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Smart city development, sustainability, and territorial communities: The case of Lutsk

Rozwój inteligentnego miasta, zrównoważony rozwój i wspólnoty terytorialne: przypadek Łucka

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Abstract:
Research objectives and hypothesis/research questions
The aim of the article is to demonstrate the importance of the smart city concept in the process of sustainable development of territorial communities, using the case of Lutsk. The study also seeks to identify the main components of smart city development and to assess the possibilities of their application in

urban development, with particular emphasis on the challenges and prospects characteristic of contemporary Ukrainian cities.
Research methods
The article applies a review of the relevant literature, an analysis of documents, reports, and secondary data related to the development of Lutsk, as well as a survey conducted in the city. The adopted research approach made it possible to combine a theoretical perspective with empirical analysis, which allowed for a multidimensional view of the studied problem.
Main results
The conducted analysis made it possible to determine the degree of implementation of smart city principles in Lutsk and to indicate the most important achievements and limitations related to this process. The results show that smart city development can constitute an important tool supporting the sustainable development of territorial communities.
Implications for theory and practice
The conclusions also have practical significance, as they may provide a basis for formulating recommendations for urban policies and for activities undertaken in the process of reconstruction and modernization of Ukrainian cities.

Keywords:
smart city, sustainable development, territorial communities, Lutsk, urban development

Abstrakt:
Cel badań i hipotezy/pytania badawcze
Celem artykułu jest ukazanie znaczenia koncepcji *smart city* w procesie zrównoważonego rozwoju wspólnot terytorialnych na przykładzie Łucka. Opracowanie ma również na celu identyfikację głównych komponentów rozwoju *smart city* oraz ocenę możliwości ich wykorzystania w rozwoju miasta, ze szczególnym uwzględnieniem wyzwań i perspektyw właściwych dla współczesnych miast ukraińskich.
Metody badawcze
W artykule zastosowano analizę literatury przedmiotu, dokumentów, raportów i danych zastanych odnoszących się do rozwoju Łucka, a także badanie ankietowe przeprowadzone w tym mieście. Przyjęte podejście badawcze umożliwiło połączenie perspektywy teoretycznej z analizą empiryczną, co pozwoliło na wieloaspektowe ujęcie badanego problemu.
Główne wyniki
Przeprowadzona analiza pozwoliła określić stopień wdrażania założeń *smart city* w Łucku, a także wskazać najważniejsze osiągnięcia i ograniczenia związane z tym procesem. Wyniki badania pokazują, że rozwój inteligentnego miasta może stanowić istotne narzędzie wspierające zrównoważony rozwój wspólnot terytorialnych.
Implikacje dla teorii i praktyki
Uzyskane wnioski mają również znaczenie praktyczne, ponieważ mogą stanowić podstawę do formułowania rekomendacji dla polityk miejskich oraz działań podejmowanych w procesie odbudowy i modernizacji miast ukraińskich.

Słowa kluczowe:
inteligentne miasto, zrównoważony rozwój, wspólnoty terytorialne, Łuck, rozwój miejski

Introduction

Cities represent a leading form of territorial organization in modern society. They will continue to serve as engines of economic prosperity, political development, and social progress, holding undeniable significance for shaping the competitiveness of any country. Each year, cities need to enhance services quality, stimulate the competitiveness of local economies, improve the system of administrative services,

boost productivity, and address environmental issues. Safe public transportation, reliable provision of basic municipal services, adequate livelihood support, and open public spaces become crucial. Today, issues related to the "urbanized world" are actively discussed at the international level. In 2015, the development of cities was included in the "Agenda for Sustainable Development by 2030". Specifically, Sustainable Development Goal (SDG) 11 emphasizes the need for proper development of cities. In May 2016, the United Nations adopted the new Urban Development Program (Habitat III), which sets guidelines for the development of cities until 2036. Additionally, in 2016, the European Cities Program was approved.

The summarizing strategy paper by the United Nations under Habitat III emphasizes the Smart City strategic focus on expanding the life quality (United Nations, 2015). It highlights the ambiguity of current definitions of a Smart City and establishes an understanding. Accordingly, a Smart City is characterized by "(1) Society: The city for its people; (2) Economy: The city must be a good place for business, etc.; (3) Environment: The city must be sustainable; (4) Governance: The city robust in its ability for administrating policies." The World Bank also clarifies that people's life quality, and life opportunities are at the core of the Smart City approach, defining it as integration of urban infrastructure and services delivery in a way to provide a citizen-centric approach (World Bank, 2023). Similarly, the European Commission formulates the smart city as a place where networks and services are made more efficient for the benefit of its inhabitants (European Commission, 2020).

Leipzig Charter on Sustainable European Cities in 2007 defined the principles of integrated urban governance as well as a balanced territorial organization within urban development, particularly implying a shift towards local structures. Participatory budgeting or local social capital programs are expressions of this governance policy. In 2020, this direction was deepened with the New Leipzig Charter. "We reaffirm support for transformation through integrated urban development, with a place-based, multi-level, participatory approach" (European Commission, 2020). In conjunction with the Smart City approach, digitalization is acknowledged as "a major transformative trend affecting all dimensions of sustainable urban development" (European Commission, 2020).

Looking at the Smart City concept in such a broad context, it is also important to examine it from the local perspective of specific cities located in different parts of Europe that seek to implement this approach in practice. In this context, Lutsk constitutes an important case for analysis as a city facing contemporary development challenges while simultaneously searching for effective paths toward sustainable urban transformation. The case of Lutsk helps to better understand the possibilities and limitations of smart city development in the context of territorial communities, particularly in relation to the conditions faced by contemporary Ukrainian cities.

1. Literature review

The idea of a smart city

The concept of a "smart city" derives from a combination of urban planning, information technology, public management, and sustainable development policy. Its dynamic development in recent years reflects the growing need for urban model transformation, which is related to increasing demographic, environmental, and technological-digital pressures (Batty, Axhausen, Giannotti et al., 2012). There are many definitions of this concept in the literature, but there is no generally accepted definition (Angelidou, 2015; Wolfram, 2012). It is pointed out that the conceptual scope of this term refers to cities that use information and communication technologies (ICT) and social innovations to improve the quality of life of their residents, promote the efficiency of public services, and contribute to sustainable development (Albino, Berardi, Dangelico, 2015; Angelidou, 2015). It can therefore be said that smart cities are an interdisciplinary field and should be analyzed as such.

When considering the concept of a smart city, it is also important to refer to social and cultural issues that go beyond purely technological aspects. This enables synergy between the perspective of social capital and urban engineering (Hollands, 2008). It is pointed out that the strategic principles of a smart city focus on three dimensions: technology, people, and institutions. They are therefore a combination of: (1) technology-supported infrastructure and services, (2) social learning to strengthen human infrastructure, and (3) management to improve the institutional dimension and citizen involvement in decision-making processes at the city level (Nam, Pardo, 2011). This approach allows for the development of a more sustainable and participatory concept of smart cities, in which residents play a key role as co-creators of development processes, rather than merely passive recipients (Kitchin, 2014). Contemporary research suggests that the real "intelligence" of a city manifests itself in its ability to strengthen human and social capital and support inclusive forms of urban co-governance (Caragliu, Del Bo, Nijkamp, 2011; Calzada, Cobo, 2015). The synergy between the engineering-infrastructure approach and the social approach enables the design of cities that are not only efficient but also socially equitable and culturally diverse.

In line with this, the most important dimensions of a smart city can be listed here: smart economy, smart people, smart governance, smart mobility, smart environment, and smart living (Giffinger, Fertner, Kramar et al., 2007). It should be noted that each of these dimensions is an indispensable component of a smart city.

The first dimension, smart economy, is the ability of the local economy to innovate, be entrepreneurial, adapt easily to change, and be flexible. It also includes the development of economic sectors based on knowledge and modern technologies,

such as start-ups and e-commerce services (Giffinger, Fertner, Kramar et al., 2007). The smart economy also calls for the creation of space for investment and local competitiveness (Komninos, 2014).

The smart people category includes not only a high level of education among residents, but also their open social attitudes, creativity, ease of adaptation to change, and high digital skills (Lombardi, Giordano, Farouh et al., 2012). A smart city is about people and their intellectual capital, their activity in the public sphere, and their involvement in local community affairs. It is also about creating space for cooperation and access to education and culture (Caragliu, Del Bo, Nijkamp et al., 2011). In this sense, the residents of smart cities are not only recipients of services, but also- and in fact, above All- their creators and moderators.

In turn, smart governance is associated with citizen participation in the context of decision-making processes and control of municipal authorities (Meijer, Bolívar, 2016). In practice, this means development in the area of participatory budgeting, citizen access to open public data, and the creation of tools for e-participation. Effective implementation of smart governance also assumes the city's ability to learn, adapt, and respond flexibly to the needs of its citizens, making governance more responsive and oriented toward co-creating public value (Gil-García, Pardo, Nam, 2015). In this respect, smart governance may also be strengthened by appreciative and participatory management practices, as Appreciative Inquiry supports trust, cooperation, civic dialogue, and the co-creation of public services in local government administration (Wójcik-Chodorowska, 2025a). This approach not only strengthens social trust, but also contributes to building more inclusive, resilient, and democratic urban communities, while appreciative discourse may additionally support adaptive capacity, engagement, and positive organizational change in highly structured public-sector organizations (Wójcik-Chodorowska, 2025b). Modern technologies promote greater transparency in administrative activities and the implementation of platforms and tools based on digital participation (Schlicher, MacIntyre, Abercrombie, 2016).

In turn, smart mobility refers to the issue of sustainable development in the context of transport and emission reduction and intermodality (Papa, Lauwers, 2015). It is important here to emphasize the quality of life that smart mobility must ensure, but also to develop the city's capacity for continuous learning and innovation (Campbell, 2012). "Smart mobility should integrate technologies, systems, infrastructures, and capabilities, where innovation is a means, not an end" (Papa, Lauwers, 2015, p. 550). A smart mobility solution is not just about using less energy or leveraging information and communication technologies, but about the ability to function as an integral part of a larger system that also takes into account participation, the quality of urban space, human capital, education, and learning in the urban environment (Katakis, 2015).

The smart environment emphasizes the development of green infrastructure, energy management, and climate protection. This dimension of the smart city

highlights the importance of environmental sustainability as the foundation for long-term urban development. Green infrastructure here includes parks, gardens, urban green spaces, but also engineering solutions, such as green roofs, plant walls, and rainwater retention systems, which support the city's resilience to climate change and extreme weather events (Kabisch, Qureshi, Haase, 2026). A number of benefits associated with the smart environment are highlighted here, for example: a positive impact on mental and physical health (Raza, Bojke, Coventry et al., 2024), economic benefits in the form of increased property prices (del Saz Salazar, García Menéndez, 2007), or increased tourism potential of a given area (Konijnendijk, Annerstedt, Nielsen et al., 2013). This approach does not exclude urbanization in any way but makes it more sustainable and takes into account the quality of life of residents, also in the context of the implementation of smart grids, real-time energy consumption monitoring systems, and increasing the share of renewable sources, such as photovoltaics and wind energy (Koirala, Van Oost, Van der Windt al., 2016). Bisheshwar P. Koirala and colleagues point to changes in the roles of local communities – from consumers to prosumers – and the emergence of new market participants who assist communities in implementing various forms of energy storage (2016). At the same time, smart cities are implementing advanced waste management and air quality monitoring systems, as well as digital platforms that support residents' eco-friendly decisions (Ahvenniemi, Huovila, Pinto-Seppä et al., 2017). Understood in this way, a smart environment is not only technologically significant, but also socially significant – it affects the quality of life, public health, and residents' sense of environmental security (Doherty, Klima, Hellmann et al., 2020).

The last dimension, smart living, covers a wide range of issues related to quality of life, health, safety, and accessibility of public services in the context of city users (residents) (Neirotti, De Marco, Cagliano et al., 2014). In terms of health, it is important to develop and implement smart, breakthrough healthcare services that enable real-time monitoring of human vital signs, and this refers to the development of innovative devices and critical health applications that can provide support in this area (Rodrigues, Da Rosa Righi, Da Costa et al., 2023). It also involves the development of artificial intelligence and the ability to use it to ensure safety and introduce solutions that facilitate infrastructure monitoring, navigation optimization, and traffic management (Lucic, Wan, Ghazzai et al., 2020). Smart living also means designing cities for the needs of people with various types of disabilities. This includes both the physical accessibility of public spaces and digital inclusiveness in the form of providing appropriate urban technologies (e.g., passenger information systems, e-health services) (Jaeger, Bowman, 2005). Finally, smart living also means promoting sustainable lifestyles that minimize the negative impact of human activity on the environment without reducing the comfort of everyday life for city residents (Lazaroiu, Roscia, 2012).

At the end of this section, it is also worth mentioning the link between the smart city concept and the Sustainable Development Goals (SDGs). This connection is

indispensable, as evidenced by SDG 11, which states: "make cities and human settlements inclusive, safe, resilient and sustainable" (United Nations, 2015). However, we cannot treat the meanings of "smart" and "sustainable" interchangeably, as the former focuses on technology and efficiency, while the latter focuses on quality of life, social and environmental justice (Ahvenniemi, Huovila, Pinto-Seppä et al., 2017). However, the literature on the subject includes the concept of smart sustainable cities, which is an attempt to integrate both paradigms and focuses on creating cities that are innovative and digital, as well as socially just and environmentally sustainable (Yigitcanlar, Han, Kamruzzaman, 2019). The concept of a smart sustainable city is therefore intended to provide a comprehensive response to the challenges of contemporary urbanization.

Capturing the smart city in the context of Central and Eastern Europe

The smart city concept is global, and its implementation depends on regional, institutional, and social conditions. In Western Europe, smart city development is most often an integral part of long-term urban planning and sustainable development strategies, supported by EU funds, extensive governance structures, and an established culture of public innovation (Mora, Bolici, Deakin, 2017). For example, cities, such as Amsterdam, Copenhagen, and Vienna, use real-time data to manage transportation, emissions, and civic participation, while investments in green infrastructure and digital public services are embedded in urban policy (Angelidou, 2017).

In Central and Eastern Europe, however, the model of smart city implementation often takes a more adaptive and reactive form. Cities in this part of Europe develop smart city components in a more modular way, responding to specific social and institutional needs and taking advantage of available international support, such as Horizon Europe, INTERREG, and Norwegian Funds (Anthopoulos, 2017). In this regional context, smart urban development is frequently shaped by limited financial resources, institutional transformation, and the need to address pressing infrastructural and social problems.

In the case of Central and Eastern Europe, local institutional capacity is a decisive factor in the effectiveness of smart city implementation. These differences indicate that while the smart city concept is based on a common set of values, such as sustainability, participation, and innovation, its actual implementation must be tailored to the local socio-political and economic context.

In Western European countries, there are also specialized institutions and urban cooperation networks that support the transfer of knowledge and good practices and create a base for the implementation of smart city innovations. An example here is the European Union initiative in the form of the European Innovation Partnership on Smart Cities and Communities (EIP-SCC) (European Commission, 2020). In the context of Central and Eastern Europe, by contrast, the role of public-private

partnerships and the involvement of local universities and community organizations becomes particularly important. Due to more limited resources, innovations are often the result of cooperation between different sectors and a response to specific problems, such as air pollution, infrastructure overload, or the need for energy modernization (Paskaleva, Evans, Watson, 2021). In both regions, the development of the smart city concept is based on the cooperation of many actors, although it differs in the structure and scale of the resources involved. Such diversity of approaches shows that successful urban transformation requires both local alignment and cross-regional knowledge sharing.

Against this background, Lutsk may be seen as an important example of a city in Central and Eastern Europe that seeks to implement selected elements of the smart city concept under complex and challenging conditions. Despite financial, institutional, and geopolitical constraints, the city has undertaken activities related to digital transformation, urban services, and sustainable development. Therefore, the case of Lutsk provides an opportunity to analyze how smart city assumptions can be implemented in practice in a Ukrainian urban context and how they may support the development of territorial communities.

2. Methodology

This section is divided into two subsections: quantitative research and qualitative research. This structure results from the adopted research strategy and makes it possible to clearly distinguish the part based on survey data from the part based on the analysis of documents and institutional materials. As a result, it is easier to present both the course of the study and the logic of interpretation of the obtained findings.

The aim of the study was to analyze the development of smart city solutions in Lutsk and to assess their importance for the sustainable development of the local territorial community. It was important not only to capture the directions of the city's smart transformation, but also to examine how this process is perceived by the residents themselves. Particular attention was paid to such issues as digital governance, the quality of public services, the development of urban infrastructure, and the level of civic engagement.

The study was conducted in 2023 within the framework of the Ihor Wyhowskyi Scholarship Programme. It had an exploratory and preliminary character. It was not intended to verify strictly formulated hypotheses, but rather to provide the most comprehensive possible recognition of the studied phenomenon and to identify the key determinants affecting the development of smart city solutions in Lutsk. For this reason, a mixed methods strategy was applied, combining quantitative and qualitative approaches. This made it possible to examine the research problem from two perspectives: on the one hand, through the opinions of residents, and on the other, through the analysis of strategic documents and institutional data.

The study was based on the logic of data and method triangulation. The empirical material included a survey conducted among the residents of Lutsk and a qualitative content analysis of documents and digital resources related to the city's development. The combination of these two components proved important, as it made it possible to compare the social perception of smart city initiatives with their institutional and strategic background. In the case of a city functioning under conditions of war, financial constraints, and uneven levels of digital competence, such an approach appears particularly justified.

Quantitative research

The quantitative part was based on an original survey conducted among the residents of Lutsk. Data were collected in two forms: paper-based and electronic. Paper questionnaires were distributed in educational institutions, offices, and selected public spaces, while the electronic version was made available via online forms. The use of both channels was intended to increase the accessibility of the study for different groups of respondents and to enable the collection of more diversified material.

The questionnaire included closed-ended and semi-open questions. They concerned residents' awareness of smart city initiatives, their assessment of the quality of municipal and public services, their willingness to participate in digitally supported urban governance, as well as their perception of the most important priorities for the development of urban infrastructure. Issues related to civic engagement and expectations toward local authorities were also included. The research tool was original and was developed in accordance with the principles of constructing instruments used in social research. Its content was consulted with experts dealing with smart city and sustainable development issues. The development of the questionnaire was also informed by selected international analytical frameworks, including the Smart City Index and Sustainable Development Goal 11. This made it possible to better embed the study in the broader context of urban analysis.

A purposive sampling strategy was applied, taking into account the spatial, age, and occupational diversity of respondents, as well as their accessibility. Only adults who had been living in Lutsk for at least three years were eligible to participate in the study. The adoption of this criterion was intended to include people with basic experience of functioning in the urban environment and thus capable of referring to the changes taking place in the city. A total of 120 respondents aged 18 to 70 participated in the study. The sample was socially and occupationally diverse, including public sector employees, such as those working in education, healthcare, and culture, as well as entrepreneurs, industrial workers, students, retirees, and internally displaced persons. It was also important to maintain spatial representation, as respondents came from all major districts of Lutsk.

The analysis of the survey material was descriptive in nature and was carried out using percentage-based indicators. This made it possible to capture the distribution of respondents' answers and to identify the dominant opinions regarding smart city development, the quality of urban services, and expectations toward local authorities.

Qualitative research

The qualitative part included a qualitative content analysis of materials related to urban development and local governance. The analysis covered strategic planning documents, local development strategies, urban development plans, urban reports, digitalization plans, statistical data, and selected digital platforms used in public administration and service delivery. These materials were supplemented by publicly available institutional sources, including data published by the Lutsk City Council, as well as reports and studies prepared by international organizations, such as the World Bank and UNDP.

The qualitative analysis was organized around several basic categories. These included smart city components, such as infrastructure, ecology, mobility, governance, and economy; the level of residents' satisfaction with urban services; the scope of civic participation; and models of governance, with particular emphasis on digital governance and social expectations toward local authorities. This system of categories made it possible to capture both the declared development priorities of the city and the practical directions of implementing smart solutions.

To increase the credibility of the findings, the analysis was conducted in an iterative manner. Survey results were compared with conclusions drawn from strategic documents, reports, and digital materials. Such triangulation made it possible to examine the development of smart city solutions in Lutsk not only from an institutional perspective, but also from the point of view of residents. The interpretation of the findings also took into account the broader context of the functioning of Ukrainian cities, including the consequences of war, financial constraints, and the differentiated level of digital competences.

The adopted methodology made it possible to capture both the development potential of Lutsk and the barriers accompanying the implementation of smart city solutions. It also created a basis for further analysis of how intelligent urban solutions may support local resilience, improve the quality of governance, and strengthen the sustainable development of territorial communities, particularly under conditions of post-war reconstruction.

3. Research results and Discussion

Smart city and sustainable urban development: the current situation in Ukraine

Ukraine remains a highly urbanized country, with more than 70% of its population living in cities. Urban centres play a key role in the country's economic, social, and cultural development, functioning as hubs of industry, education, innovation, and public life. For this reason, cities are becoming increasingly important actors in the implementation of sustainable development policies.

In recent years, Ukrainian cities have shown growing interest in adapting their local development strategies to broader international and European trends related to sustainable development and smart urban transformation. This tendency reflects an increasing awareness of the role of cities in responding to contemporary environmental, infrastructural, and social challenges.

At the same time, an analysis of the available studies indicates that, despite visible progress in the implementation of the Sustainable Development Goals, financing for Goal 11 in Ukraine remains insufficient. Although the level of commitment to the development of sustainable cities has increased, the scale of financial support still does not fully correspond to the complexity of urban needs or to the long-term requirements of lasting transformation. Compared with most European Union countries and the United States, the level of urbanization in Ukraine remains slightly lower. This is confirmed by the data presented in Figure 1.

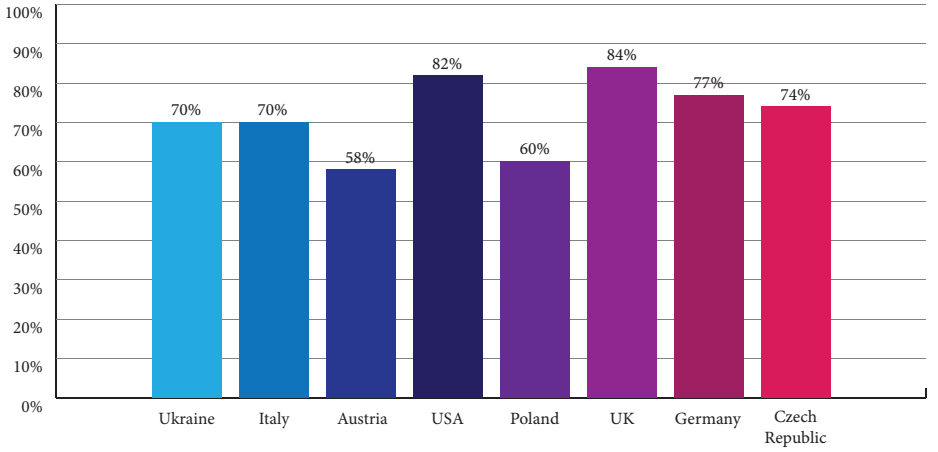

Fig. 1. Level of population urbanization in the EU and Ukraine (%)
Source: own elaboration based on: UNDP (2022)

Ukraine had already adopted a sustainable development strategy up to 2030 (UNDP, 2022), intended to align the country's social and economic development with international sustainable development agendas. Despite this strategic orientation, significant developmental barriers persisted. These included, above all, a mismatch between economic growth and environmental safety requirements, dependence on outdated and resource-intensive technologies, and a concentration on raw-material exports, all of which contributed to the persistence of a development model driven primarily by economic considerations (Gazzola, Dymchenko, Sribnyi et al., 2019). At the same time, studies suggest that Ukraine had been taking steps toward the gradual implementation of the Sustainable Development Goals (Kuzmak, Kuzmak, 2023).

Among the most serious environmental and infrastructural problems affecting Ukrainian cities are the low quality of housing and municipal services, especially in the fields of water supply and sewage systems, air pollution, underdeveloped waste management, limited access to green areas, worsening health indicators, and the increasing incidence of environmentally related diseases (Vygovska, Dekhtyarenko, 2021). In response to these challenges, all 24 regional capitals in Ukraine – although not all smaller cities – have developed and adopted sustainable development strategies (Kuzmak, Kuzmak, 2023).

At the local level, more specialized measures have also been undertaken to strengthen social cohesion and urban resilience. One example is the Kyiv municipal programme "Social Partnership", which aims to create an inclusive system for implementing public policies in the areas of social protection, the well-being of older people, gender equality, anti-discrimination, and support for persons with disabilities (Marenichenko, Shportyuk, Dobryansky, 2022). Meanwhile, cities, such as Irpin and Vinnytsia, have recorded visible progress in the field of energy efficiency. These urban centres are developing activities related to environmental sustainability, economic development, and the implementation of local sustainable development plans. Increasingly, they are also linking climate resilience strategies with reconstruction and crisis-response planning (UNDP, 2022).

However, Ukraine's socio-economic situation deteriorated dramatically as a result of the war. In the first quarter of 2022, gross domestic product fell by 15.1% compared with the same period of the previous year, while the poverty rate increased from 2% to 21%. Under these conditions, the implementation of the Sustainable Development Goals – especially those related to stability and long-term developmental resilience – was significantly disrupted. The scale of urban destruction has been immense: cities, such as Mariupol, Volnovakha, Rubizhne, Popasna, Lyman, and Sievierodonetsk, were severely damaged or destroyed. According to preliminary estimates from the Ministry for Communities and Territories Development, more than 2.4 million Ukrainian citizens are living in seriously damaged buildings. It should be emphasized, however, that these are only estimates, as under martial law and the temporary occupation of part of the territory, the exact number of

uninhabitable dwellings cannot be fully determined (UNDP, 2022). The distribution and scale of losses caused by the full-scale war in Ukraine across different sectors are presented in Figure 2.

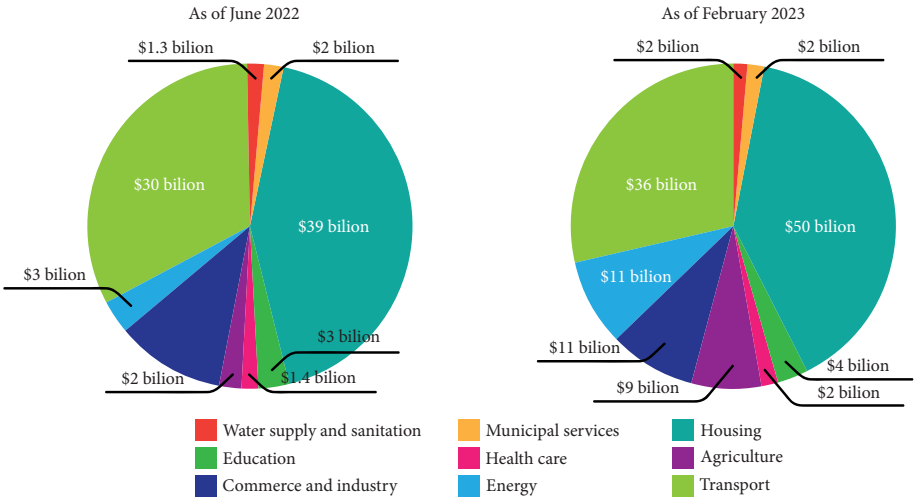

Fig. 2. Sectoral distribution of damage caused by the full-scale war in Ukraine
Source: own elaboration based on: World Bank (2022, 2023)

Data from 2023 indicate that the scale of destruction has continued to deepen. According to available estimates, the greatest reconstruction needs concern the transport sector (22%), housing (17%), energy (11%), and social protection (10%) (World Bank, 2023). This means that post-war urban reconstruction in Ukraine will require not only substantial financial resources, but also an approach grounded in the principles of sustainable development. Reconstruction alone will not be sufficient unless it is accompanied by long-term thinking about urban resilience, quality of life, and environmental safety.

This broader context provides an important interpretive background for the case of Lutsk. Like many other Ukrainian cities, Lutsk operates under conditions shaped by infrastructural pressure, financial constraints, and the need to combine day-to-day governance with long-term development planning.

Smart city elements in the case of Lutsk

Lutsk is one of the oldest cities in Ukraine and serves as the administrative centre of the Volyn region. This region occupies a special place on the map of the country due to its location near the borders with the European Union and Belarus, as well as its developed transport infrastructure and significant transit potential.

These conditions strengthen the role of Lutsk as a centre of regional development and as a city with substantial economic potential.

An analysis of institutional and strategic materials indicates that the city's economic base is formed primarily by enterprises representing the food, machinery, wood-processing, and paper industries, as well as the production of rubber and plastic goods, furniture manufacturing, metallurgy, the textile and clothing industries, extractive industries, and the chemical sector. Municipal infrastructure also remains an important area of modernization. The water supply system in Lutsk is being gradually upgraded in order to improve both efficiency and reliability. The municipal utility company "Lutskvodokanal" plans to obtain more than EUR 10 million for the modernization of the wastewater treatment plant and the sewerage network. The investment includes the installation of energy-efficient equipment, which is expected to reduce electricity consumption by approximately 550 MWh annually and extend the operational life of the treatment plant by at least 30 years. The city also has a public transport system based on trolleybuses and minibuses.

The analysed documents also suggest that the development of the urban community is based on the principles of sustainable development, understood as balancing economic, social, and environmental dimensions in a way that meets the needs of present residents without compromising the interests of future generations. In the region, projects are being implemented in the fields of technical infrastructure, public health, mobility, investment attractiveness, and cross-border cooperation. These include, among others, the modernization of municipal infrastructure, the development of medical facilities, activities related to transport maintenance and organization, and initiatives aimed at strengthening cooperation with foreign investors (Lutsk City Council, 2024). These projects form the broader institutional environment within which the development of Lutsk should be understood.

The development of Lutsk should also be considered within the wider context of decentralization reforms taking place in Ukraine. The country is undergoing a process of forming united territorial communities, and Volyn belongs to the regions with particularly high dynamics of change in this respect. So far, 39 communities have been established there, covering 45% of the region's territory, which places Volyn among the leaders in terms of the scale of local government reform implementation.

At the same time, another stage of local government reform is underway, and the State Regional Development Strategy up to 2027 points to the need to implement sustainable development goals at both national and regional levels. Nevertheless, numerous institutional barriers remain visible, including an ineffective system of public administration in the field of environmental regulation, the lack of a clear separation between environmental protection and economic functions, an underdeveloped civil society, a low level of public awareness of environmental priorities, and insufficient enforcement of environmental law (Gazzola, Dymchenko, Sribnyi et al., 2019).

At the national, regional, and local levels, the implementation of sustainable development principles based on civic participation still faces difficulties resulting from limited awareness among both decision-makers and local communities. The transition toward a more sustainable model of development requires not only changes in residents' lifestyles, but also consideration of such factors as the quality of governance, access to common goods, existing social inequalities, the level of participation and education, and the overall quality of urban life (Gazzola, Dymchenko, Sribnyi et al., 2019).

Smart city development in Lutsk

An analysis of municipal documents and institutional materials makes it possible to conclude that smart city elements in Lutsk are being introduced gradually and in a somewhat dispersed way, although they are becoming increasingly visible. In 2023, the Urban Vision Lutsk project was launched. Its first stage included research and public consultations among residents aimed at identifying the main directions of the city's development and changes in its visual identity. The concept of sustainable development in Lutsk envisages the creation of new public spaces, such as landscape parks, viewing terraces, boulevards, and zones for culture, business, and sport, linked by a network of streets and green areas forming so-called blue-green infrastructure. This framework is intended to support the city's ecological stability, protect the biodiversity of land and water ecosystems, and create favourable conditions for the development of cycling infrastructure. The spatial concept for the development of central Lutsk was based both on an analysis of the urban environment and on sociological research conducted among residents.

This project defines several main directions for the development of the central part of the city. These include strengthening spatial potential through the protection of the city's unique identity, the development of cultural institutions, the protection of the natural environment, and the creation of new prospects for business and the creative industries; shaping a comfortable urban environment that supports social interaction and the development of civic organizations; adapting urban space to current natural and climatic conditions, including the development of areas located beyond the rivers; creating an inclusive environment that combines the physical and social dimensions of public space; and enriching the city centre with new functions through a more rational use of available space.

Based on the obtained results, scenarios for the further development of Lutsk were prepared. These include, among other things, the creation of a new blue-green network in the central part of the city, composed of public green areas, streets, rivers, squares, and parks, while simultaneously adapting the urban environment to natural and climatic conditions. It is also assumed that a multi-level street hierarchy will

be formed, with a division into primary and secondary routes, taking into account residential density and the comfort of movement within the city. An important element of this vision is also the creation of new landmarks and attractive places, such as architectural monuments, squares, cultural and social facilities, historically significant buildings, viewpoints, and boulevards. The densification of the central part of the city through the modernization of old buildings and the implementation of new investments is also envisaged.

In this context, Lutsk may be treated as a city in which smart urban transformation is based not only on individual technologies, but also on an attempt to integrate spatial, environmental, and social goals. As early as 2017, the project "Lutsk – SMART Capital of Ukraine" was presented, assuming the use of modern technologies in urban space. However, the effectiveness of such initiatives depends not only on the availability of technology, but above all on the quality of human capital and the level of cooperation between local government, the urban community, and the business sector. One example of the institutionalization of these efforts is the Comprehensive City Programme "Safe City of Lutsk", the stages of whose financing in 2019-2021 are presented in Figure 3.

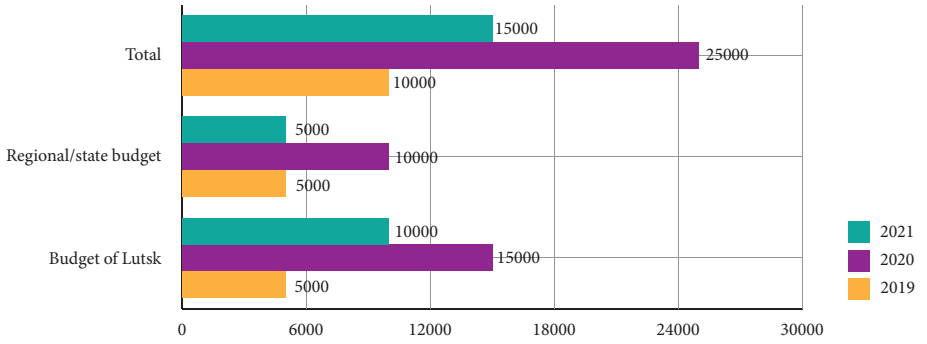

Fig. 3. Stages of financing of the Comprehensive Programme "Safe City of Lutsk" in 2019-2021
Source: own elaboration based on the official website of the Lutsk City Council

The programme assumes total funding of UAH 50 million. The most important technological solutions aimed at improving safety include video surveillance of strategic sites and public spaces, traffic control and road safety systems, devices with intervention and information functions, such as alarm sensors or police call buttons, and a unified fibre-optic network enabling law-enforcement services to obtain information efficiently. Another important component of the programme is a dispatch centre equipped with software and devices for monitoring, analysis, and early warning in emergency situations, as well as a system for informing residents about potential threats.

The programme also envisages the further development of SMART-type bus stops within the city, the installation of intelligent screens, so-called safety islands, and notification systems. These solutions are intended to improve the quality of resident services in the area of transport, while at the same time strengthening a more user-oriented model of urban service provision.

Among the smart city technologies implemented in Lutsk, Internet of Things solutions should also be mentioned. These include the automated operation of devices without direct human intervention, data exchange between users and systems, the transmission of information on network status, the regulation of device performance, and the ongoing management of the functioning of the entire system ("Live" sensors, 2019). The results of the analysis of documents and institutional materials therefore suggest that the development of smart city solutions in Lutsk is not limited to isolated technological investments, but gradually extends to broader areas of urban governance, safety, mobility, and the organization of public services.

Priority areas of smart city development in the opinion of Lutsk residents

An important part of the study was to determine which areas of urban development are considered the most important by the residents of Lutsk from the perspective of the further implementation of smart city solutions. As shown in Figure 4, the highest percentage of responses concerned expanding access to services (98.1%) and supporting economic development (96.7%). These findings suggest that residents' expectations are focused primarily on those areas that most directly affect the everyday functioning of the city and the quality of life.

Environmental sustainability was also rated relatively highly (92.7%), which may indicate that residents recognize the importance of the urban environment, although under current conditions service-related and economic issues remain the most immediate priorities. Slightly lower values were obtained for city safety (90.6%) and social justice (86.8%). This does not mean, however, that these areas are perceived as unimportant. Rather, it may be assumed that under conditions of socio-economic instability residents place greater emphasis on the most practical and immediately felt needs of everyday life.

The survey findings are partly consistent with the conclusions drawn from the analysis of municipal documents. Both the strategic materials and the opinions of respondents point to the importance of service quality, infrastructure development, and the improvement of everyday urban functioning. At the same time, the survey indicates that residents place particular emphasis on the usefulness of smart city solutions, understood not so much in terms of technological innovation as an end in itself, but rather as a tool for improving access to services, strengthening the local economy, and enhancing the overall quality of life in the city.

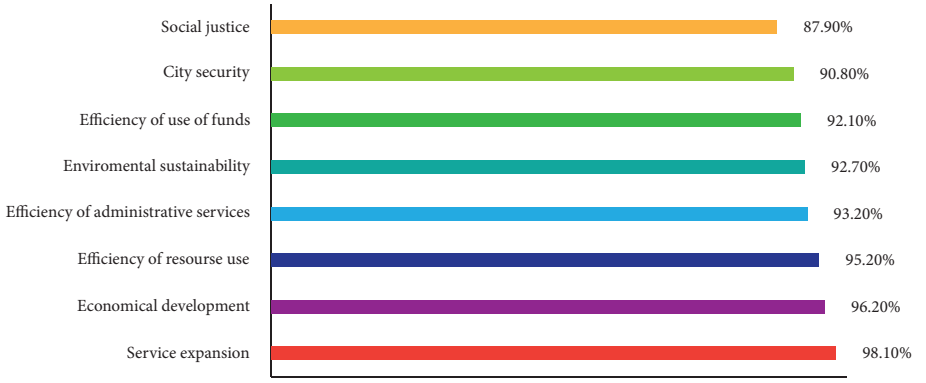

Fig. 4. Priority areas of smart city development in the opinion of respondents from Lutsk
Source: own elaboration

In this sense, smart city in the perception of Lutsk residents is not understood solely as a set of modern technologies. More often, it appears as a practical model of urban development that should support more effective governance, increase the accessibility of public services, and respond to the basic needs of the local community. This way of perceiving the smart city concept corresponds well with the broader approach that links smart urban transformation with the goals of sustainable development.

The obtained findings show that smart city development in Lutsk is gradual, selective, and strongly dependent on local institutional and financial conditions. In this sense, the case of Lutsk reflects broader observations concerning Central and Eastern European cities, where the implementation of smart city solutions is more often adaptive than systematically embedded. As Anthopoulos (2017) and Paskaleva, Evans and Watson (2021) indicate, urban innovations in this part of Europe usually emerge in response to specific needs and constraints rather than as part of a long-term and stable technological policy. The case of Lutsk confirms this pattern: the implemented solutions concern important areas of urban functioning, such as safety, municipal infrastructure, mobility, and spatial governance, but they do not yet constitute a fully integrated smart city model.

It is also noteworthy that both the analysis of municipal documents and the survey results point to a relatively broad understanding of the smart city concept. In the study, residents did not primarily associate it with modern technologies alone, but rather with improved service quality, economic development, and a better quality of life. This perception is consistent with approaches present in the literature, according to which smart city should not be reduced to its technological dimension alone, but should also be examined through the lens of human capital, participation, and the quality of governance (Nam, Pardo, 2011; Hollands, 2008; Caragliu, Del Bo, Nijkamp, 2011). This means that in the case of Lutsk, smart urban transformation gains social legitimacy primarily when it responds to residents'

everyday needs and strengthens the practical functioning of the urban community. At the same time, the case of Lutsk demonstrates that smart city development in Ukrainian cities must be analysed in close connection with the categories of sustainable development and urban resilience. As Ahvenniemi, Huovila, Pinto-Seppä et al. (2017) and Yigitcanlar, Han, and Kamruzzaman (2019) emphasize, the notions of "smart" and "sustainable" are not synonymous, yet their integration becomes essential under conditions of contemporary urban crises. In the case of Ukraine, the importance of this relationship is further reinforced by the consequences of war, infrastructural pressure, and the need to rebuild cities in a more durable and resilient way. The findings of the present study therefore suggest that in Lutsk, smart city may be understood not only as a model of technological modernization, but also as a tool supporting the city's long-term capacity for adaptation, improving the quality of governance, and strengthening territorial communities under conditions of socio-economic instability.

Conclusions

The conducted study has an exploratory character; therefore, its findings cannot be directly generalized to the whole of Ukraine. The limitations of the research stem both from the territorially narrowed scope of the analysis, focused on Lutsk, and from the specific wartime context, which may have influenced respondents' perceptions as well as the dynamics of the processes under investigation. Nevertheless, the obtained findings constitute a meaningful contribution to the discussion on the development trajectories of Ukrainian cities and their potential for transformation toward the smart city model and sustainable development. The analysis indicates that Lutsk has the potential to implement solutions characteristic of the smart city model; however, this process remains partial, uneven, and strongly conditioned by the local institutional and socio-economic context. Among the most important barriers are the consequences of war, financial constraints, differing levels of digital competences among residents, and insufficient institutional preparedness for carrying out a long-term and coherent urban transformation.

The findings also demonstrate that smart city development should not be identified exclusively with the implementation of new technologies. Equally important are service accessibility, the quality of governance, the level of civic participation, and the capacity of local authorities to take into account the needs of different social groups. Under conditions of post-war reconstruction, the inclusiveness of urban solutions becomes particularly important, so that smart infrastructure does not deepen existing inequalities, but instead supports social integration, local resilience, and the long-term improvement of residents' quality of life. From a practical point of view, this implies the need to strengthen the digital competences of both residents and public administration employees, to expand educational activities, and to build greater trust in electronic

services and digital governance tools. The reconstruction of Ukrainian cities should not consist in the simple restoration of earlier development models, but rather in the creation of more flexible, participatory, and sustainable urban structures capable of responding to new social, economic, and infrastructural conditions.

The findings remain consistent with the conclusions of the existing literature, while also showing that smart city development in Ukraine requires technology to be understood within a much broader social, economic, and institutional context. In this sense, the case of Lutsk may serve as a useful reference point for further research on the transformation of cities operating under conditions of instability, crisis, and reconstruction, as well as on the possibilities of linking smart urban transformation with the goals of sustainable development.

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