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FROM ANCIENT STREETS TO CONNECTED CITIES: ANALYZING THE IMPLEMENTATION OF SMART INITIATIVES IN ROMANIA

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Abstract
Technological implementation and innovation represent essential pillars of contemporary society and are fundamental to its progress and evolution. In the urban development field, the concept of "smart city" rethinks the way of planning and managing cities by integrating emergent digital technologies that bring improvements in citizens' way of life, while also increasing their efficiency, sustainability, and resilience. This paper aims to review a brief history of cities from ancient times until today, and the significant developments that determined the need for smart approach integration. For recent period, international and national trends and initiatives that impact smart city developments in Romania will be investigated. In addition, the innovative solutions promoted at the level of public administration will be highlighted by following the strategies and implementations in the phase of pilot projects, started or already used as prototypes, and private initiatives, as well as the impact of these smart approaches. For this purpose, an exploratory analysis is used at the level of multiple sources—town halls, county councils, various publications, specialized articles, magazines, companies, and non-governmental associations—following the mode in which the projects are framed on the thematics globally applied—people, economy, environment, governance, living, and mobility. Following the study, 1001 smart projects at the public level were identified in recent statistics, carried out by small, medium, and large cities in different stages of implementation. In addition, up-to-date private initiatives that led to urban transformation through the implementation of innovative solutions were pursued.
Keywords: smart resilient city, urban development, urban policies, citizen welfare.

1 INTRODUCTION

An overview of the topic. Cities represent the epicentres of the main socio-economic activities, characterized in particular as places that generate change and innovation. In an ever-evolving urban landscape, the question is not just how cities adapt to technology but also how technology can better serve the needs and aspirations of residents. The exploitation of data generated at the city level and about citizens' activities, as well as revolutionary ICT technologies, have become essential to meet the changing needs of cities and their inhabitants. Many cities at the global level have entered for some time a race to develop feasible projects as a response to the current problems of rapid and diversified urbanization, which are also being influenced by the stage of development of each state, the tier of the plans, programs, and measures adopted at the level of the organizations they belong to, as well as the strategies proposed nationally and locally.

In recent years, the smart city concept has spread across the worldwide public agenda. At the core of this concept there is an urban vision that values *emerging informatics technologies*, the use and exposure of *data from various sources*, and intelligent implementations reflected in a *connected and green infrastructure*. These approaches and advances have led to the transformation of cities, contributing to the main objective of increasing the citizen welfare. The process of integrating smart solutions involves multiple entities from the public and private sectors—governmental organizations, county or municipalities public administration, european funds management institutions, public service operators, academic environment, R&D institutes, private companies and suppliers, corporations, banks and investors, innovation clusters, hubs, accelerators and incubators, SMEs, startups, media, cultural organizations and institutes, professional associations, non-profit organizations, civil society, and simple citizens, whether they are permanent residents of the cities or just temporary visitors.

Prior research. Urban management supported by data is a current direction of smart cities (Bibri & Krogstie, 2020) that involves valuing the large amounts of data generetad both from internal sources, at the level of city institutions, as well as external sources. These are collected and analyzed so that the authorities can better understand the needs of the citizens, anticipate the challenges, and better manage the resources available at the city levels (Sarker, 2022).

Urban data sources are represented by ICT devices - interconnected by communication networks (WiFi, 4G, 5G, LoraWAN), servers and specific protocols - of the type of sensors and Internet of Things (IoT) devices, smart electric, gas and water meters, smart energy grids, surveillance and monitoring devices, position-reporting systems based on the GPS regarding public transporation (Harrison, și alții, 2010), digital platforms (web and online platforms, mobile applications), shared data on urban infrastructure and public services, statistical reports, census, administrative registers, crowdsourcing data shared on specific platforms or captured from Social Media (Reveiu & Arghir, 2020), etc.

The exposure and collection of data must be done responsibly by the municipalities, respecting the privacy standards of citizens, and the application of a data protection and security policy (Fabrègue & Bogoni, 2023). Data exposure is the process of providing access to stakeholders, usually through open data portals, facilitating information about the municipal budget, construction projects, demographic data, urban infrastructure, or other topics. The data can be used for various purposes, such as research, application development, and policy making. Data collection is the process of gathering information from various sources to create evidence and performing data analyses. These data can be collected using various tools and technologies (Sarker, 2022), such as online forms, interviews with citizens, physical and IoT sensors, using dedicated applications centrally managed, software robots for automation, scraping, access through specific APIs, interinstitutional digital files sharing, etc. Data storage is carried out in

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various ways, depending on the nature and volume of the data, involving both common hardware, such as servers, storage devices, as well as software, such as digital document and file systems, local storage systems, relational databases, big data solutions, cloud storage solutions, etc.

The data obtained are viewed and stored for the efficient administration of municipal resources and services, such as urban planning, collection of taxes and fees, infrastructure management, analysis of demographic trends, provision of public water services, sewage, public transport, public health, education, culture, tourism, waste, and street lighting (Paskaleva, et al., 2017), etc. Municipalities manage public services through specialized departments that collaborate with each other and can outsource certain services by collaborating with other organizations and institutions to fulfill tasks and offer better facilities to citizens, including by implementing innovative solutions based on ICT and data flows.

Data interpretation is important for extracting relevant meanings and conclusions, and it involves detailed analyses. The raw data is passed through processes of informational redundancies elimination to become the subject of various analysis based on different approaches as mathematical, statistical, temporal, spatial, predictive, text/video/image understanding, or based on machine learning, deep learning or other artificial intelligence (AI) algorithms. Results interpretation is carried out through dedicated platforms, dashboard solutions, various trend graphs, heatmaps, Geographic Information Systems (GIS), or other type of interactive representations to facilitate monitoring, observing trends, and making scenarios and predictions that can help in making more informed decisions (Heezen, Pesch, Correlje, Zoonen, & Kate, 2023), at all levels of urban management—operational, tactical, and strategic (Kubina, Šulyová, & Vodák, 2021).

Not only data exploration is an important direction, but also the adaptations reflected in the physical infrastructure that involve a better connection and a green vision, integrating innovative IT solutions and actuators that lead to the translation of commands from the digital world into physical actions (Bigelow & Lutkevich, 2022). In this sense, there are multiple models of good practices successfully applied to various urban issues, such as traffic and transport management (Rabby, Muhammad Mobaidul, & Imon, 2019), energy efficiency (Tudora, Tirziu, & Gheorghe-Moisii, 2021), and waste management (Sosunova & Porras, 2022), but these are not limited only to these areas.

Smart implementations lead to improving the quality of citizens life who must be in the middle of the smart city concept (Seung-Yoon, Dongwook , & Soon , 2021), involving them both directly through feedback and indirectly through everyday interactions and data exchanges. However, technology must be only a tool that serves citizens (Albino, Berardi, & Dangelico, 2015), without burdening or confusing them. IT solutions must be intuitive and accessible regardless of the social category or the level of expertise in the technological field of the users. In addition, this type of implementation leads to a better resources

management at the city level and increase their resilience through early analyses that help in the creation of plans for anticipation, preparation, and response to disruptive events (Arghir, 2021). The solutions must be seamlessly integrated to ensure interoperability with the systems employed by national, local, or regional administrations as well as third-party systems (ADR Vest, 2021) while adhering to established standards within the field.

The rationale for the paper and the used methodology. The main objective of this study is to assess the development direction of Romanian cities and specific projects that lay the foundation for the implementation of their smartness capabilities. This is achieved by studying the global context, strategies, and projects at the European Union (EU), and the local context. Public and up-to-date private initiatives that propose to bring significant transformations in urban management and add value to the residents' quality of life are followed.

This analysis aims to highlight examples of good practices and identify solutions and urban strategies adapted to the needs of evolving cities, focusing on the smart city pillars—people, economy, environment, governance, living, and mobility, dividing cities according to their size: small (<20,000 inhabitants), medium (20,000-100,000 inhabitants), large (>100,000 inhabitants). The research is based on an exploratory analysis using various sources such as documents published on the EU, city halls and county councils web pages, various publications, specialized articles and magazines, companies, and non-governmental associations.

An outline. The research is conducted in five chapters. The first section provides an introduction to the topic, and the second reviews the evolution of cities over time, highlighting significant revolutions and the increase in global urban agglomeration that led to the introduction of the smart city concept. The third chapter introduces the applied methodological approach. The next chapter presents the main results obtained by consulting data regarding Romania and international context to which it aligns. The last chapter underlines the conclusions of the paper.

2 URBAN EVOLUTION AND DEVELOPMENT TRENDS TOWARDS SMART CITIES

Human settlements have undergone a continuous process of evolution throughout the millennia. From the origins of civilization to the present, communities have developed and adapted in response to environmental factors, social organization, technological advances, and economic opportunities. Many of these changes have led in the contemporary period to the need for approaches to reduce the impact produced by industrialization, massive urbanization, excessive consumption of resources, and natural and anthropic disasters (National Geographic, 2015), gathering in the foreground the support of sustainable and resilient behaviour, and the use of technology for optimal management of resources.

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Through archaeological research, genetic studies, or analysis of artefacts from ancient times, insights into the way of life of early human civilizations could be obtained. In the beginnings of society, communities were formed by small groups of people whose main purpose was to satisfy the needs of survival and the availability of basic resources for living. These nomadic human groups lived near water sources and were constantly searching for food and shelter. The buildings in which they lived were rudimentary, represented by caves and temporary shelters made of natural materials.

Over time, humans developed new and new technological and social skills, leading to the emergence of early societies. From simple plant collectors from the spontaneous flora, they switched to agriculture. Instead of hunting animals, they domesticated and raised them. With these discoveries, they could gradually abandon temporary settlements and move to permanent settlements. The constructions thus became more and more solid by using materials such as stone or adobe. The grouping of dwellings in certain areas led to the emergence of villages and later cities. The development of infrastructure, buildings, and institutions contributes to the organization and functioning of communities.

The transition from the early to the ancient society was achieved gradually in various areas of the planet through the influence of social, economic, political, and cultural factors. The growth of demography and the complexity of economic and social activities led to the emergence of urban centers. Agriculture being increasingly developed has made possible the flourishing of trade and the exchange of goods. Complex political and social institutions emerged, and groups of individuals began to live in common places and follow the same rules. Cities had their political systems, armies, and currencies, but they shared popular and religious culture. Gradually, the transition was made from a layout without rules to cities that facilitated hygiene, circulation, and defence through their organization. Centuries later, cities were founded in Europe and around the Mediterranean Sea. Cities had edifices for both religious and recreational activities, such as baths and theatres. Urban planning, architecture, and cultural influence are elements that have influenced the further development of communities everywhere.

The transition to medieval cities occurred around the 5th century, when intensive migratory movements occurred in Europe (Encyclopædia Britannica, 2024). Conquering armies attacked cities, and in response, fortifications were elevated around them for defence. In the 10th century, trade was increasingly developed, so cities were founded in areas close to rivers or important roads to facilitate this activity. These were structured on small streets where commercial activities were conducted and connected to the city centre, where the religious edifice was located. In the eastern area, city-empires appeared.

Premodern cities appeared in the 15th century, with the discovery of new trade routes, as well as the American continent (Wikipedia, 2024). European cities developed intensively on the basis of these new discoveries. In the 17th-18th centuries, urban architecture was improved in many European cities by

building wider and paved streets to facilitate circulation, aligning buildings, demolishing defensive walls, and building regular-shaped buildings, promenades, shops, cafes, and theatres. The industrial revolution of the 18th and 19th centuries enabled major innovations (Desoutter Industrial Tools, 2024). Steam engines, mechanization, and trains have improved transportation and trade. These technological advances enabled the transition from an agricultural to an industrial society. The rural population had begun to migrate to urban areas because of the factories and ports existing in those areas. Cities expanded into outlying areas to provide housing for workers. In the middle of the 19th century, the construction of wide boulevards, impressive landscaped gardens and parks, and sewage networks began.

TABLE 1 - THE EVOLUTION OF CITIES AND THE INFLUENCE OF INDUSTRIAL AND TECHNOLOGY REVOLUTIONS

Period	Beginnings of society		Emergence of cities			Continuous development of cities				
	PRE AGRARIAN (3.3 million years BCE)	EARLY SOCIETY (~10000 BCE)	ANCIENT CITIES (~3000 BCE – 5th century)	MEDIEVAL CITIES (5th century – 15th century)	PREMODERN CITIES (15th century – 18th century)	MODERN CITIES (18th century – 19th century)		CONTEMPORARY CITIES (19th century – 21st century)		
Population	~50.000 total population.	~4 million total population.	~300 million total population.	~500 million total population.	~600 million total population. (~36 milion at the urban level)	~800 million total population. (~52 milion at the urban level)	~1.3 billion total population. (~143 milion at the urban level)	~3.6 billion total population. (~1.3 billion at the urban level)	~7 billion total population. (~3.6 billion at the urban level)	~8 billion total population. (~ 4.5 billion at the urban level)
Main revolution	-Adaptation to various environments.	-Neolithic revolution. -Use of rudimentary tools; -First Agricultural Revolution.	-Emergence of civilizations.	-Relatively efficient agriculture; -Commercial revolution.	-Economic and cultural development of cities.	-Mechanization / Industry 1.0 -first industrial revolution (1765).	-Electrification / Industry 2.0 - second industrial revolution (1870).	-Automation and globalization / Industry 3.0 - first information revolution (1969).	-Digitalization / Industry 4.0 - second information revolution (2011).	-"Smartification"/ Industry 5.0 - third information revolution (2020).
Demography	-Nomad; -Low in numbers.	-Sedentary; -They lived in sparsely populated low-density communities.	-Limited urban concentration; -Low population.	-Most of the population is concentrated in the rural area; -Relatively small cities, sparsely populated.	-Rural-urban migration; -Urban population growing.	-Demographic explosion; -Large urban agglomerations.		-Massive urban concentration; -Megalopolises.		
Organization	-Dispersed.	-Villages and rural environment.	-Simple structures; -City centre "forum"/ "agora".	-City centre as a place of meeting and commerce; -City-states emerge.	-More systematic urban planning; -Better organized and planned city centre.	-Planned urban development; -Modern infrastructure.		-Focus on sustainable urban planning; -Advanced technology.		
Architecture	-Primitive constructions; -Caves and temporary shelters (built from branches, leaves, grass, and animal skins)	-Permanent settlements; -Stone and earth structures, megalithic temples, pyramids	-Temples; -Defence walls; -Markets; -Massive constructions.	-Churches; -Castles; -Romanesque, Gothic, Islamic architecture.	-Renaissance architecture; -Imposing buildings -Central markets; -Nobility palaces; -Cathedrals, Churches.	-Tall buildings; -Modern and contemporary architecture.		-Mix of traditional and modern architecture; -Focus on sustainability.		-Focus on passive and Nearly Zero Energy (nZeb) buildings and houses.
Water systems	-Natural sources (rivers, lakes, springs, rain).	-Natural sources (rivers, lakes, springs); -Simple sewage and water storage systems (trenches, vessels).	-Rudimentary sewage and water supply systems.	-Development of water and sewage systems.	-Public fountains; -Sewerage systems that bring water to the city from distant sources.	-Running water; -Modern sewage systems.		-Sustainable use of water resources; -Recycling technologies.		
Trade	-They were hunters, gatherers.	-Direct exchange.	-Negotiations; -Commercial exchanges.	-Development of trade and guilds.	-Guilds, trades, crowded markets, fairs.	-The centre of trade and economic activities.		-Globalized trade; -Development of commercial and business areas.		
								-Emergence of electronic commerce.	-Large-scale adoption of online commerce; -The appearance of new home delivery methods.	
Infrastructure	-Natural	-Paths; -Trails.	-Rudimentary roads and driveways.	-Roads and bridges; -Fortifications.	-Better roads, bridges facilitating transport and trade.	-Developed transport networks; -Advanced communication systems.		-Modern public transport; -Digital infrastructure.		
Main skills			-Physical strength.					-Mental capacity.		-All skills.
New capabilities and technologies	-Biped walking; -Speech; -The invention of the first tools; -Discovering how to start a fire.	-Domestication of animals; -Discovery of irrigation techniques; -Invention of the axe, the wheel, writing.	-Limited to simple technologies and basic tools.	-Using tools and crafts; -Invention of the printing press.	-Maritime navigation.	-Mechanization allows mass production; -Emergence of the mechanical weaving war; -Steam locomotive.	-Electricity; -Telegraph; -Telephone; -Bulb; -Internal combustion engine; -First Ford "T" automobile; -Railways.	-Production automation; -Electronics, semiconductors; -Emergence of the computer, telecommunications, internet, interconnection; -First mobile phone.	-Digitalization; -Machine learning; -Robotics; -IoT; -Autonomous vehicles; -3D printing; -Virtual and augmented reality; -Wearable devices; -Nanotechnology; -Biotechnology; -Energy storage; -Cloud computing; -Blockchain; -Telecommuting; -Coworking spaces.	-Advanced technological innovations; -Use of artificial intelligence; -Generative AI; -Virtualization of all life aspects; -Digital twins; -Metaverse; -Digital money; -Self-driving cars; -Quantum computers.
Social aspects	-Living in small tribes led by leaders.	-Living in villages led by religious leaders, aristocracy/monarchs, military leaders.	-Strict social structures; -Power concentrated in the leaders.	-Well-defined social hierarchies; -Feudal system.	-Middle class growing; -Strengthening the power of the nobles and the bourgeoisie.	-Social diversity; -Emerging middle class.		-Multicultural society; -Focus on equality, equity and inclusion.		
Surrounding environment	-Natural.	-Landscape changes with deforestation to make way for permanent settlements and agricultural work.	-Closer relationship with the environment; -Natural architecture.	-Impact on the environment through fortifications and constructions.	-The fortifications and the emergence of suburbs outside these walls led to the degradation of habitats and the excessive consumption of resources.	-Environmental impact through urbanization and pollution.		-Emphasis on sustainable development and environmental protection, in parallel with an alarming increase in natural resource consumption.		
Central element of industrial development	-Survival in nature.	-Exploitation and control of nature.				-Power and efficiency.	-Speed and scalability.	-Memory.	-Interconnection.	-Artificial intelligence.
Culture	-Nomadic culture of tribal community.	-Sedentary culture in a stable community.			-The development of a cosmopolitan culture, attracting migrants from rural areas and other regions.	-The culture of the division of labour.	-National industrial culture; -Emphasis on industrial power.	-Globalized industrial culture; -Emphasis on economic growth and consumption.	-Informational culture; -Decentralized focus on economic growth and consumption.	-Smart culture; -Emphasis on sustainability.

Source: representation based on (Dieffenbacher, 2024), (Encyclopædia Britannica, 2024), (Wikipedia, 2024), (Desoutter Industrial Tools, 2024), (Zinkina, Ilyin, & Korotayev, 2017)

The second industrial revolution was represented by electrification, which revolutionized urban infrastructure and provided a reliable and widespread source of energy. The improvements brought by

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this discovery had an impact on public and household lighting, the development of electric transport—replacing animal traction and being an alternative to steam transport; the appearance of household appliances, and the spread of television and radio. At the end of the 19th century, the urban population in Europe tripled from 10%, in 1800, to 29%, in 1890 (Zinkina, Ilyin, & Korotayev, 2017).

Contemporary cities bring a new breath. Due to the exodus of the population to the city, housing complexes, hospitals, theatres, and city halls began to develop. The 20th century continues the expansion of urban population all over the planet, with a share of 15% at the beginning of the century, reaching 46% at the end of the century. The causes of this growth are both rural-urban migration and natural growth.

The evolution over time of human settlements and more recently of cities has been significant from a social, economic, cultural, and technological point of view. Organization, architecture, and other dimensions have undergone considerable transformations over time, and the influence of major technological breakthroughs has accelerated their evolution. In Table 1, this evolution is briefly presented through comparative analysis.

3 METHODOLOGICAL APPROACH

Based on the methods of analysis and synthesis, the improvements brought to urban areas, which led to the transformation of traditional cities to smart cities, are tracked. For this purpose, current worldwide trends are studied, as well as medium- and long-term projects, plans, and strategies adopted at the level of the EU and Romania. The main purpose of this study is to extract models of good practices that impact urban communities by researching various sources, including media, data presented by EU, government, or municipal administrations, county councils, various specialized publications and magazines, consulting companies, and nongovernmental associations. In addition, it is proposed to create an overview as faithfully as possible of the quantitative statistics regarding smart city implementations at the level of Romania. After studying various sources, valuable data were identified from the perspective of the situation regarding the cities. ArcGis, a specialized mapping and geospatial analysis software, was used to build an interactive representation that suggestively surprises the comparative situation between the cities that have smart initiatives for the reference year 2022. For the data analysis, the identified row datasets were introduced into Python, represented by the names of Romanian cities and the number of owned projects. Based on these results, the geographic coordinates of the representation were automatically obtained using the Nominatim geocoding library. With the help of a conditional logic, the cities were categorized according to the number of inhabitants as follows: small (<20,000 inhabitants), medium (20,000-100,000 inhabitants), and large (>100,000 inhabitants). The classification was performed following the INSE Tempo indicator statistic "Population by residence" (POP107D) for the same period.

4 RESEARCH RESULTS

4.1 Coordination of urban reinvention through international initiatives

Globally, recent technological breakthroughs have initiated a transformative reconfiguration of citizens' daily routines. Noteworthy strides have been made in communication modalities, technological innovations, modes of transport, and social interaction, all propelled by an escalating cognizance regarding the imperative to judiciously manage resources. This heightened awareness has generated widespread initiatives embracing renewable energy utilization, the proliferation of eco-conscious transportation alternatives, and advocacy for sustainable consumption paradigms.

Legislation at the EU level is developed through proposals of the European Commission, followed by revision and modification by the European Parliament and the EU Council, until the final form is adopted by consensus. In addition to the adopted legislation, the EU implements programs and initiatives to support sustainable urban development and the regeneration of cities in member states. Starting with the years 1990-2000, the foundations were laid for the first initiatives regarding the reduction of economic and social discrepancies between regions and subsequently coherent and sustainable urban development. The first initiatives were *URBAN I* and *URBAN II*, which specifically proposed an approach to urban development, proposing the mobilization of member states and local authorities for a more balanced development of cities, emphasizing the revitalization of disadvantaged urban areas. The application of these plans proved to be a valuable experience through the integrated approach to economic, social, and environmental issues to achieve the sustainable development of urban areas (Ministry of Environment and Sustainable Development, 2008).

Starting with the years 2000-2010, more and more awareness of the urban dimension began at the EU level, being addressed in various structures, such as the *Urban Development Working Group*, which supported informal cooperation for the exchange of experiences and best practices in the field of urban development. The *Leipzig Charter* (2007) led to a paradigm shift, realizing a more comprehensive and integrated approach to urban development with a balanced territorial organization based on a polycentric European urban structure. The *Toledo Declaration* (2010) underlines the importance of optimizing the existing urban capital, valorizing and conserving the built environment and heritage, and sustainable urban development, and the need for an urban agenda at the EU level is discussed (Bailesteanu, 2018).

In the years 2010-2020, smart initiatives in the urban field are being approached more and more. Thus, the *Smart Cities and Communities* program (2011) promoted the use of information and communication technologies to improve the efficiency and sustainability of cities. The *White Paper* on transport (2011) proposed concrete initiatives to reduce carbon emissions in transport by 60% until 2050 and a reduction

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of oil imports and fuel consumption (ADR, 2016). The territorial development *Integrated Territorial Initiative* instrument (2014) focuses on promoting integrated and sustainable development in problem regions (Advisory Committee on Territorial Cohesion, 2012). The *Riga Declaration* (2015) emphasized the importance of innovation and cooperation between cities to address common challenges and capitalize on opportunities. In the same year, the *Sustainable Development Goals* (2015) were adopted, representing a commitment to address major sustainable development issues, including those related to urbanization. Specifically, Goal 11 addresses the development of inclusive, sustainable, and resilient cities and human settlements. The *New Urban Agenda of the European Union* (2016) addresses cooperation between cities in the EU space for integrated and coordinated urban development using innovation and digitalization, having the objective of improving the financing, regulatory, and policies framework at the EU level (Bailesteanu, 2018). The *WiFi4EU* program (2017) led to an increase in accessibility and digital connectivity in cities by installing Wireless Internet access points in public spaces, including parks, squares, libraries, museums, and health centers (WiFi4EU, 2024). Subsequently, the *Green Deal* (2019) became a central element of the European policy agenda, promoting the idea of greener, environmentally friendly, low-emission, and more sustainable cities, proposing an ambitious goal of climate neutrality until 2050 and a reduction of net emissions by at least 55% until 2030 (European Union Council, 2024).

Numerous recent projects have been launched after the year 2020, that support sustainable development and provide coordinated directions regarding urban areas. The *NextGenerationEU* instrument, that foresees the sustainable, prosperous recovery and the acceleration of the transition towards a digital and green Europe, provides measures to reduce the impact produced by the pandemic; the *National Recovery and Resilience Plan* (2021), as part of this instrument, brings significant benefits in regarding the modernization of urban infrastructure and increasing the competitiveness of cities through investments in digitization, research, innovation, education, energy efficiency, renewable energy development, transport, health, efficiency of public services. Approximately 20% of the total allocated funds are directed toward digitization objectives (European Commision, 2022). Completing the milestones in the projected times allows for attracting funds or grants by EU members. A bold concept, the *15-minute City* has become a relevant topic in discussions about the urban future. This approach promotes that the services and facilities necessary for daily life need to be located nearby inside the city at a distance of 15 minutes on foot or by bicycle, thus becoming more accessible, compact, and sustainable (c40 Knowledge hub, 2020).

The directions addressed by the projects and strategies proposed at the EU level provide a unitary and coherent framework, bringing to the fore common priorities and values, such as environmental protection, combating climate change, reducing poverty and promoting social inclusion, and resilience to natural or

man-made disasters. Even if at the European level all cities face similar challenges in terms of strategy, processes, technology, or data (Yesner & Ozdemir, 2017), each local community has specific needs, resources, and contexts (Kubina, Šulyová, & Vodák, 2021). By adopting a contextualized approach, communities can adapt and apply global directives and strategies according to their local specifics. This requires careful analysis of the available resources, cultural traditions, social customs, and priority needs of the community.

These strategies, programs, and projects represent initiatives with both a medium- and long-term horizon, with the main goal of economic, social, and sustainable development, reducing the gaps between the countries in the EU space and between the cities within countries. They are designed to provide major benefits, helping to build resilience and stimulate growth at all levels of development through access to finance, technical assistance, and training.

4.2 National and local initiatives leading towards Romanian smart cities development

Through its membership in multiple international organizations and being a member of the United Nations since 1955, World Bank since 1991, European Union since 2007, Romania has adopted a strategic and coordinated approach in policy formulation. This generated a coherent and directed conduct toward the objectives set at a centralized level. Since joining the EU, the country has managed to absorb important sources of European financing in the net amount of 61.6 billion euros in non-reimbursable funds (Zamfir, 2024). These amounts contributed significantly to socioeconomic development and the improvement of the quality of life of the country's inhabitants. Over time, these financial resources have also been directed toward the development and modernization of cities, generating tangible benefits for communities in various fields, such as technologies and urban infrastructure, environmental protection, social and cultural services, etc.

Romania is going through a period of significant economic growth fueled by a series of macroeconomic factors and its territorial potential. However, despite the progress made, the country faces some economic vulnerabilities that are reflected both externally, compared to other states in the European Union, and internally, between regions within the country. In 2023, Romania recorded a relatively equal distribution between urban and rural residential environments, with 55.8% in favor of the urban, according to data published by the National Institute of Statistics (Dan, 2024). Although the urban area shows a gap compared to the European average, considering also the peri-urban area, the percentage amounts to approximately 76% (Guvernul Romaniei, 2021). The reference year 2050 predicts that the urbanization rate will reach 70%, exclusively in urban areas. The migration of the population outside the country borders is high, a sharp demographic decline being recorded. Romania consists of eight development

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regions, which do not currently have an administrative status, and 41 counties, 103 municipalities, and 217 cities. In the rural area, there are 2,861 communes and 12,957 villages. The Municipality of Bucharest, the capital of the country, occupies an area of approximately 240 km², with a stable domicile population of 2,161,000 inhabitants in the reference year 2023 and a density of approximately 9,004 inhabitants per km². It is divided into six districts coordinated by six district mayors and a general one.

Romania faces significant challenges in the development and management of cities, which are generated by continuous urbanization, pollution, traffic congestion, climate change, outdated infrastructure, waste management, and vulnerability to natural or human-made disasters. The wide range of plans adopted leads to a direction of urban and intelligent development that can reduce the impact of these factors, involving digital technology and leading to a green transition. At the national level, a series of plans and strategies are adopted to transform cities at various levels. The *Sustainable Development Strategy* (horizon 2013-2020-2030) aims at creating a cleaner environment, efficient use of resources by reducing food waste and waste, promoting recycling and reuse, by introducing elements of the circular economy and developing social cohesion to create a more prosperous standard of living (Romanian Government, 2018). Horizon 2030 aims to bring Romania significantly closer to the average level of EU countries with regard to sustainable development indicators (Ministry of Environment and Sustainable Development, 2008). To make it easier for people to get around, the *Sustainable Urban Mobility Plan* focuses on more efficient road transport, infrastructure improvement, low-emission zones, and encouraging alternatives for travel such as electric cars, public transport, walking, or cycling. Mobility plans are developed at the city level, or coordinated strategies at the level of counties or development regions, in accordance with the EU vision to increase the attractiveness and quality of the environment and the urban landscape (ADR, 2016). Following the green trend, the *Sustainable Energy and Climate Action Plan* (horizon 2016-2020-2030) aims to reduce greenhouse gas emissions and focuses on the use of green energy. The municipalities voluntarily adopted specific measures, respecting the framework proposed at the European level by the Convention of Mayors, which Romanian cities have joined. The *General Urban Plan* ensures that cities are well designed, require efficient use of land, create multifunctional green spaces, and promote functional mix so that areas have a balance between housing, commercial spaces, and offices. The long-term vision is outlined by the *National Integrated Urban Development Strategy for Resilient, Green, Inclusive, and Competitive Cities* (horizon 2022-2035), which wants cities to face climate, social, and economic challenges by developing a green infrastructure, ecological transport, and energy-efficient buildings that are accessible to all residents and have an attractive business environment. It represents the first strategic document dedicated to urban development in Romania. *Integrated Urban Development Strategies* transform ambitious objectives into reality by identifying specific investment projects that will bring to life the smart city concept throughout Romania.

From the perspective of digital performance, Romania occupies the last position in the EU in 2022, according to the Digital Economy and Society Index (DESI) (European Commision, 2022), located in the four addressed themes—human capital, connectivity, integration of digital technology, and the digitization of public services—below the European average. In the component of the index, there are multiple sub-indicators in which the country is better positioned and others in which sustained work is still needed to register developments. Compared to the European level, Romania presents a small number of smart city projects, which are quite fragmented. The lack of an integrated vision has a significant impact on the rapid and coordinated transformation of cities. In particular, smart city solutions must present characteristics that bring clear improvements compared to traditional solutions, be transparent, integrable, scalable, being able to be easily replicated with the aim of large-scale implementation (West Regional Program, 2021).

In Romania's efforts to achieve the desired digitization of cities, the fast and efficient Internet connection represents a valuable asset, occupying the 10th place in the world ranking for fixed Internet (Neagu, 2023). This facilitates access to information and online services by both institutions and citizens. Romania also benefits from a well-educated human capital, occupying the 4th place in terms of graduates, and having the largest number of IT professionals per thousand inhabitants in Europe, being placed in sixth place in the world (Radio Romania News, 2024), but without sufficiently covering the need in the field. In addition, the adoption of technical solutions in accordance with EU standards represents an effective strategy for harmonizing regulations and reducing development gaps. One such example is the digital identity platform RoEid (Authority for Digitization of Romania, 2024), which implements the Electronic Identification, Authentication and Trust Services (eIDAS) regulation, which is an essential project for guaranteeing the security and integrity of citizens' personal data in the digital environment in relation to authorities. This platform not only simplifies administrative processes but also promotes a trusted environment for online interactions between citizens and public institutions, both nationally and locally. Among the town halls of the Romanian cities that have created the interconnection with the centralized platform are Timisoara, Craiova, Resita, Bucharest - District 6, Alba Iulia, but also the Iasi County Council - which owns several administrative units in the county, including cities. The number of registered municipalities is currently reduced, as well as that of citizens. The platform also facilitates the interconnection to other national services in the context of electronic governance (Authority for Digitization of Romania, 2024) —the „Domestic worker" platform (the national platform through which payments are made to small tradesmen), the „Virtual desk" (the national platform for duties and local taxes), and the electronic „Unique Contact Point" (the platform that connects the administration public by electronic means, in order to reduce the time for obtaining approvals, authorizations, qualifications, certificates etc).

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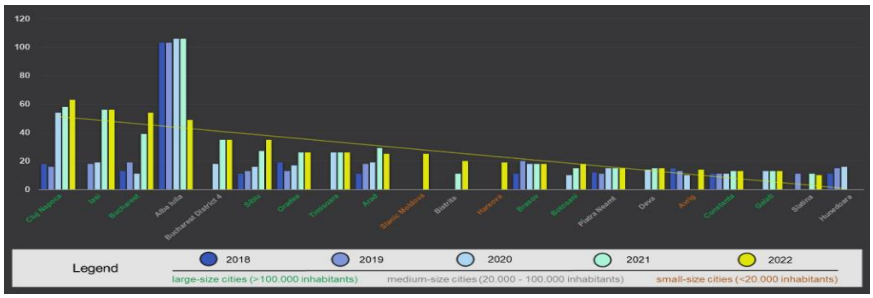
At the decentralized level, the smart city paradigm started with the proposal and development of some local initiatives that advanced from the design stages to the implementation in the cities where they were developed. In 2010, pioneering projects appeared at the national level (Ibanescu, Pascariu, Banica, & Bejenaru, 2022) as "Timisoara Smart City" and "Targu Mures Digital European City", followed in 2013 by their debut in other cities, such as "Sibiu Smart City" and "Cluj-Napoca Smart City". The country's capital piloted the first project in 2015, followed by Alba Iulia and Oradea in 2016. In 2018, Alba Iulia was declared the first truly smart city, with the most smart projects proposed aiming to supervise traffic, implement intelligent lighting, monitor and improve air quality and water consumption, reduce losses in distribution networks, create an integrated tourism platform, and facilitate parking through intelligent technologies (Alba 24, 2018).

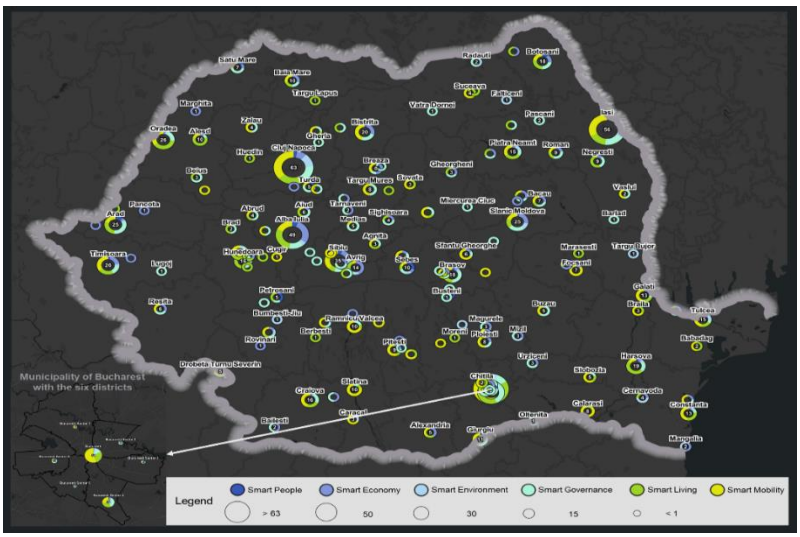
In the most recent available statistics, conducted by a consulting company (Vegacomp Consulting, 2022), at the level of the reference year 2022, 1001 smart city initiatives were carried out in 144 cities, including Bucharest and the 6 districts of Bucharest – 27 in large-size, 54 in medium-size, and 63 in small-size cities in the country, from the total of 320 cities in the country. Of the total number of initiatives, 209 were in the planning phase, 34 were in the pilot stage, 288 were ongoing, and 470 projects were finalized. This statistic keeps in the calculation only the existing or completed initiatives, eliminating those from previous years that were abandoned. A decrease in the number of initiatives is also observed at the level of Alba-Iulia city, which, however, maintains a leading position in terms of the number of initiatives. Figure 1 shows the evolution of the number of smart initiatives for the main cities in Romania. Yellow highlights the situation at the level of the reference year 2022, the most recent year for which data are available.



Source: author's own representation based on (Vegacomp Consulting, 2022)
FIGURE 1 - EVOLUTION OF THE ROMANIAN SMART CITY PUBLIC INITIATIVES IN THE PERIOD 2018-2022.

Romania outlines its smart city strategy by adopting, at the level of its policies, a six-level Smart City division framework: Smart People (*Social and Human Capital*), Smart Economy (*Competitiveness*), Smart Environment (*Natural resources*), Smart Governance (*Participation*), Smart Living (*Quality of life*) and Smart Mobility (*Transport and ICT*) , in line with global and European Union approaches. At a statistical level, during the cumulative situation from the period 2018-2022, most projects were in the Municipality

of Bucharest (Vegacomp Consulting, 2022). In total, the districts of Bucharest together with the general town hall totaled 115 projects. Most of these initiatives focus on mobility issues, aiming to modernize transport and traffic management. In this theme, in 2022, at the country level, there were 322 ongoing projects in various stages of implementation. The next positions were governance, with 238 projects; quality of life, with 217 projects; and economy, with 130 projects. The last two places were occupied by environmental initiatives, with 59 projects, and those that have citizens in the foreground, with 35 projects. Figure 2 shows the geographical distribution of smart initiatives in Romanian cities; the type of initiatives is represented in the form of a pie chart, and the size of the pie highlights the number of projects. On the left side, the situation of the projects in the Municipality of Bucharest and the six districts is highlighted.



Source: author's own representation based on (Vegacomp Consulting, 2022)
FIGURE 2 - STATISTICS REGARDING ROMANIAN SMART CITY INITIATIVES (REGARDLESS OF THE STAGE OF DEVELOPMENT - PROJECT PHASE, IN PROGRESS OR COMPLETED, IN THE PERIOD 2018-2022).

Analyzing in depth the statistical situation of the projects, by applying the Pearson correlation coefficient on the data on the number of smart projects in relation to the number of cities' population, a score of approximately 0.584 was obtained, which indicates a moderate-positive correlation at the level of 2022. Cities with a larger population tend to implement a larger number of smart city projects, having a more complex infrastructure network, for which the identification of solutions becomes a priority. The large-size cities that propose to realize a transformation at the smart level, with the most projects, are Cluj Napoca, with 63 projects; Iasi, 56 projects; Bucharest at the level of the General Municipality, 54 projects; Bucharest at the level of District 4, 35 projects; and Sibiu, 35 projects. As for medium-sized cities, although it may be difficult for them to compete with large cities in terms of financial resources and infrastructure, the stimulation of innovation and urban modernization must remain a desire for the creation of more sustainable and smarter communities. Statistics show that the average cities with the most initiatives are

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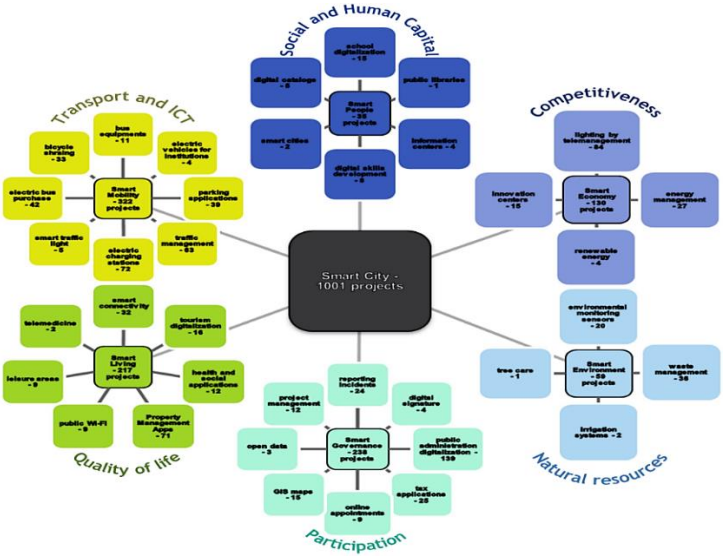
Alba Iulia, with 49 projects; Bistrita, 20 projects; Hunedoara, 16 projects; Deva, 15 projects; Piatra Neamt, 15 projects; and Tulcea, 15 projects. Cities with a smaller population benefit from projects that are more adapted to the specific needs of the communities; however, due to more limited resources, they end up proposing fewer projects. Exceptions are the small towns that have significant achievements in the adoption of projects, such as: Slanic Moldova, 25 projects; Harsova, 19 projects; Avrig, 14 projects; Alesd, 10 projects; and Negresti, 9 projects. Although there is a positive correlation between the two variables—the size of the city and the number of projects—it is important to mention that this correlation does not necessarily imply a direct causal relationship, as other factors not included in the analysis are also involved (financial resources, government policies, community needs, the emergence of public-private partnerships and international collaborations, etc.). Figure 3 presents the total number of smart city projects approached at the national level, distributed on the six levels, being specified at the level of each one the number of relevant new projects from 2022 year of reference, as presented by (Vegacomp Consulting, 2022) in the recently published report.



Source: representation based on (Vegacomp Consulting, 2022) and (Centre of Regional Science, 2007)
FIGURE 3 - CLASSIFICATION OF ROMANIAN INITIATIVES ON THE SIX SMART CITY DEVELOPMENT LEVELS.

4.3 Innovative smart solutions for Romanian urban transformation

Initiatives for the development of smart cities have begun to take shape at the governmental, county councils and municipalities' levels, proposing the use of green and digital technologies to improve the efficiency of public services, the creation of a smarter, more sustainable, and more environmentally friendly urban area. In the same direction, collaborations between private institutions, NGOs, startups, and local or governmental organizations complete projects initiated by municipalities that innovatively address community issues. Concerns have led to the implementation of intelligent solutions in areas such

as alternative transport, waste management, and the creation of informal workspaces, etc, to bring about significant changes at the community level. Some of the latest and relevant smart implementations are:

- *"Sustainability Box" infrastructure pop-up* – an association between an NGO and two private banking companies have taken a first step to create a multifunctional point that integrates several services to promote sustainability, being addressed to citizens of Bucharest District 3. It integrates facilities for:
  - promotion of alternative mobility by creating stands for the secure storage of personal bicycles. This is used by connecting to the "iVelo" application, which allows access to the parking lot, and selecting the available stand for docking the bike, securing it additionally with a personal anti-theft system;
  - sustainable transport by providing charging stations for cars and electric scooters. This can be used in two ways: either by using an RFID card or by an application well-known by electric car drivers "E-Charge";
  - waste management and encourage selective collection by providing collection stations for plastic/glass/aluminum containers as part of the national guarantee-return program and issuing a receipt for the value of the returnable bottles. These must have intact labels and a volume between 0.1 and 3 liters;
  - energy efficiency by equipping with photovoltaic panels. This ensures the functionality of the multifunctional point, alternatively to the electricity network source;
  - optimizing the logistics of parcel deliveries by equipping with storage boxes. This system realizes the connection between merchants, FanCurier delivery man, and customers. The system works both for sending and receiving packs. Picking up the package is done by presenting the QR code/validation code and paying by card to merchants.

Source: author's own representation based on https://palindrom.eu/pop-up-de-infrastructura-adica-si-sustenabil-si-la-indemana/

FIGURE 4 - FIRST MULTI-INFRASTRUCTURE POP-UP POINT ADOPTED IN BUCHAREST DISTRICT 3, ROMANIA.

The proposed solution is complex from the perspective of the various facilities included, being aligned to the needs of the current society, but it also has some limitations. First, it is only available in a certain area,

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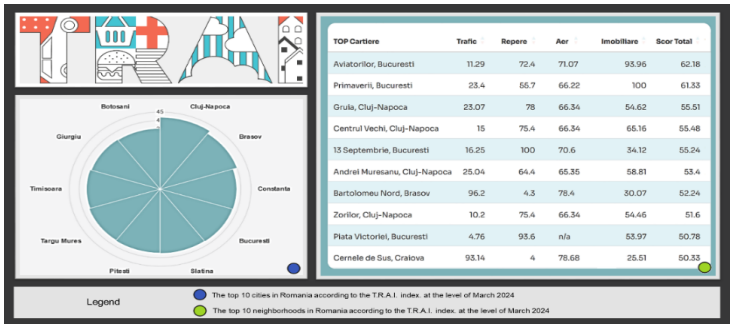
currently being only one installed. At the moment, the facility to issue receipts for settling the value of containers is not implemented, probably because it is not affiliated with a trader; the national return system is thought to issue a ticket that can be used at the trader where the return is made. Each of the services works with a different application, which makes it difficult for citizens to use; in addition, the bicycle storage application requires the registration of an identity card and a bank card when configuring.

- *"Nooka Space" unconventional workspaces* – a romanian-irish start-up offers for rent intelligent proximity offices adapted for work (Nooka Space, 2022). These are designed either as exterior or interior spaces, soundproofed, and specially designed for work needs. They ensure:
  - a professional atmosphere, with height-adjustable ergonomic furniture, having specific features for office work, collaborative work or business meetings;
  - access to the premises for a fee through the dedicated mobile application "Nooka Space", which allows remotely unlocking of the smart lock;
  - intelligent equipments - it has 15 sensors to ensure comfort, integrated sockets, intelligent lighting, air conditioning and air recirculation control system; al the features are controllable through the mobile application;
  - high-speed WiFi internet connection.

Source: author's own representation based on https://www.retail.ro/articole/stiri-si-noutati/parklake-aduce-in-centrul-comercial-birouri-smart-nooka-space-pentru-munca-remote-4700.html
FIGURE 5 - "NOOKA SPACE" – UNCONVENTIONAL WORKSPACES LOCATED IN AREAS IN ROMANIA.

The solution is innovative, but it also has small limitations because the spaces are numerically reduced, located only in certain commercial areas from Bucharest and Cluj-Napoca, and are dependent on the utilities and working hours of the commercial centers. They can generate quite high costs for daily use. They are not sufficiently predictable; if the working period is extended and overlaps with another schedule, an extension cannot be obtained. A balanced climate should be maintained that does not lead to user isolation.

- *The "T.R.A.I. Index." and the "Voice of the Neighborhoods" to identify good areas for buying houses* – a real estate announcement platform that facilitates the meeting between various actors in the real estate market, agents, developers, owners and clients or tenants, has created a solution based on data about Traffic (T), Point of Interest (R), Air (A) and real estate (I) (Storia, 2024); this also utilizes the results of applied questionnaires on samples of inhabitants of the neighborhoods in the cities at which the study is applied. The index contains:
  - a traffic score, which includes data regarding cars speed in the neighborhood area and reporting to the maximum speed allowed in that area. A score close to 100 represents a low level of traffic. The data are obtained based on Google Traffic;
  - a score regarding landmarks in neighborhoods, such as shops, restaurants, schools, parks, health facilities, public transport. A score as close as possible to 100 shows that the respective area has more points of interest per square meter. The data are obtained based on Google Places;
  - a score regarding air quality, by integrating indicators of pollution, temperature, atmospheric pressure, humidity and wind speed. A score as close to 100 indicates clean air in the respective area. The data are obtained based on Airly sensors;
  - a score regarding the average cost per square meter of housing in the area of interest, compared to the national average. A score as close as possible to 100 indicates that those areas have homes with higher prices. The data are obtained on the basis of the Storia platform.



Source: author's own representation based on https://trai.storia.ro

FIGURE 6 - "T.R.A.I. INDEX" TO IDENTIFY GOOD AREAS FOR LIVING.

The solution is a private initiative that offers an interesting overview of some relevant indicators at the neighborhood level. The index is presented only at an aggregate level, especially with regard to the Points of Interest. It is not clear which is the proximity to specific points of interest, including the public transportation stations; also, no distinction can be made if there are schools or hospitals in the proximity, and not just shopping centers for example. The index does not cover the many problems faced by cities, but Storia presents another solution called "Voice of the Neighborhoods"; this covers other issues, but as

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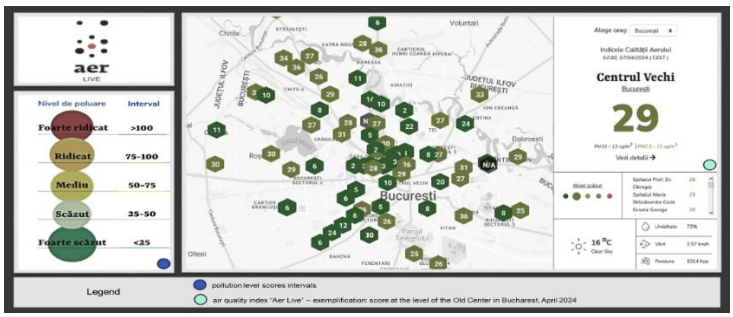
it is a subjective source, created on the basis of surveys applied to the inhabitants, the results can be affected by bias.

- *"Live Air" platform for air quality measurement* – a platform that brings together air quality data from Bucharest and Cluj-Napoca, and the surrounding areas, from over 120 sensors located at various points of interest (Aer Live, 2023) - schools, hospitals, kindergartens, major intersections, squares, shopping centers. The initiative started as a project of a private entity, to which Bucharest City Hall and multiple partnerships were added along the way. The platform presents:
  - the air quality index (AQI), presents an aggregate score determined based on the concentrations of carbon monoxide (CO), nitrogen dioxide (NO2), suspended particles - dust with a diameter of less than 10 microns, respectively 2.5 microns (PM10, PM2.5), sulfur dioxide (SO2), calculated according to the French Common Air Quality Index (CAQI) methodology. Measurements are made at fixed intervals of 15 minutes, with the help of which hourly averages are established. To calculate the AQI, it is done by converting from the unit of measure transmitted by sensors - parts per million (ppm) to micrograms per cubic meter (µg/m3);
  - to measure the concentrations of suspended particles, atmospheric pressure, temperature, and humidity, "Purple Air" sensors (Aer Live, 2023) are used. Connected via WiFi, they transmit the data centrally to the dedicated PurpleAir platform and Live Air;
  - the measurement is also carried out with the help of other sensors, namely "Nubo Claritech" (Aer Live, 2023), which offers real-time monitoring of air pollution in addition to the measurement of particles smaller than 1 micron, as well as barometric pressure, and dew point. They are also equipped with self-diagnosis means that announce when the measuring cartridge must be replaced.



Source: author's own representation based on https://aerlive.ro/
FIGURE 7 - AIR QUALITY MEASUREMENT PLATFORM "LIVE AIR".

This solution fits the global concerns of measuring air quality in cities. These measurements are susceptible to certain limitations and vulnerabilities: the statistics may be influenced by sensors that may be sensitive to various factors or weather conditions, leading to inaccurate results. A lack of sensors or a

reduced number in certain areas can lead to the underestimation or overestimation of pollution problems. The lack of more intense promotion of the platform and the non-display of sensor measurements in public places does not develop awareness of the responsibility that every citizen has to maintain as much cleaner air as possible.

The identified smart innovative solutions represent small steps that lead to the improvement of the quality of life in cities. At the moment, each of these is addressed to a limited number of cities and even dedicated only to certain areas or neighborhoods, promoting sustainability, awareness toward a cleaner and healthier environment, and innovation through the development of unconventional workspaces. The creation of indicators as focused as possible for the objective assessment of the community's needs and the orientation of resources toward vulnerable areas must also become an aim at the level of city management to reduce socioeconomic discrepancies. For this purpose, the use of non-conventional data sources, together with official statistics, can lead to the creation of images of different moments, and even the real-time capture of certain situations.

5 Conclusions

Technological innovations and contemporary demographic changes have generated a significant transition from traditional settlements to smarter and more sustainable cities, which is an ongoing process. This evolution is facilitated by the use of emerging ICT, the exploitation of data, and the development of a connected and ecological infrastructure, leading to the "smartification" of cities and increasing citizen welfare. At the same time, urban culture is being redefined, emphasizing sustainability and adapting to the contemporary needs of urban communities.

Analyzing international trends and initiatives, a convergence toward a unitary approach in the development of smart cities is observed. In this context, EU strategies, programs, and projects provide a legal framework and coherent policies for the implementation of these objectives at the level of member states, including Romania. However, Romania must develop its own directions for urban development, considering the particularities and needs of local communities. Achieving the proposed objectives in smart and sustainable urban development is essential to benefit from the financial and technical support of the EU in this direction.

According to the most recent statistics available, in Romania, 1001 smart city projects are underway at the public level by local administration authorities in various stages of implementation. These initiatives reflect the commitment of the authorities to modernize and improve urban infrastructure and services to meet the increasingly complex needs of local communities, covering a wide range of fields on all six levels of smart city development. The number of projects is correlated with the population of the cities, reflecting

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the needs and available resources. Thus, larger cities can run a larger number of projects to cope with a larger population and a more complex urban infrastructure. However, there are some challenges regarding citizens and local authorities joining such initiatives. A notable aspect is the division and fragmentation of efforts, as well as the low degree of participation in some key initiatives. For example, regarding the registration of citizens in the RoEid portal, which should be an important pillar of the digital infrastructure for smart city projects, there is a low number of registered citizens. This low number can be attributed to a lack of awareness or reduced accessibility to the platform, a lack of confidence in the protection of personal data, but also due to the small number of registered and active municipalities in this initiative.

Although there is significant enthusiasm both at the level of public authorities and in private initiatives for the implementation of the smart city concept in Romania, there is a need for additional efforts to improve cohesion and participation on the part of citizens, local authorities, and other stakeholders to ensure the success and sustainability of these initiatives.

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