa S.B., 2015; Kummitha R.K.R., Crutzen N., 2017; Beretta I., 2018).

The aging of society and urbanization are two global trends that together create two major forces shaping the 21st century. Simultaneously, as cities grow, the share of residents aged 60 and over in their development increases. Building a smart and senior-friendly city, supported by digital technologies, is not only a duty but an investment in the future. The changing demographic structure in Europe means that an increasing percentage of society consists of older people. Their needs, expectations, and capabilities should be considered in the planning of urban living space. An age-friendly city is one that provides its senior residents with a high quality of life, enabling them to participate actively in social, cultural, and economic life. It is a place where older people feel safe, comfortable, and can develop their passions.

This work is an attempt to present an integrated approach to the concept of smart cities and age-friendly communities. Although these ideas are widely promoted by the European Union (EU) and the World Health Organization (WHO), they are often perceived as separate. Meanwhile, these concepts are closely linked in theory and practice regarding the promotion of healthy and active aging, the universal design of the urban environment (i.e., the utility and accessibility of environments friendly to the elderly), reducing the digital and robotic divide, and reducing the social isolation of older people (Pochlak M., 2018).

The present work fits into this extremely topical and important issue, presenting a new approach to the concept of a smart city and age-friendly communities. Based on a critical literature review, the first (theoretical) part of the study defines the concept of a smart city and characterizes its most important dimensions in relation to the type of innovations generated and implemented. The second (empirical) part of the article presents the results of desk research aimed at a comparative analysis of cities – capitals of European Union countries – and determining their ranking, taking into account six domains (factors) of urban life, to identify the cities most friendly to elderly communities in the context of promoting healthy and active aging, digital integration, and reducing social isolation among seniors.

Aim Of the Paper and Research Methodology

The aim of this study is a comparative analysis and the development of a ranking of cities – capitals of European Union countries that have implemented solutions supporting a dignified life and the aging of seniors to a broad or lesser extent. The research sample was purposively selected and included all capital cities of the 27 European Union Member States. A comparative analysis of EU capital cities and the presentation of their ranking will allow for demonstrating the state of development of capital cities providing an appropriate standard of living for the elderly. Furthermore, the ranking revealed model solutions of those capital cities providing very good, even exemplary, solutions that can become an inspiration for the development of other cities ensuring a dignified existence for seniors. Thus, the analysis of these cases will allow for the identification of best practices and the formulation of recommendations for the development of cities with weaker smart city potential, especially in Central and Eastern Europe, including Poland. For this reason, in the first stage of the research – based on the authors' own research – six criteria (domains) were developed, namely: smart economy, smart people, smart governance, smart mobility, smart environment, and smart living. In the second stage, the authors conducted further analyses, and for each criterion, factors were developed which, in the authors' opinion, will allow for a fairly precise identification of the state of development of individual capital cities in terms of the quality of life for elderly people. The study utilized methods of literature review, comparative analysis, and statistical methods. Quantitative data regarding development trends of elderly-friendly smart cities in Western Europe (WHO) and Central and Eastern Europe (including Poland) were drawn from the databases of Eurostat (Statistical Office of the European Union), the United Nations (UN), the Organisation for Economic Co-operation and Development (OECD), Statistics Poland (GUS), and the study by TU Wien – Smart Cities Ranking of European medium-sized cities.

Smart Cities Friendly to Seniors – A Review of Selected Concepts from The World

At the beginning of the 21st century, the discourse regarding the modernization of urban spaces became very important. Local administrations, especially in urban areas, must meet the growing expectations of various social groups, both as citizens and as consumers, employees, entrepreneurs, investors, as well as family and community members (Sikora-Fernandez 2019). Furthermore, in the context of demographic changes, urban modernization must take into account issues such as the aging of society, the increase in average life expectancy, growing

pressure on the needs of people with disabilities regarding the elimination of architectural barriers and the accessibility of public infrastructure, the depopulation of certain districts, as well as unfavorable changes in birth, fertility, and mortality rates (Klimczuk A., Tomczyk Ł. 2019, European Commission 2015).

According to the United Nations (Abaya 2015), the process of "double aging" of the population is particularly noticeable, i.e., the rapid increase in the number of elderly people (75-84 years) and the oldest-old (over 85 years) in the population. Based on UNPD data, the population of people aged over 80 will increase worldwide from 175 million in 2026 to 426 million in 2050 (UNPD 2025). In urban areas, these changes will be reflected primarily in increased demand for care, health, and social services (OECD 2025, European Commission 2025). However, it should be noted that the aging of society not only significantly reduces the potential for informal care provided mainly by families.

The aging of the population entails many consequences (social, economic, political, and cultural), but it is also a challenge to create new solutions so that societies can function better in the future. In particular, attention should be paid to older generations because, according to demographic forecasts, the growth rate of the retirement-age population in Europe will increase rapidly. Poland, the Czech Republic, Hungary, and Slovakia (Central European countries) have particularly begun to feel the effects of demographic changes in recent years through phenomena such as the depopulation of large cities (European Commission 2025). However, progressing urbanization in Central and Eastern Europe forces the implementation of new socio-technical solutions in local urban systems along with the full transfer of the idea of active aging to various areas of life. Active aging allows people to realize their potential and participate in social life. This approach points to the need for a multidimensional approach to supporting the elderly. An age-friendly environment, consisting of appropriate resources for educational and learning institutions, is one of the factors enabling the activation of older people.

The discussed demographic changes force the search for innovative solutions in terms of employment, health, work-life balance, participation in culture, recreation, and sports, as well as the provision of public services facilitating the implementation of various tasks and goals of stakeholders (e.g., transport, telecommunications, social housing, environmental protection). The aging of society is therefore an important stimulus for creating technological and social innovations. The main goals of the "Europe 2020" Strategy (European Commission 2010), which were adopted by the EU in 2010, are the pursuit of smart, sustainable, and inclusive growth.

The European Commission report "The Growing Silver Economy in Europe" (European Commission 2015 - https://commission.europa.eu/publications/annual-activity-reports-2015_en) indicates that 110 European regions consider healthy and active aging as their smart specialization priority in the coming years. This means that these regions intend to focus on support provided to the "silver economy" industries, i.e., the system of production and distribution of goods and services aimed at aging societies (European Smart Cities 2025). These sectors include, among others, cosmetics and fashion, silver tourism, service robotics, the health and wellness sector (including medical equipment, pharmaceuticals, and telemedicine), functional food, safety, culture and lifelong learning, entertainment, smart and autonomous transport (e.g., self-driving cars), assistive technologies, and banking and financial services dedicated to the elderly.

In the context of the silver economy and smart development, the concept of smart cities can be understood in particular as urban areas that extensively use information and communication technologies (ICT) to organize and provide all urban functions, e.g., to reduce infrastructure maintenance costs (e.g., roads, bridges, subways, airports, seaports, public transport, and sewage systems), resource consumption (e.g., gas, electricity, and water supply), better utilization of vacant spaces, as well as citizen engagement in local management. Terms similar to smart city include digital city, electronic communities, information city, knowledge-based city, and intelligent city. At this point, it is sufficient to mention that in 2012, the European Innovation Partnership on Smart Cities and Communities was launched (European Commission 2015), the aim of which is to connect cities, industry, Small and Medium-sized Enterprises - SMEs, the financial sector, research, and other stakeholders in activities related, among others, to knowledge sharing, creating international partnerships, and developing and implementing solutions for smart cities.

A special position in the concept of smart cities can be given to (Abaya 2015) smart homes and the technologies installed in them, which aim to facilitate activity during aging. The concept of smart homes includes solutions such as mobile applications and network-based functions for control, monitoring, and automation of apartments, such as lighting, heating, ventilation, alarm systems, video surveillance, fire systems, emergency power supply, and a management system for renewable energy production and storage (OECD 2025).

Smart cities also focus on the integration of data on community activities and big data analysis, which allows for the creation of "tailor-made solutions" at the local level. Municipal institutions collect huge amounts of data in digital form, which, through appropriate linking and processing, constitute a vast source of information for those responsible for creating urban spaces. Increasing and improving the quality of databases is possible thanks to the broader use of the "Internet of Things" concept, which extends the network through devices and household equipment in a smart home. A smart home system can make life easier for societies, urban agglomerations, and especially seniors. Based on the literature analysis and the authors' own thoughts, and according to the World Health Organization guidelines (WHO 2025), 6 key domains were adopted for the evaluation of EU capital cities, which through development define a model of a smart city friendly to elderly communities in the context of promoting healthy and active aging.

These are the areas:

- the first is "smart people," i.e., the human and social capital of city residents. Indicators such as education level, tendency for lifelong learning, social and ethnic diversity, flexibility, creativity, cosmopolitanism, openness, and participation in public life are used to measure this area.
- the second area is "smart living," which is defined as quality of life. This area includes factors affecting the lives of city residents, such as the accessibility of cultural and educational institutions, health conditions, personal safety, housing quality, tourist attractiveness, and social cohesion.
- the third is "smart economy," understood as competitiveness. This field is measured by indicators describing the innovation climate, entrepreneurship, the image of the local economy, productivity, labor market flexibility, the city's embedding in international cooperation networks, and the capacity for continuous city transformation.
- the fourth area is "smart governance," which is broadly understood as social participation. Indicators for this area include citizen participation in decision-making bodies, the scope of public and social services, management transparency, public policies, and political perspectives.
- the fifth area is "smart mobility," related to both transport and the use of information and communication technologies. Indicators include local, national, and international accessibility of the city, the presence of ICT infrastructure, and sustainable, innovative, and safe transport systems.
- the sixth area is "smart environment," i.e., the approach to natural resources. Indicators of this dimension are the attractiveness of natural conditions, pollution levels, environmental protection, and sustainable resource management (Fig. 1).

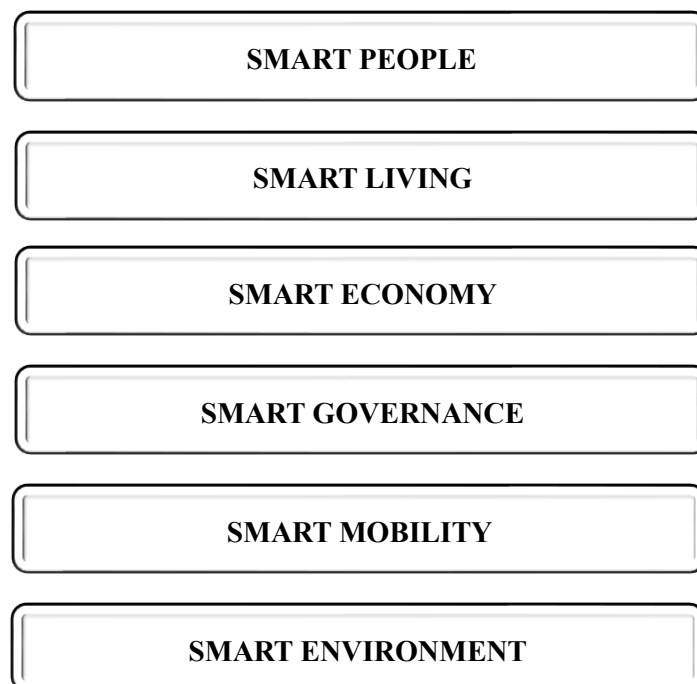


Fig. 1. Key factors shaping the identity of age-friendly cities

Source: own study based on Global age-friendly cities; a guide, WHO, 2007, 2025.

Criteria For Assessing European Capitals in The Context of Senior-Friendly Cities

In order to conduct a comparative analysis and develop a ranking of EU capital cities in the subsequent part of the research, it was necessary to develop a hierarchical structure in which each domain was described by x factors, as shown in Fig. 2 (Figure 2).

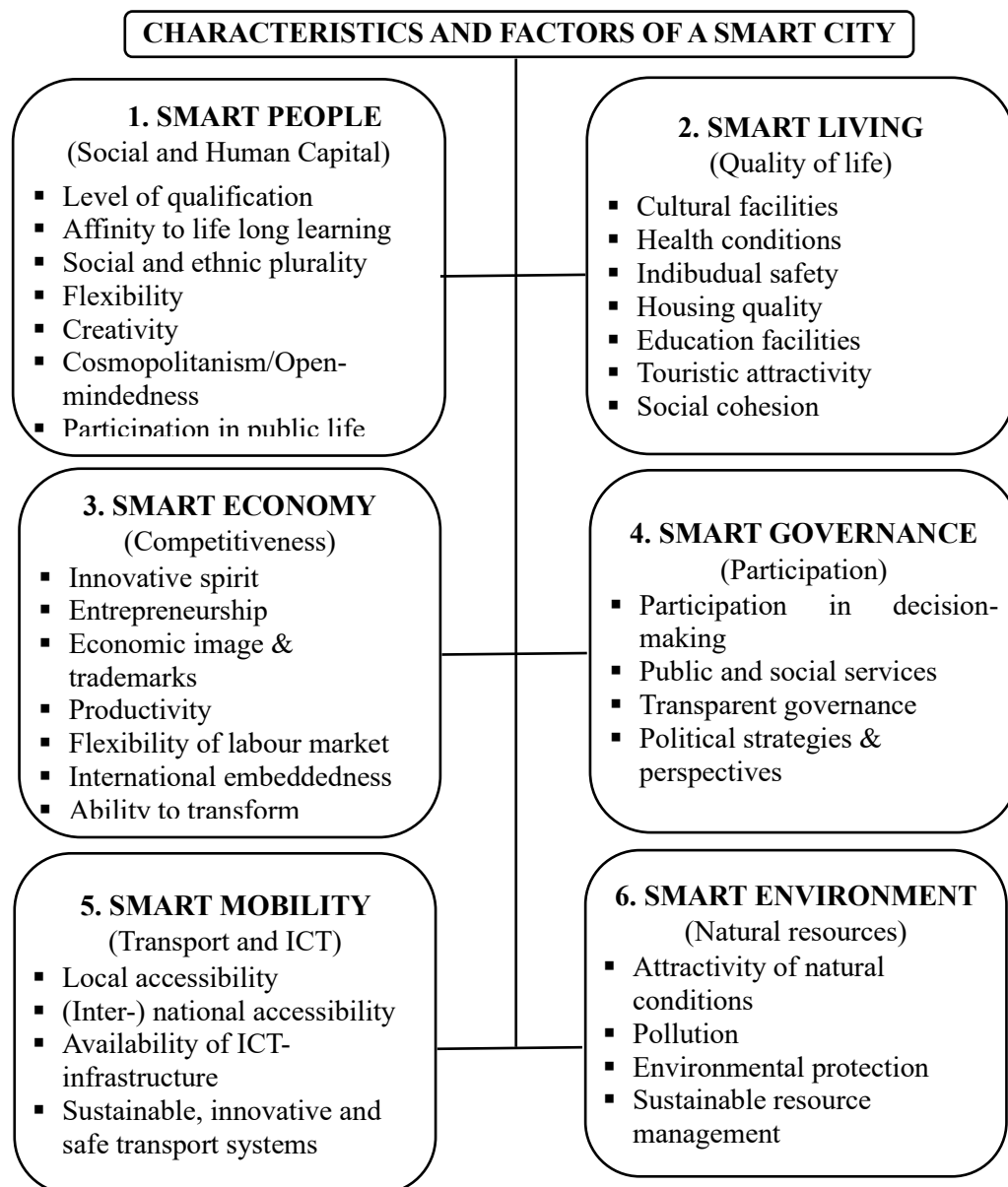


Fig. 2. Domains and factors of a senior-friendly smart city

Source: Own analysis, *Smart cities - Ranking of European medium-sized cities*, Vienna University of Technology, Wien, 2007, WHO 2025.

The domains and factors presented in Fig. 2 provided the framework for evaluating EU capital cities as smart and age-friendly cities, and each of the 33 factors across the 6 domains determined the friendliness of EU capital cities according to a point scale from 1 to 10, where a score of 1 represented a very low rating of the city and a score of 10 represented the highest rating. A set of 33 factors with the highest point scale of 10 defines a model of an

inclusive city, both in terms of intelligence and friendliness to elderly communities in the context of promoting healthy and active aging.

The analysis of conditions and city research results showed that this ranking of EU capital cities focuses on cities of various sizes. All six domains and their 33 factors collectively describing smart city conditions originate from publicly available data sources (https://www.smart-cities.eu/download/smart_cities_final_report.pdf), as well as from the authors' own research.

The inclusion of national data from the 27 EU Member States was necessary both for the expansion of the database and due to the availability of particularly valuable information at this level. Efforts were made to use the most up-to-date data possible; however, due to limitations in data availability, it was also necessary to supplement the dataset with information obtained from other sources as part of the authors' individual research. This approach allowed for an ultimate data coverage level of approximately 90% for the entire research population.

To enable comparisons of the various 33 factors across the 6 domains for the purpose of developing the ranking of EU capital cities, standardization of the results was necessary. One of the standardization methods used was the Z-transformation (Fig. 3).

$$Z_i = \frac{X_i - \mu}{\sigma}$$

where:

- Z_i – transformation (standardization),
- X_i – value of the indicator for the i-th city,
- μ – the average value of this indicator for all cities,
- σ – standard deviation of this indicator.

Fig. 3. Z transformation

Source: own work based on Smart Cities – Ranking of European Medium-Sized Cities, https://www.smart-cities.eu/download/smart_cities_final_report.pdf

Thus, the authors adopted the Z-transformation for the analysis and development of the ranking of the studied cities. This method transforms all indicator values into standardized values with a mean of 0 and a standard deviation of 1. Its advantage is the inclusion of intra-group variability while preserving metric information. Furthermore, it is characterized by high sensitivity to changes. To obtain results at the level of the six domains and their corresponding 33 factors, as well as the final result (ranking) for each capital city, aggregation of indicator values was necessary. During the aggregation of indicators at the dimension level, the degree of data coverage for each indicator was also taken into account. Aggregation at all levels was carried out without additional weighting. The aggregation was additive in nature and was subsequently divided by the number of values included. This approach also allows for the inclusion of cities for which not all indicators are available – their scores are calculated based on the available data.

Ranking Of Senior-Friendly Cities – Capitals of European Union Countries – A Case Study

Based on the research of the capital cities of the 27 European Union countries, and relying on the obtained results of 33 different factors across 6 domains on a scale of 1 to 10 as the degree of city friendliness to seniors, the authors conducted a standardization of results based on the Z-transformation. The ranking of cities is presented in Table 1.

The ranking of European Union capital cities as smart and senior-friendly, presented in Table 1, illustrates the multidimensionality of implementing the concept of age-friendly smart cities. This ranking is based on the synergy between the human factor in the context of an aging society, modern technological solutions, and elements integrating technology with society, such as local governments, social leaders, NGOs, and the private sector offering innovative technologies. Age-friendly smart cities are a complex structure in which a key role is played by the appropriate balance between "soft factors" (socio-political) and "hard solutions" (technological and infrastructural). Such cities and communities should be based on a reliable diagnosis of the needs of an aging society, conducted by central institutions and local government units. Policy towards the aging of society, taking into account the development of smart cities and communities, should be treated as an integral part of social policy covering the entire human life cycle. Implemented solutions and achieved results must serve to build a "society for all ages," in accordance with United Nations guidelines. Such an approach allows for the creation of cities and communities that not only respond to the needs of seniors but also contribute to improving the quality of life for all residents, regardless of their age and life situation in every city of the European Union countries.

The analysis of European Union capital cities indicates that the cities best prepared for the challenges of an aging society combine:

- the development of smart city technologies,
- high quality of social services,
- accessibility of public spaces,
- active social integration policies for seniors.

The best results are achieved primarily by Scandinavian and Western European cities; however, Central and Eastern European capitals are dynamically closing the gap thanks to the digitalization of public services and investments in urban infrastructure.

In the future, a key direction for the development of smart cities in the context of the challenges of an aging society will be the integration of digital technologies with social policy and urban planning to create inclusive, accessible, and friendly cities for all age groups.

Table 1. Ranking of EU Capital Cities

Ran-king	City	Country	Senior-Friendliness Rating (1–10 scale)	Z-score	Main Strengths for Seniors
1	Vienna	Austria	9.5	1.85	healthcare, transport, safety
2	Copenhagen	Denmark	9.3	1.62	urban infrastructure, social care
3	Helsinki	Finland	9.1	1.40	health system, safety
4	Stockholm	Sweden	9.0	1.29	senior policy, transport
5	Amsterdam	Netherlands	8.9	1.17	space accessibility, healthcare
6	Berlin	Germany	8.8	1.06	health infrastructure, transport
7	Luxembourg	Luxembourg	8.7	0.95	high level of public services
8	Lisbon	Portugal	8.5	0.72	climate, safety, services for seniors
9	Madrid	Spain	8.4	0.60	health system, social activity
10	Rome	Italy	8.3	0.49	healthcare, cultural offer
11	Paris	France	8.1	0.26	availability of medical services
12	Brussels	Belgium	8.0	0.15	health infrastructure
13	Dublin	Ireland	7.9	0.04	healthcare, transport
14	Tallinn	Estonia	7.8	-0.08	short distances, digital public services
15	Vilnius	Lithuania	7.7	-0.19	safety, cost of living
16	Prague	Czech Republic	7.6	-0.31	public transport
17	Warsaw	Poland	7.5	-0.42	development of healthcare, infrastructure
18	Riga	Latvia	7.4	-0.53	cost of living, service availability

19	Bratislava	Slovakia	7.3	-0.65	transport, short distances
20	Athens	Greece	7.2	-0.76	climate, social offer
21	Ljubljana	Slovenia	7.1	-0.88	compact city, safety
22	Nicosia	Cyprus	7.0	-0.99	climate, cost of living
23	Budapest	Hungary	6.9	-1.10	healthcare, culture
24	Zagreb	Croatia	6.8	-1.22	cost of living
25	Sofia	Bulgaria	6.7	-1.33	low cost of living
26	Bucharest	Romania	6.5	-1.55	developing infrastructure
27	Valletta	Malta	6.4	-1.67	small urban space, limited infrastructure

Legend:

- **Most senior-friendly** ($SZ > 1\$$): Vienna, Copenhagen, Helsinki, Stockholm, Amsterdam, Berlin, Luxembourg, Lisbon
- **Around the EU average**: Tallinn, Vilnius, Prague, and others
- **Lowest values** ($SZ < -1\$$): Budapest, Zagreb, Sofia, Bucharest, Valletta

Source: Own study based on the authors' research

The analysis of the presented concepts and case studies of age-friendly EU capital smart cities allows for the formulation of three key research directions requiring further exploration:

1. It is necessary to develop more integrated theoretical approaches to social and technological innovations related to the aging of the population in cities and communities. In particular, the interactions between technological solutions, social policy, and the participation of seniors in social and economic life should be considered.
2. An extremely important research issue is the analysis and synthesis of the degree of organization of older people, and their participation in the popularization and implementation of innovations, especially pro-social ones. This research should include identifying barriers to the development of senior initiatives and their impact on aging policy at the local, national, and EU levels.
3. It would be advisable to conduct comparative studies of different implementations of the age-friendly smart city concept. This analysis should take into account the dependencies between these implementations and welfare state models and strategies for the development of an innovative smart economy. Comparing the experiences of different countries could provide significant insights into effective political and urban planning strategies, especially in the context of seniors' lives.

Conclusions

The future of senior-friendly smart cities requires an interdisciplinary approach, integrating technological, social, and economic aspects. The effective implementation of the smart city concept should not be limited to the development of infrastructure and digital technologies but should also include the active involvement of seniors in decision-making processes and the adaptation of social policy to the challenges associated with an aging society. It is also necessary to strengthen cooperation between the public and private sectors, social organizations, and local governments, enabling the effective implementation of solutions tailored to the needs of seniors. In this context, it will be crucial to monitor the effectiveness of social policies and adapt them to changing demographic and technological conditions. In the long term, senior-friendly smart cities should form the foundation for building an inclusive society in which all age groups have equal opportunities to participate in social and economic life. The integration of modern technologies with proactive social policy can contribute to improving the quality of life for seniors and strengthening their role in the society of the future, not only in capital cities but in all cities of the European Union countries.

The cities of the future in the EU are climate-neutral, green, and smart cities, focusing on sustainable development, high quality of life, modern technologies, and social participation. Challenges include climate change, social exclusion, poverty, and the necessity of energy transformation. Perspectives include innovative management, green infrastructure, and digitalization.

In the summary of the work, based on the conducted research, the authors formulated conclusions in the form of key visions and challenges for the 27 EU capital cities. These are:

1. climate neutrality and ecology: Cities are to become green, free of smog and pollution, and resilient to climate change. This vision includes "sponge cities" that absorb rainwater.
2. smart city management (Smart Cities): Using advanced technologies to optimize resources, improve residents' lives, and manage traffic.
3. society and inclusiveness: Counteracting unemployment, segregation, and poverty. Emphasis on social justice and protection of European values.
4. economic transformation: Building a strong, innovative economy based on knowledge and modern technologies.
5. spatial planning (effective consideration of, among others, so-called urban air corridors, related to the spontaneous ventilation of the city from smog and other forms of air pollution): New forms of flexible management of urban areas where more than two-thirds of Europe's population lives.

The authors' visions and challenges formulated in the conclusions are consistent with the EU priorities for 2019-2029, which emphasize green transformation, digitalization, and social justice.

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