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PREFRACE

Urban areas across the European Union are facing unprecedented challenges and opportunities as they strive for sustainable transformation. The PhD conference "Urban Transformation in the EU: Challenges and Opportunities" provides a unique platform for emerging scholars to share innovative research and fresh perspectives on the evolving urban landscape.

As cities respond to climate change, energy transition, and the need for resilient and inclusive spatial planning, the importance of collaborative knowledge exchange has never been greater. This conference, co-funded by the European Union and organized under the PM4U initiative with the support of EUList projects, brings together doctoral students and early-career researchers from diverse disciplines and countries. Our aim is to foster an open and interdisciplinary dialogue that addresses both the complexities and opportunities present in urban transformation across the EU.

The conference programme covers a broad range of topics—from healthy cities and well-being, to digital innovation and smart city strategies, to the critical role of project management in shaping sustainable urban futures. By exploring these themes, we seek to encourage new approaches, highlight best practices, and inspire future research collaborations across borders.

We extend our gratitude to all contributors, participants, and committee members whose dedication and expertise make this event possible. We hope that this conference will spark new ideas, strengthen professional networks, and support the next generation of urban scholars in their pursuit of sustainable, vibrant, and resilient European cities.

We wish all participants an inspiring and productive conference!

On behalf of the Organizing Committee,
Prof. Nataliia Yehorchenkova
Slovak University of Technology in Bratislava, Slovakia

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Conceptual Framework For Sustainable Urban Development

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Abstract: This article explores the conceptual framework of sustainable urban development through a comprehensive analysis of international experiences and theoretical foundations. Emphasizing the evolving paradigm of urbanization, it highlights the interplay between economic efficiency, social inclusiveness, and environmental sustainability as core pillars of modern city planning. The study identifies key factors contributing to the investment potential of urban areas, including innovation clusters, public-private partnerships, infrastructure quality. Drawing from global best practices-from the United States to East Asia and Europe-the research substantiates the critical role of smart specialization and systematic innovation management in shaping resilient and competitive urban environments.
Keywords: Sustainable urban development, investment potential, innovation clusters, public-private partnerships, urbanization, urban planning, economic resilience.

The current paradigm of urban development is characterized by a transformation in the understanding of the nature of urbanization processes and mechanisms for generating investment potential. Rapid urbanization is changing the spatial organization of economic activity, creating new opportunities for the development of territories and at the same time generating complex challenges for local communities. Cities are turning into key centers of economic growth, accumulating human capital, technological innovations, and investment resources, which is confirmed by studies of the formation of "smart specialization" in the Ukrainian economy [1].

An analysis of global experience shows a strong correlation between the level of urbanization of territories and economic development, which is especially evident in the world's leading economies. In the United States, where the level of urbanization exceeds 82%, urban agglomerations such as New York, San Francisco, and Boston form powerful innovation ecosystems and account for more than 80% of national GDP. The experience of American cities demonstrates the effectiveness of the cluster approach to urban development, when the concentration of high-tech companies, research centers, and financial institutions creates a synergistic effect for economic growth.

The experience of East Asian countries, where urbanization has become a key driver of economic breakthroughs, is particularly illustrative. In Japan, where the level of urbanization reaches 91%, cities such as Tokyo, Osaka, and Nagoya have formed a unique model of integrating traditional industrial clusters with innovative technology hubs. South Korea demonstrates a successful example of planned urban development, where Seoul and other major cities strike a perfect balance between industrial development, technological innovation, and quality of life. China, implementing a large-scale urbanization program, has created a network of world-class megacities - Shanghai, Shenzhen, Guangzhou - that have become centers of global economic activity.

The European experience of urban development demonstrates the importance of an integrated approach to planning and management. Germany, relying on a network of medium-sized cities and powerful regional centers such as Munich, Hamburg, and Frankfurt, ensures an even distribution of economic activity and high standards of living. The Scandinavian countries of Denmark, Sweden, and Norway have created a model of sustainable urban development that combines economic efficiency with environmental responsibility and social justice. Particularly noteworthy is the experience of the Netherlands and Belgium, where high population density has stimulated the development of innovative approaches to urban planning and resource management. In the context of newly industrialized countries, the experience of Singapore, which has transformed from a port city into a global financial and technological center, is illustrative. The city-state demonstrates a unique example of effective management of limited resources and creation of a favorable environment for international business. Dubai and Abu Dhabi in the UAE have chosen a similar path, and through strategic planning and large-scale investment in urban infrastructure, they have become global centers of trade, finance, and innovation. The experience of these cities confirms that effective urban planning and the creation of favorable conditions for investment are key factors for success in global competition.

An analysis of the experience of these countries shows that the cities leading global development demonstrate the highest rates of resource efficiency and the highest concentration of innovation activity, forming powerful economic clusters and attracting significant amounts of investment, which is discussed in detail in urban planning studies [2]. At the same time, successful urban development practices are based on a combination of economic efficiency, social inclusiveness, and environmental sustainability, which creates the basis for long-term sustainable growth. The investment potential of sustainable urban development is formed through the interaction of many factors of economic, social and environmental nature. The study of the investment attractiveness of urban areas demonstrates the critical importance of developed infrastructure, quality of human capital, and efficiency of local governance. Of particular importance is the introduction of innovative forms of territorial cooperation and mechanisms for intensifying investment activity, as evidenced by the results of regional development studies [3].

Integrated urban development requires a systematic approach to managing innovation processes. The experience of European countries demonstrates the effectiveness of the cluster model of managing innovative development of territories. The formation of innovation clusters creates a synergistic effect, enhancing the competitive advantages of urban areas and increasing their investment attractiveness [4].

The development of public-private partnerships is becoming an important aspect of shaping the investment potential of cities. A study of theoretical and methodological approaches to organizing the interaction of the public and private sectors indicates the need to improve mechanisms for cooperation and risk sharing. The successful implementation of public-private partnership projects creates additional opportunities for attracting investment in the development of urban infrastructure [5]. Revitalization of urban areas is an important tool for increasing their investment attractiveness. The study of the European experience of urban revitalization demonstrates the effectiveness of an integrated approach to the restoration of degraded urban areas and the creation of new points of economic growth. Successful implementation of revitalization projects helps to improve the urban environment and attract private investment [6]. Ensuring the economic stability of cities in times of crisis requires the introduction of effective mechanisms to stimulate investment activity. The study of methods of stabilizing the economy in crisis conditions indicates the need to diversify sources of financing for urban development and the formation of sustainable mechanisms for attracting investment. Of particular importance is the creation of a risk management system and ensuring the transparency of investment processes [7].

Project management in public administration is an effective tool for implementing strategic urban development initiatives. Implementation of modern project management methods allows to increase the efficiency of resource use and ensure the achievement of planned results.

International experience in the development of smart cities demonstrates the growing role of integrating big data technologies into urban planning and construction processes. An analysis of the practice of using Big Data technologies to optimize urban development indicates the possibility of significantly increasing the efficiency of resource use and improving the quality of the urban environment. The introduction of big data analytics systems allows making informed decisions on the development of urban infrastructure and attracting investments [8].

Conclusion

The conceptual foundations of sustainable urban development are defined, which allowed to form a theoretical basis for understanding the mechanisms of formation of its investment potential in modern conditions. The analysis shows that the current paradigm of urban development is characterized by a fundamental transformation of understanding the nature of urbanization processes and mechanisms for forming investment potential. The study revealed a stable correlation between the level of urbanization of territories and indicators of economic development, which is confirmed by both theoretical developments and empirical data.

The experience of European countries demonstrates the effectiveness of the cluster model of managing innovative development of territories. It is proved that the formation of innovation clusters creates a synergistic effect, enhancing the competitive advantages of urban areas and increasing their investment attractiveness.

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Systems analysis in project management for urban transformations

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Abstract: The systemic integration of European law aligns with the global "green transition" policy, creating opportunities for local climate action to be consistent with regional and national strategies. The concept of sustainable spatial development refers to the process of creating livable and environmentally-friendly urban areas while addressing economic and social challenges, based on the principles of systems analysis for the assessment and management of the risks of global transformation projects.
Keywords: Urban sustainability, Systemic approach, sustainable spatial planning.

Introduction

The twenty-first century has been called the Age of Cities. By the early 2010s, more than 50% of the world's population lived in cities, which produce more than 60% of economic output and the majority of greenhouse gas emissions worldwide, with a relentless growth trend [1]. The transformation of the urban environment in order to adapt to climate change and other needs important for the survival of society requires the application of systemic principles for sustainable spatial planning. Based on the principles of systems analysis, investigators indicate that urban areas, which are megasocial systems, are characterized by enormous social inertia (which consists of the ideals and rules of the past, everyday routine, cultural layers, technologies, conservative features of social groups). The most accumulated modern systematic approach to solving multi-level problems is the concept of sustainable spatial planning called Nature-based solutions (NbS). A concept is presented for a systematic analysis of circumstances and factors that mobilise the natural environment of cities to respond to natural challenges of various types and strengths, in such a way as to obtain various benefits for human well-being and biodiversity. Project management using the NbS methodology is becoming a powerful tool for overcoming the systemic risks of urban transformation projects and achieving a more climate-resilient, sustainable, dynamic and inclusive urban economy. Natural Capital Accounting (NCA) is a methodology of tools for systems analysis, assessment and monitoring of preferences when choosing certain types of NbS for financing [2].

The aim of our research is to structure the challenges faced by governments and mayors of cities in terms of urban transformations and to identify appropriate systemic approaches to establishing project management in the "green" transformation of cities.

Research Description

Modern principles of systems analysis are implemented in international politics for the Global Covenant of Mayors network in the form of thematically and hierarchically structured sensitive components, for the balancing of which the latest approaches to project management for urban transformations are developed [3]. Climate change adaptation is deeply intertwined with multi-level governance (MLG) at the city and regional level. Cities around the world are increasingly facing challenges that combine climate change pressures, demographic changes and resource scarcity. Growing energy needs are largely at the heart of urban governance, to which the European Union (EU) has introduced the 20-20 dynamic targets at the transnational level, setting ambitions for a 20% reduction in CO_2 emissions and energy consumption and achieving 20% of energy consumption from renewable sources.

The basic methodology of systems analysis is widely used in the scientific community and is based on four key principles: 1) system definition, 2) system structuring, 3) data collection, and 4) data evaluation and analysis [4]. The combination of innovative solution providers offering tools, technologies, and strategies for urban transformations is achieved through applying systemic principles in providing project management to financing community development projects and decarbonization in ecosystems, through established interaction with financial specialists and impact investors [5]. Systemic structuring of problems and risks allows for the development of approaches and practices for good management, helping cities to solve the challenges of green transformation, overcoming the following main obstacles: (i) policy fragmentation, referring to the phenomenon that local energy strategies are often developed in isolation from other policy areas, such as spatial planning or mobility, leading to inconsistent and incompatible strategies and political plans; (ii) lack or instability of political commitment through political cycles and through uncertain benefits of proposed actions; in this regard (iii) a short-sighted focus on short-term goals, prioritizing profits over long-term sustainability goals; and (iv) the fact that local authorities are only one participant in city processes with (often) limited influence on the energy sector and market [4].

A systemically structured database of over 1,000 NbS interventions across Europe distinguishes eight main categories under which they list 29 NbS types [2]. Based on NbS lists from four European projects, this typology establishes seven classes under which 32 NbS types are grouped. An example of innovative municipal financing approach for large urban park interventions are municipal climate bonds, which are (financial instruments that have economic value) issued and managed by municipalities. These securities have been certified under the Climate Bonds Standard and Certification Scheme to fund climate mitigation and adaptation measures. Such bonds are typically bought by market participants who have an interest in investing in the city's sustainability such as insurance companies. Systems analysis provides tools to promote continuity in official positions and processes of achievement according to program documents at the European and global levels, by introducing the concept of transformative sustainable development management (TSM), to realize the needs for establishing coordinated project cycles at the European and global levels [5-7]. Local Government cannot bring about change on its own; complex problems require the mobilization of a broad range of stakeholders. Systemic approaches for urban transformations should be ensured at all levels of governance by a process that promotes cooperation at all levels of governance, from local municipalities to national authorities, in some cases - from local to transnational producer associations, standardization systems and investment programs [8]. In the context of global economic transformation and transnationalization, the most important actors of urban transformations, along with countries and their governments, are transnational platforms with a wide range of founders [9, 10]. This especially applies to urban transformation programs implemented by the EU, UNIDO, and the World Bank with their partners, based on systems analysis approaches, which allows for the activation of donor flows to support the implementation of innovative projects.

Conclusions References

The ability to achieve sustainable spatial planning in accordance with the set of principles of sustainable development becomes one of the central and critical issues of scientific and practical activities in public administration, which can be successfully resolved only under the conditions of consistent application of the principles of systems analysis. A systems analysis of urban transformation risks lays the foundation for collaboration and implementation within the framework of the Covenant of Mayors, built by combining micro-foundations at the level of local structures, processes, tools and skills, enabling progress in actions in the project management cycle, fundamentally increasing the strategically important role of local government and public administration at the continental level and in the global dimension.

Cities are considered as potential "drivers" and loci of sustainable development, innovation and social progress. Project management for urban transformation plays a dual role, serving as a basis for systemic analysis of problems and solutions for sustainable development across a set of challenges, combined with the needs of combining efforts on climate change, energy transition, digitalization of processes and strengthening financial support, combining the efforts of numerous social groups, local and global levels.

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Promoting Smart Cities In The Digital Environment

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Abstract: Smart cities, like other territories, need active promotion - both internally, among their own residents, and externally - to attract investors, tourists, labour and strategic partners. Today, digital promotion is particularly effective, as it allows for reaching a wider audience, delivering messages to target groups, adapting to changes more quickly, and better analysing advertising campaigns.
Keywords: smart city; digital environment; promotion; digital marketing; territory marketing.

Smart cities are a concept of the future that is already becoming a reality in many countries. It combines technology, innovation, and management approaches to create a comfortable, safe, and sustainable environment for residents. By using artificial intelligence, the Internet of Things (IoT), big data and other advanced developments, smart cities are able to optimise transport systems, reduce energy consumption, improve the environment and ensure a high standard of living.

According to the IMD Smart City Index 2025, the number of cities actively implementing the smart city concept has increased to 146. Zurich (Switzerland) and Oslo (Norway) are consistently at the top of the list (Table 1).

TABLE I. TOP 10 SMARTEST CITIES IN THE WORLD IN 2025

Smart City Rank 2025	**City**	**Country**	**Smart City Rank 2024**	**Change**
1	Zurich	Switzerland	1	-
2	Oslo	Norway	2	-
3	Geneva	Geneva	4	+1
4	Dubai	United Arab Emirates	12	+8
5	Abu Dhabi	United Arab Emirates	10	+5
6	London	United Kingdom	8	+2
7	Copenhagen	Denmark	6	-1
8	Canberra	Australia	3	-5
9	Singapore	Singapore	5	-4
10	Lausanne	Switzerland	7	-3

Source: compiled by the author based on [1]

To become a smart city, municipalities must develop in 6 key areas: Smart People, Smart Governance, Smart Living, Smart Economy, Smart Mobility, Smart Environment. [2] Despite this, many cities face difficulties in implementing an integrated approach. The reasons for this may include limited resources, low levels of digital literacy, poor coordination between departments, or a lack of a clear strategy.

It is especially important not only to implement technologies but also to effectively promote them to the public and potential partners. That is why the marketing promotion of the Smart City concept is becoming a key tool for: building the trust of residents, actively engaging them in using new services, improving the city's reputation, attracting investment and international support.

The marketing promotion of smart cities, especially in the digital environment, helps to attract the attention of investors, citizens, and partners, promoting innovation and building a positive image to attract resources and support development.

The main channels for promoting territories in the digital environment are a website, a mobile device, and social networks [3, p. 71]. In accordance with these channels, the following main digital methods of smart city promotion can be distinguished:

– *Search engine marketing (SEM)* is a digital promotion method that allows municipalities to communicate information about a smart city to their target audience through search engine advertising (SEA) and website optimisation and organic promotion using SEO (Search engine optimisation).

– *Internet Advertising* is a method of promoting a smart city and its popularisation through various types of advertising: contextual advertising, video advertising, native advertising, banner advertising, product placement, viral advertising, targeted advertising, geo-targeted advertising, viral advertising.

– *Social media marketing (SMM)* is a method of promoting city initiatives, services and values through social platforms such as Facebook, Instagram, Twitter (X), TikTok, YouTube, LinkedIn, etc. It should be noted that to increase the visibility of smart cities, it is advisable to use such SMM tools as content marketing and collaboration with influencers.

– *3D Marketing* is the use of three-dimensional visualisation, animations, AR/VR (augmented and virtual reality) for the effective presentation of urban solutions, projects and services. This is especially relevant for infrastructure changes, architectural concepts, new technological solutions in the city, etc.

The digital environment is a powerful tool for conveying the benefits of smart cities and shaping their positive image. In the context of a smart city, the digital environment becomes the foundation for interaction between authorities, citizens, businesses, and infrastructure. Digital marketing methods such as SEM, online advertising, SMM, 3D marketing allow cities to speak to citizens in a modern language, ensuring accessibility, transparency and efficiency of communication. This is not just an additional element, but an integral part of the digital transformation of urban governance.

Thus, marketing promotion in the digital environment plays a key role in the implementation of the Smart City concept. It not only informs residents about new services, but also builds trust, engages them in interaction, and creates a positive image of the city as innovative, open, and comfortable for living.

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Investigating the spatial relationships pattern of Surface Urban Heat Islands on Vulnerable Populations: A Case Study of Bratislava

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Abstract: This study examines the spatial distribution of Surface Urban Heat Islands (SUHI) and heat vulnerability across various age demographics in Bratislava, utilizing Landsat 8 imagery from the summer of 2020. Land Surface Temperature (LST) was derived using the Split-Window Algorithm, and SUHI indices were subsequently calculated. Population data from World Pop facilitated the assessment of heat vulnerability across three age groups: children (0–5), adults (5–65), and the elderly (>65). The Heat Vulnerability Index (HVI) was computed individually for each group and as a composite index employing CRITIC-based weighting. The findings indicated that the highest SUHI intensities were concentrated in the northeastern, southeastern, northwestern, and southern regions of the city, with an average SUHI of 0.001 and a range from -2.29 to 3.87. The southwestern region, particularly Petržalka, exhibited the highest HVI values, correlating with the highest population density. Bivariate analyses of SUHI and HVI for both male and female populations demonstrated consistent spatial patterns, suggesting no significant gender-based differences in thermal vulnerability. The central and eastern urban cores showed the highest convergence of heat intensity and vulnerability, likely due to dense built environments and limited vegetation cover. These results underscore the urgent need for targeted urban heat mitigation strategies in high-risk areas, including the expansion of urban greenery, the use of high-albedo materials, and the enhancement of cooling infrastructure. This study highlights the essential role of spatial analysis in climate-resilient urban planning and the protection of vulnerable populations from heat-related health risks.
Keywords: Urban surface heat island, population vulnerability, bivariate analysis, Bratislava city

Introduction

SUHI constitute a well-documented phenomenon characterized by elevated ambient temperatures in urban areas compared to their less-developed surroundings (Aghazadeh et al., 2025). This temperature differential, which can reach up to 8°C in certain cities, exacerbates heat stress, particularly during extreme heat events, with significant public health implications (Núñez Peiró et al., 2016). Projections from the Intergovernmental Panel on Climate Change (IPCC) suggest that climate change will increase the frequency and duration of extreme heat events, thereby intensifying SUHI effects and heightening risks for urban populations (Sánchez-Guevara Sánchez et al., 2017). Vulnerable demographic groups, such as the elderly and young children, are disproportionately affected due to their limited thermoregulatory capacities (Culqui et al., 2013). This vulnerability is further amplified in densely populated urban settings with restricted access to cooling resources, underscoring the necessity for targeted urban interventions (Sánchez-Guevara Sánchez et al., 2017).

The global rise in urbanization has intensified SUHI effects, with projections indicating that over 60% of the world's population will reside in urban areas by 2030 (United Nations, 2019). In regions such as Latin America, where urban populations exceed 80% (Quintana-Talvac et al., 2021), the combined effects of rapid urban expansion and climate change exacerbate heat stress (Banerjee & Bhiwapurkar, 2023; Ascencio et al., 2023). The replacement of natural landscapes with heat-absorbing materials, such as asphalt and concrete, contributes to elevated land surface temperatures (LST), a key indicator of SUHI intensity (Parker et al., 2021). Remote sensing studies have documented significant intra-urban temperature variations, revealing that low-income neighborhoods often experience the highest LST due to limited vegetative cover and green infrastructure (Diaz-Sarachaga et al., 2020). These areas also face increased energy demands for cooling, imposing additional financial burdens on households affected by energy poverty. Addressing these challenges necessitates the integration of high-resolution temperature data with demographic analyses to prioritize interventions in highly vulnerable communities (Banerjee & Bhiwapurkar, 2023).

The health implications of the SUHI effect are significant, with increased temperatures closely linked to heightened morbidity and mortality, particularly during extended heatwaves. Vulnerable populations, including the elderly (aged 65 and older) and young children, are at increased risk due to physiological limitations in thermal regulation (Sánchez-Guevara Sánchez et al., 2017). Research conducted in cities such as Madrid and Richmond indicates that older adults are particularly vulnerable, with heat-related mortality rates significantly higher among individuals over 60 years of age (Wong et al., 2016). Similarly, children are at risk due to immature physiological responses to heat stress (Díaz et al., 2002; Suen, 2022). The combination of daytime and nighttime heat, common in arid and temperate urban climates, imposes additional stress on these groups, reducing recovery periods and increasing health risks (Simon et al., 2005).

Age-related vulnerabilities to SUHI are exacerbated by urban design and infrastructure.The elderly and young children often depend on public spaces for mobility and recreation, yet many urban areas lack adequate shade or green infrastructure to mitigate heat stress (Park et al., 2021). In Heidelberg, research highlights that vulnerable groups, including pregnant women and individuals with pre-existing medical conditions, face increased health risks during heat events due to limited access to thermally comfortable pathways (European Environment Agency, 2022; Foshag et al., 2024). Poor housing quality, prevalent in low-income areas, exacerbates indoor heat exposure, particularly for older adults who spend more time indoors (Macintyre et al., 2018). In Madrid, approximately 24% of households struggle to meet cooling needs, disproportionately affecting elderly residents in energy-inefficient homes (López Moreno et al., 2015). These conditions underscore the urgent need for interventions, such as building retrofits and green space development, to reduce heat exposure among vulnerable age groups.

This study aims to investigate the spatial relationships pattern of SUHI and vulnerable populations in Bratislava. By integrating global and regional evidence, the research seeks to identify areas where the elderly, children, and adults face the greatest heat exposure. Through a comprehensive analysis of SUHI impacts and demographic vulnerabilities, this study contributes to the growing body of literature on climate justice and urban resilience, advocating for equitable strategies to mitigate the disproportionate effects of urban heat. The objectives of this study are as follows:

1. To examine the SUHI in Bratislava
2. To calculate the HVI for different age groups
3. To analyze the spatial relationship between SUHI and HVI indicators using bivariate analysis.

Study area

The study area under consideration is Bratislava, the capital city of the Slovak Republic, situated in the southwestern region of the country, proximate to the borders with Austria and Hungary (Figure 1). Spanning an area of approximately 367.6 km², Bratislava is the largest city in Slovakia in terms of both geographical extent and population, with 475,503 inhabitants recorded in 2021, as reported by the Statistical Office of the Slovak Republic (Statistical Office of the Slovak Republic, 2022). The Danube

River traverses the city, while the Morava River delineates its western boundary. Positioned at the base of the Small Carpathian Mountains, Bratislava exhibits notable variations in settlement patterns. The northern section of the city extends into the hilly terrain of the Malé Karpaty, with elevations ranging from 162 to 559 meters, whereas the southern section is situated in the flat Danube Lowland, reaching elevations up to 200 meters above sea level. The highest elevation, Devínska Kobyla, is 514 meters, and the lowest point is 126 meters above sea level (Šalkovič & Pauditšová, 2023). Bratislava is characterized by a mild continental climate, with an average annual temperature of 10°C and an average annual precipitation of 738 mm. The city is administratively divided into five districts (Bratislava I to V), with urban greenery comprising approximately 30% of its area, although its distribution is notably uneven (Bobáľová et al., 2024). The contemporary city has developed through the amalgamation of its historic core with surrounding villages. The study area includes 36 cadastres (basic territorial units), comprising 19 cadastres within the city of Bratislava and 17 cadastres from adjacent villages (Baus et al., 2014). This diverse geographical and administrative composition renders Bratislava a distinctive region for investigation.

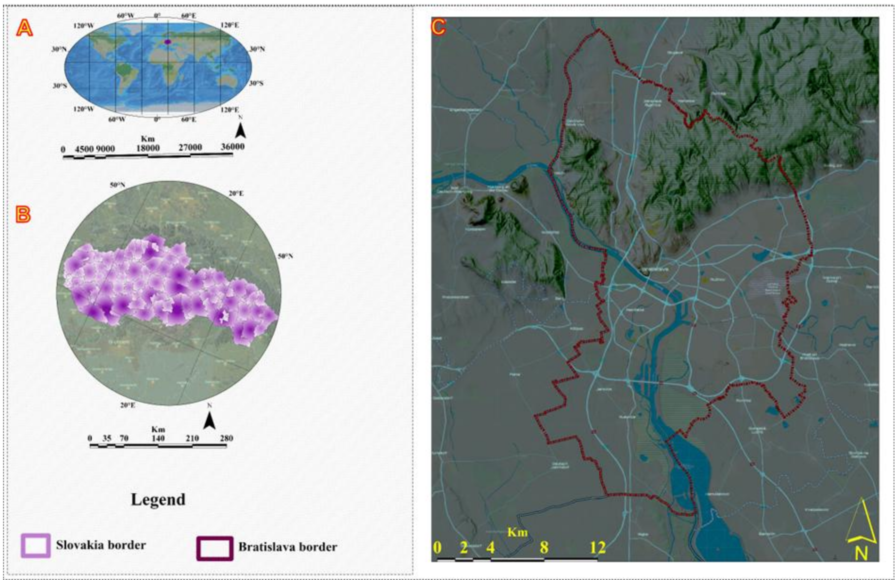

Figure 1. Location of the studied area

Data

In this study, Landsat 8 imagery from the summer of 2020 was utilized to calculate Land Surface Temperature (LST) and Surface Urban Heat Island (SUHI) effects. The sensor's spatial resolution is 30 meters for optical bands and 100 meters for thermal bands, with a temporal resolution of 16 days, which has been reduced to 8 days with the inclusion of Landsat 9 calculations. Additionally, data from worldpop.org were employed to assess the vulnerability of different age groups. These data possess a spatial resolution of 100 meters (on a 100-meter grid) and are available for various age groups from 2000 to 2020. In this research, age categories were defined as 0–5 years for children, 5–65 years for youths and adults, and over 65 years for the elderly.

Method

Principle of the Split-Window Algorithm

The split-window algorithm, based on radiative transfer theory, enables the estimation of land surface temperature (LST) under conditions of cloudlessness and thermodynamic equilibrium. The radiance Bi(Ti) observed at the top of the atmosphere (TOA) in a thermal infrared channel of a satellite sensor can be approximated as follows (Du et al., 2015):

$$\mathrm{Bi(Ti)} = \varepsilon\mathrm{i}\,\mathrm{Bi(Ts)}\,\tau\mathrm{i} + (1 - \varepsilon\mathrm{i})\,\mathrm{R}\downarrow\mathrm{atm,i}\,\tau\mathrm{i} + \mathrm{R}\uparrow\mathrm{atm,i} \quad (1)$$

In this context, τi signifies the effective atmospheric transmittance for channel i, while εi denotes the effective surface emissivity of the channel. The Planck function Bi characterizes the radiance, with Bi(Ts) representing the radiance for a blackbody surface at temperature Ts (in Kelvin). The terms R↑atm,i and R↓atm,i correspond to the upward and downward atmospheric thermal radiances, respectively. The initial term in Equation (1) accounts for surface-emitted radiation attenuated by the atmosphere. The second term reflects the downward atmospheric radiance that is reflected by the surface and subsequently reaches the sensor, whereas the third term represents the direct upward atmospheric emission detected by the sensor. Equation (1) suggests that accurate Land Surface Temperature (LST) retrieval requires information on surface emissivity and atmospheric conditions. The split-window algorithm mitigates atmospheric effects by exploiting differential absorption between two adjacent thermal infrared channels, typically centered around 11 and 12 μm. By combining the brightness temperatures linearly or nonlinearly, the algorithm estimates LST without necessitating precise atmospheric profile data during satellite acquisition, thereby making it widely applicable for LST retrieval across various sensors. An enhanced version of the generalized split-window algorithm, introduced by Wan (2014), incorporates a quadratic term based on the brightness temperature difference between the adjacent channels (Ti, Tj), expressed as:

$$\mathrm{LST} = \mathrm{b0} + (\mathrm{b1} + \mathrm{b2}\,\varepsilon/(1-\varepsilon) + \mathrm{b3}\,\Delta\varepsilon\text{^}2)\,(\mathrm{Ti} + \mathrm{Tj})/2 + (\mathrm{b4} + \mathrm{b5}\,\varepsilon/(1-\varepsilon) + \mathrm{b6}\,\Delta\varepsilon\text{^}2)\,(\mathrm{Ti} - \mathrm{Tj})/2 + \mathrm{b7}\,(\mathrm{Ti} - \mathrm{Tj})\text{^}2 \quad (2)$$

In this equation, Ti and Tj are the TOA brightness temperatures for channels i (~11.0 μm) and j (~12.0 μm), respectively. The term ε represents the mean emissivity of the two channels ($\varepsilon = 0.5[\varepsilon i + \varepsilon j]$), and

Δε denotes the emissivity difference (Δε = εi − εj). The coefficients bk (where k = 0,1,…,7) are determined using simulated datasets.

Detection of Surface Urban Heat Island (SUHI)

The primary focus of this study is the calculation of the SUHI index, determined using Equation 3. In this equation, LST represents the land surface temperature value of an individual pixel, LSTmean denotes the average LST across the study area, and STD refers to the standard deviation of LST values (Aghazadeh et al., 2023). Based on Equation 3, LST corresponds to the value of each pixel in an image, while LSTmean represents the average value of all pixels within the image. The STD encapsulates the standard deviation of all pixel values over a specified temporal period for the given image. In other words, the STD in Equation 3 reflects the standard deviation of LST values across all pixels in the analyzed LST image. Consequently, the SUHI index is a dimensionless quantity.

$$\mathrm{SUHI} = (\mathrm{LST} - \mathrm{LSTmean}) / \mathrm{LSTstd} \quad (3)$$

Heat Vulnerable Index (HVI)

In this study, we utilized the Socially Vulnerable Groups and the SUHI to calculate the Heat Vulnerability Index. Initially, this index was determined for each vulnerable group using Equations 4–6. Subsequently, the index was aggregated across all vulnerable groups in accordance with Equation 7 (Table 1):

Table 1. HVI index formula and description

HVI	Formula	Description	Equation
Children	$HVI_C = P_C \cdot SUHI$	In this context, HVI_C, $HVI_{A\&Y}$, and HV_E represent the Heat vulnerability of children, young adults, adults, and the elderly, respectively. P_C, $P_{Y\&A}$, and P_E denote the populations of children, young adults, adults, and the elderly, respectively. The weights assigned to these vulnerable groups, denoted as w_C, $w_{Y\&A}$, and w_E, were determined using the CRITIC method. Additionally, SUHI refers to surface urban heat islands.	4
&Youths Adults	$HVI_{A\&Y} = P_{A\&Y} \cdot SUHI$		5
Elderly	$HVI_E = P_E \cdot SUHI$		6
C.A&Y. E	$HVI_{C.A\&Y.\,E} = (P_C . w_C .\, SUHI) + (P_{A\&Y} . w_{A\&Y} .\, SUHI) + (P_E . w_E .\, SUHI)$		7

CRITIC method

The CRITIC method effectively captures the distributional differences among indicators and determines their weights based on the interplay of contrast strength and conflict among them (Qi et al., 2022). In this context, contrast strength is quantified through the standard deviation, where a higher standard deviation indicates more pronounced differences, thereby exerting a greater influence on the bearing capacity. Conversely, a stronger correlation between indicators reduces conflict, strengthens their interdependence, and amplifies their impact on the bearing capacity. The computational procedure involves the following steps: initially, the standard deviation and covariance for each indicator dataset are computed, followed by the construction of the covariance matrix. Subsequently, the correlation coefficient matrix, $\boldsymbol{rij}$, is derived from the covariance matrix.

$$\mathrm{Rj} = \sum_{i=1}^{n}(1 - \mathrm{rij}) \qquad \mathrm{Cj} = \sigma\mathrm{j} \times \mathrm{Rj} \qquad \mathrm{W\,j} = \frac{\mathrm{C_j}}{\sum_{j=1}^{n}\mathrm{Cj}} \qquad \text{8-10}$$

Matrix relationship (Bivariate analysis) for spatiotemporal analysis (<u>Sequential-sequential type</u>)

The matrix relationship assessment framework is designed to represent quantitative associations and identify interconnections among various factors. To illustrate the linkage between pairs of variables, this framework utilizes a spectrum of color gradients, systematically categorizing the colors associated with each variable into distinct color groups. The outcome of this framework is a visual map that effectively demonstrates the interconnections and dependencies among the variables. Moreover, when variables exhibit overlapping data, a normalization technique may be employed to enhance the visualization's clarity. This framework is divided into four distinct categories, each comprehensively described in Figure 3 (Brewer, 2016).

Sequential-sequential

This approach is utilized to evaluate the connection between two numerical variables or a defined group of quantitative factors associated with a specific geographical region. It is primarily applied to vector data that includes an attribute field, facilitating comprehensive statistical evaluations. A notable feature of this model is its ability to illustrate smooth spatial transitions, enabling researchers to measure trends and detect spatial groupings where distinct patterns emerge. For instance, it can depict the spatial association between unoccupied land and crime rates in a city, assisting policymakers in determining if neglected properties are linked to heightened criminal behavior. Beyond urban studies, this model is highly relevant in economic geography, where it can explore spatial relationships between household earnings and property values, or in agriculture, where it connects soil nutrient levels to agricultural productivity. This technique enables in-depth analysis of spatial trends through numerical data, facilitates predictive modeling based on past correlations, and assists in identifying high-risk areas for targeted policy actions (Brewer, 2016).

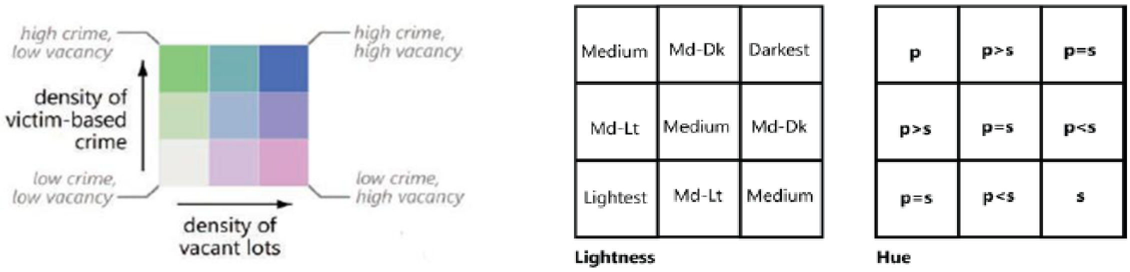

Figure 2. Sequential-sequential type matrix relationship model

RESULT

LST and vulnerable people

Figure 3 presents the Land Surface Temperature (LST) alongside the spatial distribution of vulnerable population groups, categorized into age groups of 0–5, 5–65, and >65 years, corresponding to children, adults, and the elderly, respectively. The figure indicates that the northeastern, southeastern, northwestern, and southern regions of the study area exhibit the highest LST values. The mean LST across the study area is reported to be 30.79°C. In terms of the maps depicting vulnerable population groups, the 0–5 age group demonstrates an average population density of 0.35 for male children and 0.33 for female children per pixel. For the 5–65 age group, the average population density is 2.37 for males and 2.49 for females. Lastly, for the >65 age group, the average population density is 0.43 for males and 0.67 for females. These findings suggest that, within the study area, male children outnumber female children in the 0–5 age group, whereas females outnumber males in the other two age groups, with the disparity being notably more pronounced in the >65 age group (Figure 3).

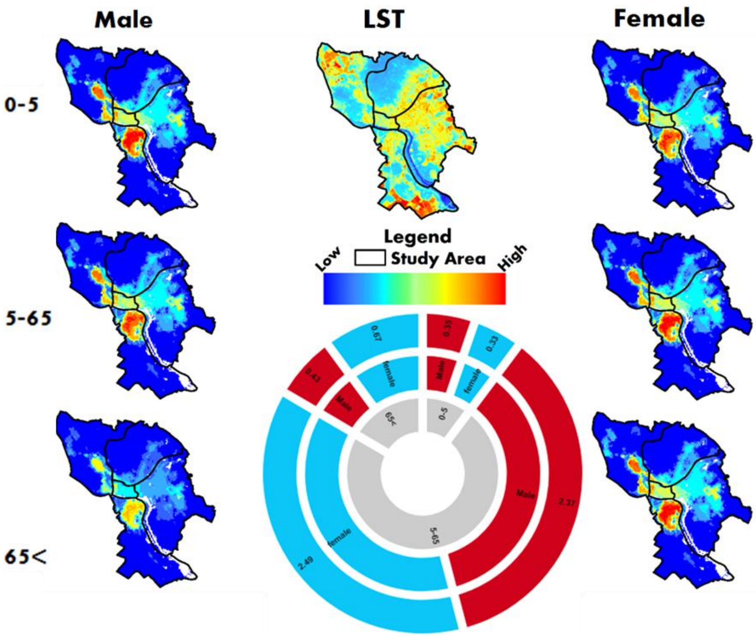

Figure 3. Spatial distribution of vulnerable population groups and LST

SUHI and HVI

Figure 4 presents the outcomes of the SUHI and HVI indicators. The HVI was calculated separately for the previously mentioned vulnerable groups and as a composite index. To derive the composite HVI, the CRITIC method was utilized to assign weights to each vulnerability group, as detailed in Table 2. The figure indicates that heat islands are predominantly located in the northeastern, southeastern, northwestern, and southern regions of Bratislava. Furthermore, the minimum, maximum, and mean values of this index are -2.29, 3.87, and 0.001, respectively. In terms of the HVI, the spatial distribution of all vulnerable groups is consistent, with the highest concentration observed in the southwestern part of the study area, specifically in Petržalka. Therefore, interventions to mitigate urban heat islands should be prioritized in this area to alleviate the adverse effects of heat stress, particularly for vulnerable age groups such as children and the elderly, who are the primary focus of this study.

Table 2. Weights Derived from the CRITIC Method for Vulnerable Groups

Vulnerable group	Female	Male
0-5	0.336	0.333
5-65	0.327	0.326
65<	0.336	0.341

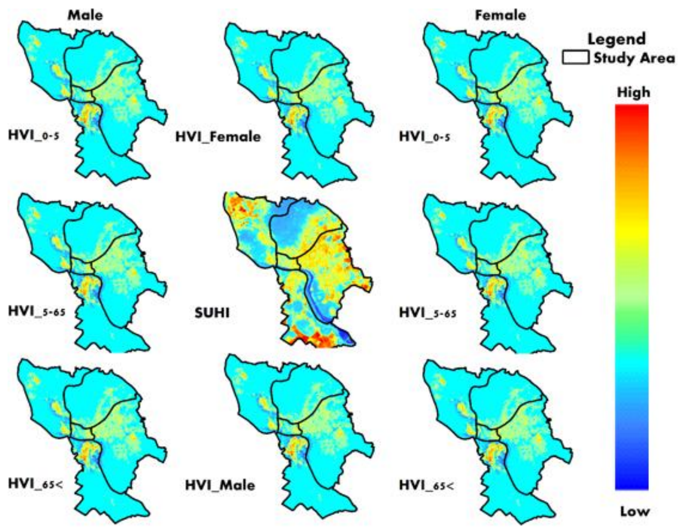

Figure 4. Spatial distribution of SUHI and HVI indices for vulnerable population groups

Bivariate analysis

The analysis of the provided maps, illustrating the bivariate relationship between the Surface Urban Heat Island (SUHI) intensity index and the Heat Vulnerability Index (HVI) for males and females, reveals analogous spatial distribution patterns for both indices. The maps employ a color matrix to categorize regions based on SUHI intensity (ranging from low to high on the horizontal axis) and HVI (ranging from low to high on the vertical axis). Darker shades, such as deep purple, denote areas with elevated SUHI and HVI, whereas lighter shades, such as pale pink, correspond to regions with lower values. The uniform color distribution across the maps for both genders suggests no significant differences in the patterns of heat vulnerability and SUHI intensity between males and females. A closer examination indicates that the central and eastern regions, marked by darker purple hues, exhibit the highest levels of SUHI and HVI, indicating a pronounced concentration of urban heat island effects and thermal vulnerability in these areas. These zones likely correspond to densely populate urban centers characterized by limited vegetation, high population density, and extensive impervious surfaces, which contribute to elevated temperatures and increased thermal vulnerability. Conversely, peripheral areas, particularly in the western and southwestern parts, are depicted in lighter shades, such as pink and pale blue, signifying lower SUHI and HVI levels. These regions may encompass rural or suburban areas with greater vegetation cover and lower population density, which mitigate urban heat island effects. Furthermore, the striking similarity between the maps for males and females underscores that environmental and urban factors exert comparable influences on both genders, with negligible gender-based differences in this context. This finding aligns with previous studies emphasizing the role of environmental factors in driving SUHI intensity and highlights the critical need for urban planning strategies to mitigate SUHI and HVI impacts. Targeted interventions in high-priority areas (darker-colored regions), such as expanding green spaces, employing high-albedo building materials, and enhancing cooling systems, are recommended to reduce thermal vulnerability. This analysis underscores the importance of addressing spatial patterns in urban planning to alleviate the impacts of climate change and safeguard public health (Figure 5).

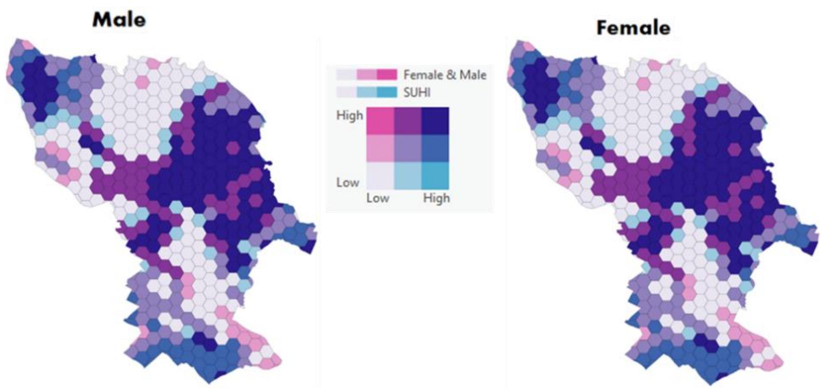

Figure 5. Bivariate spatial relationship analysis between SUHI and HVI for vulnerable population groups

DISCUSSION

The findings of this study elucidate the complex relationship between LST, SUHI index, and HVI within the study area, with a particular emphasis on Bratislava. The spatial distribution of LST and SUHI reveals that the northeastern, southeastern, northwestern, and southern regions exhibit the highest thermal values, which are associated with densely urbanized areas, extensive impermeable surfaces, and limited vegetation cover. Furthermore, the elevated concentration of HVI in the southwestern region, notably in Petržalka, highlights the significant vulnerability of sensitive age groups, specifically children (0–5 years) and the elderly (>65 years). These findings underscore the necessity for targeted interventions in these areas, such as the augmentation of green spaces and the utilization of high-albedo building materials, to mitigate the adverse effects of heat stress. The uniformity of HVI and SUHI distribution patterns between men and women suggests a similar impact of environmental and urban factors on both genders, indicating no significant gender differences in heat vulnerability in this context. This observation aligns with the findings of Macintyre et al. (2018), who demonstrated that the environmental temperature experienced by individuals across different age groups does not vary significantly by geographic location, and nearly all age groups in a given area encounter similar temperatures during heat events. Additionally, the results are consistent with the studies by Sánchez-Guevara Sánchez et al. (2017), which identified a significant vulnerable population located in some of the hottest areas of Madrid, posing substantial health risks to these groups. These results emphasize the importance of urban planning to mitigate the impacts of urban heat islands and safeguard public health, particularly in areas at higher risk due to population density and urban characteristics. A detailed analysis of bivariate maps depicting the relationship between SUHI and HVI reveals a strong correlation between the intensity of urban heat islands and heat vulnerability in the central and eastern regions of Bratislava. These areas, marked with darker colors (e.g., deep purple), are at greater risk due to high population density, dense urban infrastructure, and a lack of vegetation cover. In contrast, peripheral areas, particularly in the west and southwest, exhibit lower levels of SUHI and HVI, attributable to greater vegetation cover and lower population density. These spatial differences underscore the importance of designing heat island mitigation strategies tailored to the characteristics of each area. Recommendations such as the development of green infrastructure, enhancement of cooling systems, and the use of high-reflectivity building materials can help reduce heat vulnerability, especially for sensitive groups. This study also demonstrated that environmental and urban factors impact both men and women equally, underscoring the need for inclusive policies in urban planning.

Conclusion

This research provides compelling evidence that the spatial distribution of the SUHI and HVI is intricately linked to both environmental and urban factors, including population density and land cover characteristics. Areas exhibiting elevated SUHI and HVI, particularly in densely populated urban regions, necessitate targeted interventions such as the enhancement of green infrastructure, the utilization of materials with high reflectivity, and the improvement of cooling systems. Comparative analyses with existing studies underscore the pressing need to integrate diverse datasets into urban planning to mitigate heat island effects and safeguard vulnerable populations. Future research should prioritize evaluating the efficacy of proposed interventions and investigating the long-term impacts of climate change on demographic vulnerability. This study advocates for localized strategies in sustainable urban management and climate resilience, offering an evidence-based framework for policy development.

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Facial Matching Technologies In Smart Cities: Enhancing Public Safety And Personalized Urban Services

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Manual identification and verification of individuals in dense urban environments are time-consuming and error-prone. Governments and businesses require efficient, real-time solutions to enhance public safety and deliver personalized urban services (e.g., identifying suspects, contactless access). A facial matching system powered by Machine Learning algorithms and Computer Vision automates the identification process. The system integrates with smart city infrastructure (e.g., CCTV networks, IoT devices) to detect faces in real-time crowds, extract unique facial features and match features against databases for identification or authentication.

Facial matching systems rely on deep learning-generated embeddings. Compact numerical representations called feature vectors that encode unique facial characteristics. Unlike traditional pixel-based comparisons, embeddings enable efficient similarity matching by converting faces into mathematical vectors in a high-dimensional space. These models are trained to ensure that embeddings from the same person are clustered closely, while those from different individuals are pushed apart.

FaceNet: A Unified Embedding for Face Recognition and Clustering

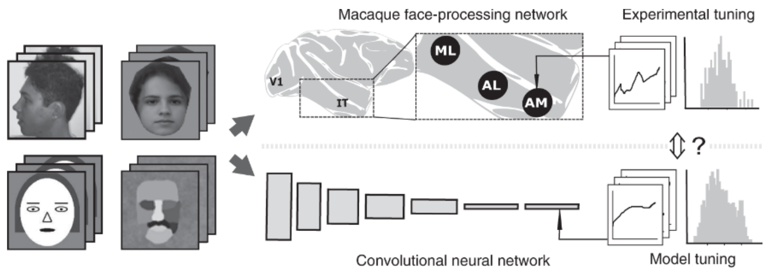
FaceNet is a deep learning-based facial recognition system developed by Google researchers in 2015. Unlike traditional methods that rely on intermediate representations (e.g., landmark detection), FaceNet directly learns a compact Euclidean embedding (128-dimensional vector) from face images, enabling highly efficient face verification, recognition, and clustering.

DeepFace: Facebook's Pioneering Deep Learning Model for Face Recognition

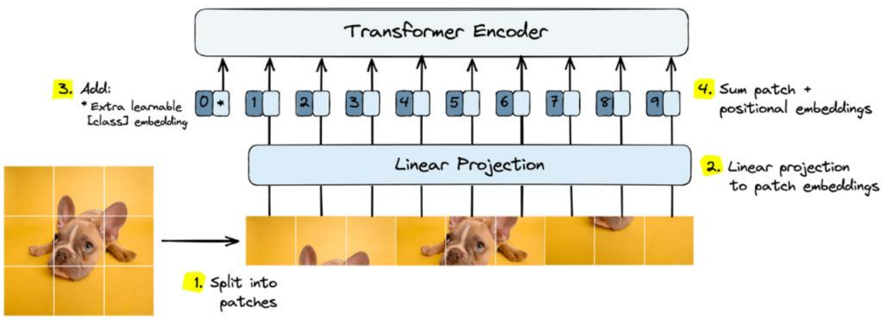
DeepFace is a deep neural network-based facial recognition system developed by Facebook AI Research (FAIR) in 2014. It was one of the first models to achieve near-human-level accuracy on the Labeled Faces in the Wild (LFW) benchmark, significantly advancing the field of facial analysis.

ViT-Face: Vision Transformers for Facial Recognition

ViT-Face is a facial recognition model based on Vision Transformers, adapting the success of transformer architectures originally developed for Natural Language Processing. Unlike traditional Convolutional Neural Networks (CNNs) like FaceNet or DeepFace, ViT-Face processes faces as sequences of image patches, capturing long-range dependencies and global facial structures more effectively.



Picture 1. The standard representation of Convolutional Neural Networks



Picture 2. The standard representation of Vision Transformers

Facial matching system create a unique representation for each individual it encounters. To ensure high performance of the system, it is necessary to store and process millions of images in real time. There are a lot of technologies for quick vector search. One of them is FAISS. The library optimized for fast nearest-neighbor search in high-dimensional spaces. It reduces search complexity Big O notation:

$$O(n) \rightarrow O(\log(n)) \tag{1}$$

Effective vector search processing is provided with vector databases. Their goal is to ensure fast vector search. The best approach for building the system is combination FAISS with vector stores, and in some cases PCA for decreasing dimensions, and resourses optimization.

Contactless Fare Gates with Liveness Detection

The primary goal is to provide a seamless, secure, and efficient passenger experience while reducing reliance on physical tickets or IC cards. Key objectives include implementing contactless access through facial authentication, preventing identity spoofing with liveness detection, and optimizing operational efficiency during peak travel times. The system target is to reach processing speed under **0.5** second per passenger.

The system is controlled by False Acceptance (FAR) and False Rejection rate (FRR):

$$FAR = \frac{False\ Acceptances}{Total\ Incorrect\ Attempts} * 100\% \tag{2}$$

$$FRR = \frac{Number\ of\ false\ rejections}{Total\ number\ of\ genuine\ attempts} * 100\% \tag{3}$$

Facial recognition system represents a significant advancement in smart city transit solutions. By combining high-speed processing, robust anti-fraud measures, and strict privacy protections, the project sets a global standard for ethical and efficient public infrastructure. Future work will focus on scaling the technology while maintaining its commitment to security and user trust.

Conclusion

Facial matching technologies offer a powerful solution for enhancing public safety and personalized services in smart cities, leveraging AI models like FaceNet and ViT-Face alongside efficient vector search systems such as FAISS. To build an effective system, key considerations include real-time processing, robust anti-spoofing measures, and strict privacy safeguards to ensure both accuracy and public trust. As these technologies evolve, maintaining a balance between performance, security, and ethical compliance will be essential for their sustainable integration into urban infrastructure.

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Budget Forecasting using Data Science Methods

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Abstract: This study proposes a lightweight pipeline for forecasting budgets from as few as 21–24 monthly observations. Building on classical time-series methods, our approach fits separate Seasonal ARIMA (SARIMA) and TBATS models, then forms a convex ensemble whose weight is selected by minimizing root-mean-square error (RMSE) on validation data. Experiments on two real ledgers—personal finance (24 months) and corporate energy costs (21 months)—demonstrate that the optimized ensemble (90% SARIMA, 10% TBATS) reduces MAE by 4 % and RMSE by 2.6 % relative to SARIMA alone, and by 6–9 % relative to each component. Despite differences in scale, chart-of-accounts structure, and seasonality patterns, both ledgers share recurring monthly and quarterly cycles as well as unpredictable "shock" expenses, which our unified workflow captures without per-case retuning.
Keywords: Budget forecasting, Seasonal time-series, SARIMA, TBATS, Ensemble modelling, Short-data forecasting

Introduction

Forecasting cash-flow budgets from short, sparse historical records is a pervasive challenge across household finance, small- to medium-sized enterprises, and public agencies. While deep-learning architectures require hundreds of observations, practitioners often have no more than 24 months of data. Traditional statistical methods—if used alone—either overfit transient noise or fail to capture multiple seasonalities and irregular spikes. We therefore adopt a hybrid approach, pairing the strength of SARIMA's seasonal differencing with TBATS's capability to model complex or nested cycles, then blending them into a single, interpretable forecast.

Related Work

The Box–Jenkins ARIMA framework, extended to SARIMA for regular seasons, remains the cornerstone of univariate time-series forecasting [1]. To accommodate multiple or evolving seasonal patterns, Hyndman et al. introduced TBATS—integrating trigonometric seasonality, Box–Cox transforms, and ARMA errors [2]. More recently, Bhambu et al. demonstrated that recurrent-ensemble RVFL neural networks can outperform classical methods on financial series of similar length [3], while Liu & Wang's survey highlights that deep-learning solutions still struggle on very short panels [4]. Probabilistic forecasting advances such as Ensemble Conformalized Quantile Regression offer robust uncertainty intervals but add computational complexity [5]. Transformer-based architectures have also been adapted for time series, excelling on long sequences but incurring heavy resource demands [6]. We ground our work in the CRISP-DM process model to ensure reproducibility and broad applicability [7].

Data and Methods

We analyze two real ledgers: a personal-finance record with 24 monthly aggregates and a corporate energy-cost record spanning 21 months. Outliers are removed via the interquartile range rule and variance stabilized by a Box–Cox transform. Data are divided into a training set and a six-month hold-out for back-testing.

A SARIMA(p,d,q)(P,D,Q)$_{12}$ model is fitted by minimizing AIC over a restricted parameter grid, capturing the dominant monthly cycle. Separately, TBATS is trained with up to two harmonic seasonal terms to address nested or drifting seasonal effects. Forecasts are then blended as in (1).

$$\hat{y}_t(\omega) = \omega \hat{y}_t^{SARIMA} + (1-\omega)\hat{y}_t^{TBATS} \qquad (1)$$

ω is chosen from {0.50, 0.55, …, 1.00} to minimize RMSE on the hold-out. All computations complete in under one minute on a standard laptop (Python 3.10, statsmodels, tbats).

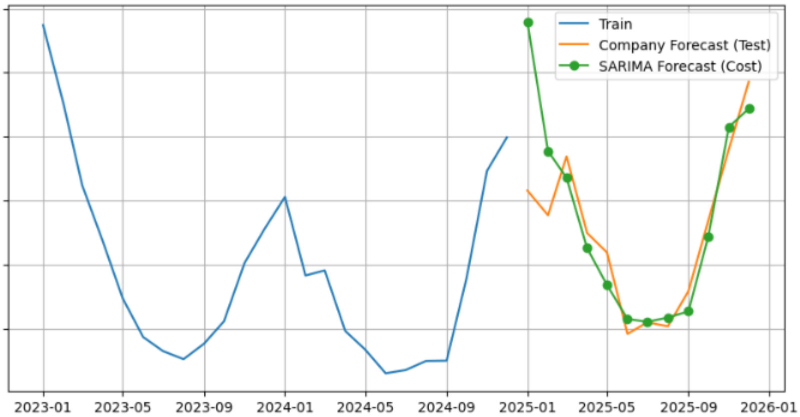
Results and Findings

Table 1 summarizes six-month back-test performance. SARIMA alone attains MAE = 26 725, RMSE = 42 975, MAPE = 9.19 %, and R^2 = 0.47. TBATS and an XGBoost baseline perform poorly on these short panels. The optimized ensemble (90 % SARIMA, 10 % TBATS) achieves MAE = 25 727 (–4 %) and RMSE = 41 845 (–2.6 %), with R^2 = 0.50.

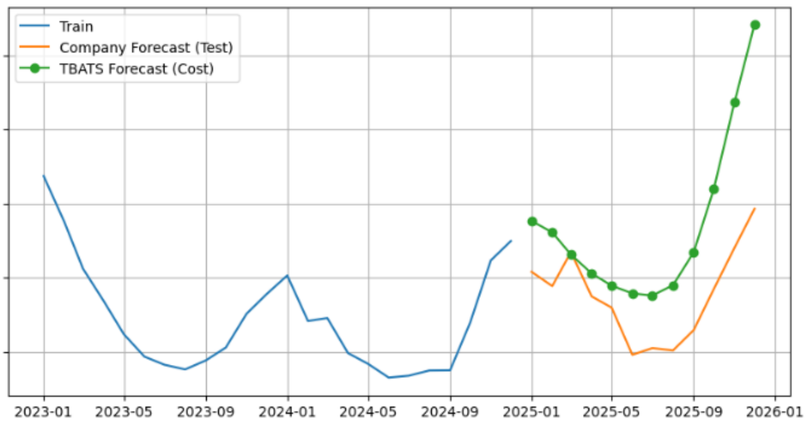
FORECAST METRICS ON THE ENTERPRISE LEDGER.

Model	***MAE***	***RMSE***	***MAPE (%)***	***R²***
SARIMA	26 725	42 975	9.19	0.47
TBATS	94 339	115 862	33.83	– 2.85
XGBoost	80 458	94 879	34.33	– 1.54
Ensemble of SARIMA and TBATS (0.9/0.1)	25 727	41 845	9.06	0.50

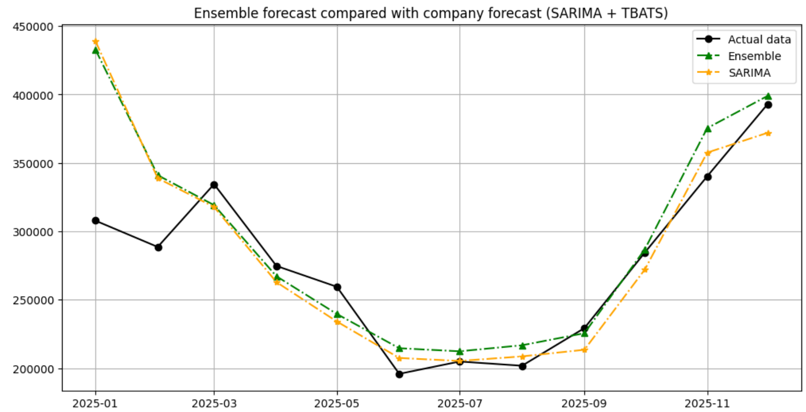
Figures 1–3 illustrate that SARIMA captures pronounced peaks but amplifies noise, TBATS smooths fluctuations but lags trend shifts, and their blend preserves both responsiveness and stability. Importantly, applying the same pipeline, parameters, and weight to both personal and corporate data yields consistent accuracy gains without per-case retuning.



Comparison of actual data with SARIMA
monthly energy-cost forecast



Comparison of actual data with TBATS
monthly energy-cost forecast



Comparison of actual data with SARIMA + TBATS ensemble and SARIMA monthly energy-cost forecast

Scientific Novelty

Our contribution demonstrates that a simple, grid-optimized convex blend of SARIMA and TBATS delivers state-of-the-art accuracy on extremely short time series (≤ 25 points). Unlike deep-learning ensembles that demand extensive data and computation [4, 6], our method runs in under a minute on commodity hardware, provides diagnostic residuals for auditability, and applies unchanged to budgets of vastly different scales.

Conclusions and Outlook

The weighted SARIMA–TBATS ensemble offers a computation-light, interpretable solution for budget forecasting on short, noisy ledgers. Future work will explore the integration of exogenous regressors (e.g., commodity prices, weather indices), dynamic weight adjustment across seasons, and embedding the pipeline into BI platforms for live decision support.

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Post-War Urban Transformation in Ukraine: A Path Towards Sustainable Recovery

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Abstract: Russia's full-scale invasion of Ukraine has inflicted widespread destruction on urban infrastructure and left deep societal scars. This paper explores the ongoing post-war urban transformation in Ukraine, emphasizing sustainable recovery through energy-efficient reconstruction, digital innovations, and inclusive governance. It highlights key initiatives such as the "Green Post-War Recovery of Ukraine" and SUN4UkrainianCities, which align rebuilding efforts with climate goals and community needs. The study also examines mental health interventions, international cooperation, and the use of digital platforms for planning and citizen support. Ukraine's reconstruction is not merely physical—it represents a reimagining of urban life rooted in resilience, equity, and sustainability.
Keywords: urban transformation; post-war recovery; sustainable development; rebuilding cities, importance of international support.

Russia's full-scale war against Ukraine has left scars on most cities of Ukraine in the form of destroyed infrastructure, homes, basic services for citizens, damaged or destructed cultural heritage, death and suffering. History says "Any war always ends in peace", and what future peace will be depends on the consciousness of citizens Ukraine Ukraine will soon face unprecedented opportunities: rebuilding destroyed cities on the basis of sustainable development, which includes resilience to future crises, social engagement, and inclusion . The process of rebuilding Ukrainian cities, which began with the beginning of the full-scale war and continues in parallel with new destruction, is rather a reconstruction from scratch and symbolizes a rethinking of a more comfortable, efficient, calmer and more humane urban life.

One of the fundamental factors of post-war recovery in Ukraine is the strategy of "Green Post-War Recovery of Ukraine" [1], which integrates the principles of sustainable development into all levels of the reconstruction process, from urban planning to the implementation of infrastructure projects, by improving energy efficiency and the introduction of clean technologies. The non-profit organization SUN4UkrainianCities, with funding from the European Union, adapts urban reconstruction plans to achieve climate neutrality of twenty municipalities selected for technical assistance in order to align reconstruction projects with international standards of sustainable development [2].

Visions and new models based on sustainable development involve the repair and reconstruction of buildings using energy-efficient technologies, a comprehensive transformation of urban space, which involves increasing the area of green spaces, and the creation of an ecological public transport network.

At the same time, no urban transformation process will be successful without the active participation of its citizens. SUN4UkrainianCities initiatives promote mechanisms to increase the significance of local self-government and measures to involve citizens in the decision-making process. In cities such as Chernihiv and Mykolaiv, conferences, surveys, open tables and seminars are held to ensure the priority needs of the population. Such steps of dialogue with society are a key factor for the effective use of resources and strengthening social interaction [3].

As of October 2024, approximately 46% of Ukrainians have mental health problems caused by the war. In Kyiv, the situation is even more difficult, with 80% of the capital's residents showing symptoms of post-traumatic stress disorder (PTSD). The solution and example of the application of digital technologies at the local level, not only in city administration, but also in providing mental assistance to the population, is the initiative of the digital platform "Digital Kyiv". The added tool for supporting the mental health of the population allows access to psychological consultations, therapy and resources for emotional well-being [4].

The use of digital tools goes beyond mental health care. In collaboration with UN-Habitat, some Ukrainian cities are using platforms of sophisticated analytical models to calculate the cost of damage, plan resource use, optimize logistics, and compare probabilities [5].

Urban transformation in Ukraine is taking place thanks to strong international support. The European Union, together with the United Nations Development Programme, has established ten Recovery and Development Offices in different regions of the country. These are coordination centers between local governments, multilateral organizations and civil society actors, promoting a shared vision for Ukraine's urban future [6].

In addition, financial institutions such as the European Bank for Reconstruction and Development (EBRD) have made significant investments of at least US$1.56 billion to strengthen strategic sectors such as energy, critical infrastructure, and small and medium-sized enterprise development. This funding has enabled the physical reconstruction and economic recovery of cities severely affected by the war [7].

But the path to sustainable recovery is not without challenges. Curfews, constant shelling, and mined locations complicate construction work. The problems of debris disposal, temporary housing for internally displaced persons, and infrastructure restoration—water supply, electricity, and transport—require flexible solutions and effective coordination. In addition to economic and environmental challenges, social challenges—a deteriorating demographic situation due to the outflow of intellectual capital, low birth rates, and high mortality rates—all require adaptive, inclusive urban planning.

The war has exposed the vulnerabilities of urban systems, but it has also catalyzed their capacity for transformation. As noted at the outset, Ukraine faces a choice: to rebuild the past or to shape the future. Decisions made today will affect the country for decades to come. It is crucial that the reconstruction process is based on the principles of integrity, sustainability, equity, inclusion, and efficiency.

The post-war transformation of Ukrainian cities is not just about patching holes and laying bricks, it is the beginning of new shifts in national consciousness, reassessment of current circumstances, and changes in the established order for the sake of a bright and peaceful future. Thanks to the support of international partners, the introduction of technologies, and the active participation of citizens, Ukraine is forming a new model of urban life, which may become a future experience for other countries in the context of rehabilitation after armed conflicts. Cities will never be the same again — but they can become better: greener, cleaner, safer, more comfortable.

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The Role of Recreational Opportunities and Economic Impact of Cultural Ecosystem Services in Urban Public Spaces for Tourism

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Abstract: As urban populations continue to grow, the role of urban public spaces in delivering Cultural Ecosystem Services (CES) becomes increasingly significant, especially in enhancing tourism and local economies. CES, including recreation, aesthetics, cultural identity, and education, are non-material advantages obtained from ecosystems that enhance the connection between humans and the environment. This study explores how recreational and economic opportunities offered by urban public spaces contribute to tourism growth and city attractiveness. Through a comprehensive review of approximately 40 recent academic sources, it highlights global successful examples demonstrating how CES enhance urban vibrancy, support cultural expression, and stimulate economic development through tourism. The findings emphasize that integrating CES into urban planning is essential for sustainable tourism and urban resilience, encouraging cities to preserve natural and cultural heritage while boosting economic and social well-being.
Keywords: Cultural Ecosystem Services, Recreation, Tourism, Urban public spaces

Introduction

The United Nations projections show that the global population will reach approximately ten billion people by 2050, with two-thirds of the population living in cities (FAO, 2020). Urban spaces are increasingly important for providing the necessities of society in terms of economic and sustainable, resilient ecosystems (OECD, 2020). Urban areas encounter a distinct challenge as they predominantly depend on regions beyond their boundaries while simultaneously needing local provision for certain ecosystem services that cannot be moved, including regulating and cultural services (Go´mez-Baggethun and Barton, 2013). Ecosystem Services are defined as "the benefits individuals derive from ecosystems" (MEA, 2005) and are typically categorized into four types: provisioning services, regulating services, supporting services, and cultural services. While research on Cultural Ecosystem Services (CES) in rural regions appears rational, increased emphasis on urban areas could effectively address deficiencies related to diverse social groups, particularly in the context of the escalating urban population, which currently exceeds half of the global populace (Kosanic and Petzold, 2020). CES are essential elements of urban ecosystem services (Liu et al., 2021). These non-material services enable communities to get advantages from urban ecosystems by strengthening their relationship with nature (MEA, 2005; Clark et al., 2014; Dickinson & Hobbs, 2017). Urban public spaces enhance community well-being through accessibility, functionality, thoughtful design, and their role in fostering social connections (Dias et al., 2023; Keidar and Silver, 2024; Brown and Corry, 2020; Kapsalis et al., 2024; Sheller, 2023). These spaces are often catalysts for local economic development, attracting tourism and stimulating various sectors such as hospitality, retail, and recreation (Nag et al., 2024). Green public spaces contribute to urban biodiversity, improve air quality, and provide recreational opportunities (Besma and Belkacem, 2022; Sandaruwan and Hewawasam, 2021). Tourism is pivotal in the global economy, offering manifold benefits to destinations and visitors (Wondirad et al., 2021). It drives economic growth through spending on various sectors and fostering job creation (Moyle et al., 2020), facilitates cultural exchange by bringing people from diverse backgrounds together (Kastenholz & Gronau, 2022), supports conservation efforts (Cai et al., 2021), propels infrastructure development (Svitlichna et al., 2024), diversifies the economy (Chen & Li, 2023), and promotes peace and understanding through cross-cultural interactions while empowering local communities and preserving traditional livelihoods (Kohsaka & Rogel, 2021). CES is often overlooked in planning and management due to the challenges associated with its measurement (Hegetschweiler et al., 2017). While empirical research on CES has predominantly focused on urban landscapes from the perspective of local residents (Grzyb, 2024; Dai et al., 2019; Gai et al., 2023; Ferguson et al., 2024), studies exploring the role of CES of urban public spaces in increasing tourism are limited (Zoderer et al., 2016). To address this research gap, this study examines the impact of CES recreational and economic opportunities in urban public spaces on tourism growth. The aim of this study is to explore the perceived recreational and economic opportunities of urban public spaces and assess how they impact tourism.

Method

The present study, relying on documentary sources, provides an overview of up-to-date and emerging sources on the role of recreational opportunities and the economic impact of CES as a necessity for attracting tourists to urban public spaces in recent decades. In this study, by studying about 40 recent scientific articles, an attempt has been made to introduce this new approach and explain it comprehensively, along with successful global examples in this field.

Theoretical Framework

Recreation and Tourism Demand

Recreational opportunities in urban public spaces are a key attractor for tourists. Urban green spaces provide recreational opportunities such as walking, picnicking, and social gatherings. Tourists often prioritize these amenities, which can drive visitation rates and longer stays (Bing et al., 2021). These spaces, such as parks, greenways, and waterfronts, provide a variety of activities that enhance the tourist experience (Larson et al., 2016). Similarly, urban waterfront spaces, when combined with regional culture, create unique and attractive landscapes that foster social cohesion and identity, thereby enhancing their appeal to tourists (Xie, 2023). The availability of recreational opportunities in urban public spaces also influences the economic impact of tourism. For example, the Vistula River in Warsaw, Poland, is highly valued for its recreational benefits, with visitors expressing high satisfaction with the aesthetic and emotional experiences it provides (Grzyb, 2024).

Cultural identity and heritage are deeply intertwined with urban public spaces. These areas often serve as platforms for cultural expression, preserving and promoting local traditions, history, and artistic endeavors. For example, art festivals in public spaces, such as the Bandung Festival in Indonesia, have been effective in reconstructing cultural identity and promoting cultural tourism. These events not only celebrate local culture but also attract tourists and foster intercultural exchange and appreciation (Lahpan et al., 2024). In addition, urban public spaces often host historical and cultural landmarks that attract tourists. For example, the village of Dachra El Hamra in Algeria, with its unique architecture and integration into the natural landscape, is a cultural model that attracts visitors (Belhannachi et al., 2024). Among successful global projects is the transformation of underused spaces into vibrant public parks, such as the Jardim Botânico in Curitiba, Brazil, which has not only improved the urban landscape but also become a source of cultural pride and tourist attraction (Ribeiro & Silveira, 2006).

The economic implications of recreational opportunities in urban public spaces are profound. For instance, the development of urban waterfronts, such as those in Sydney and Toronto, has transformed these areas into vibrant tourist destinations, contributing significantly to local economies (Nag et al., 2025).

Economic Impact of Cultural Ecosystem Services

The economic impact of cultural ecosystem services in urban public spaces is significant. These services, which include aesthetic, educational, and recreational benefits, contribute to the local economy through tourism (Zheng et al., 2023). In addition to direct economic benefits, CES also contribute to the overall attractiveness of a city, making it a desirable destination for tourists. For example, the cultural heritage and educational values of urban parks in Zhengzhou, China, are highly appreciated by both local residents and visitors, contributing to the city's appeal as a tourist destination (Song et al., 2023). Investing in CES boosts local economies through cultural tourism. UNESCO notes that public spaces serve as platforms for festivals, markets, and art displays, generating revenue and community-led initiatives (UN, 2024). CES, such as aesthetic, educational, and recreational benefits, attract tourists. This influx of visitors generates revenue for local businesses, including hotels, restaurants, and shops (Li, 2024; Lew & Wu, 2017).

Conclusion

This research provides compelling evidence that CES in urban public spaces play a vital role in enhancing tourism by offering recreational, aesthetic, and cultural experiences that attract visitors. In conclusion, recreational opportunities and the economic impact of cultural ecosystem services in urban public spaces are essential for sustainable tourism development. Recreational opportunities of CES in urban public spaces are a powerful driver of tourism and a key influencer of cultural, economic, environmental, and social aspects of urban development. These spaces serve as cultural hubs, economic catalysts, environmental assets, and social venues, contributing to the overall sustainability and vibrancy of cities. The findings from various studies highlight the importance of understanding and integrating landscape management and planning to optimize the economic benefits of these services. By leveraging these insights, cities can enhance their appeal as tourist destinations while promoting the conservation of their cultural and natural heritage. Cities that integrate CES into urban planning can leverage these benefits to boost tourism revenue while fostering sustainable development.

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Development of models and information technology for predicting TV viewing metrics using data science methods

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Abstract: Accurate TV-metric forecasts are essential for broadcasters and advertisers. This study builds a data-science framework that predicts core measures—Rating, GRP, TRP and the Affinity Index—using panel people-meter data. Four models are compared on daily and weekly series: ARIMA, exponential smoothing (ETS), Prophet and an LSTM network. Parameters are auto-tuned, with performance tested by MAPE, RMSE and MAE. ARIMA and ETS lead (daily MAPE ≈ 10–13 %), and weekly aggregation improves accuracy further. By forecasting target and base GRPs we derive reliable affinity estimates, helping planners pick the most efficient channels and programmes and thus optimise campaign reach and cost-effectiveness.
Keywords: TV Audience Measurement, Affinity Index Forecasting, Time-Series Forecasting, Gross/Target Rating Points (GRP/TRP).

Introduction

In the highly competitive TV broadcasting market, reliable estimates of future audience levels are essential for decision-making. Broadcasters use audience forecasts to schedule programs and set advertising prices, while advertisers rely on them to allocate budgets and predict campaign reach. Key TV viewing metrics such as program Rating (the percentage of a target audience watching) and cumulative Rating Points (GRP/TRP) form the currency of TV advertising deals [1]. Even slight inaccuracies in these metrics can lead to suboptimal ad placements or mispricing of commercial slots. Therefore, developing accurate forecasting models for TV audience metrics is of great importance to maximize advertising efficiency and return on investment.

Forecasting TV viewership poses unique challenges. Television audiences exhibit strong temporal patterns (e.g. daily and weekly seasonality in viewing habits) and are influenced by content and external events (holidays, premieres, news cycles). Traditional forecasting approaches used in industry often rely on simple heuristics or historical averages. In this work, we leverage modern data science methods to improve forecast accuracy. We develop an information technology solution that integrates data-driven forecasting models into the TV audience measurement framework.

TV Audience Measurement and Metrics

Television audiences are measured with a panel of carefully selected households. Each home has a peoplemeter that logs viewing 24/7: household members press their button when they start or stop watching, while the device creates an audio fingerprint of the broadcast and matches it against a reference database to identify the channel. These second-by-second records are then projected to the whole TV population, letting analysts track ratings, audience flow and ad-campaign reach & frequency [2].

Several fundamental metrics are produced from the panel viewing data. Audience Rating (often just **Rating** or **TVR**, for "Television Rating") is the cornerstone metric that represents the average percentage of a given population (audience) that is watching a specific program or time period. In advertising, the concept of Rating Points is used to accumulate exposure over time or across multiple spots. One **Gross Rating Point (GRP)** represents one percent of the base audience viewing one advertising spot. The total GRPs of an advertising campaign is the sum of the ratings of all the ad spots in that campaign for the base audience. Similarly, **Target Rating Points (TRPs)** represent the sum of ratings among the target audience of interest. TRP is analogous to GRP but specifically for the target demographic a brand is aiming to reach.

For campaign targeting efficiency, the Affinity index is particularly valuable. The affinity (AFF%) is defined as the ratio of the target audience rating to the base audience rating for the same program or time period (Affinity Index Is An | PDF | Target Audience | Advertising). In formula:

$$\text{Affinity} = \frac{\text{TRP}}{\text{GRP}} \times 100\%, \qquad (1)$$

expressed as an index. An affinity above 100% (index > 1.0) means the program or channel skews more towards the target audience than the average channel, indicating a high concentration of the desired demographic[3].

In summary, the TV audience measurement system provides granular data on "who watched what and when," from which metrics like Rating, GRP, TRP, and affinity are computed. These metrics allow evaluation of advertising campaigns and are the target outputs for our forecasting models.

Forecasting

We worked with daily EqGRP data for a leading Ukrainian channel covering 1 Jan 2023 – 28 Feb 2025. Values are reported separately for the base audience and the target audience the daily affinity series is implicit as their ratio.

For model development, the data were split chronologically:

- Training window: 1 Jan 2023 – 31 Dec 2024.
- Test window: 1 Jan 2025 – 28 Feb 2025 (54 daily points ≈ 8 weeks).

Forecasting methods

- ARIMA – auto_arima (pmdarima) searched orders ≤ (3, 2, 3) × (2, 1, 2) with a seasonal difference D = 1; the AIC-best model showed white-noise residuals (Ljung-Box $p > 0.05$).
- ETS – ExponentialSmoothing tried additive seasonality (period 7) with/without damped trend; rolling validation selected ETS(A, Ad, A) for both series [5].
- Prophet – default Prophet (piece-wise linear trend, yearly + weekly seasonality) was fitted on training data and projected 8 weeks ahead; no holiday terms were added.
- LSTM – a single-layer, 50-unit LSTM (TensorFlow) used the past 14 days to predict the next; trained ≤ 200 epochs with Adam and early stopping, hyper-parameters tuned on late-2024 to minimize MAPE.

All implementations were in Python: *pmdarima* for ARIMA, *statsmodels* for ETS, *prophet* for Prophet, and *TensorFlow/Keras* for the LSTM. These four models were then evaluated on the reserved test period to compare forecast accuracy [4].

Results

All four models were fit on the daily data (2023–2024) and used to predict the daily EqGRP values. for January–February 2025. Table 1 summarizes the forecast accuracy for the target audience daily series in the test period. The ARIMA model achieved the lowest errors with a MAPE of about 11%, indicating its predictions were on average 89% accurate. The ETS model was a close second in performance. The Prophet model and the LSTM model yielded slightly higher errors (MAPE around 13–14%). In terms of RMSE, ARIMA and ETS were also better, suggesting they captured the day-of-week variation more effectively. The LSTM had a somewhat higher RMSE, which may reflect some difficulty in learning the weekly seasonal pattern or slight overfitting. Overall, the differences are not extremely large, but the ranking is consistent across MAE, RMSE, and MAPE: ARIMA performs best, followed by ETS, then LSTM and Prophet. It is notable that even a relatively small neural network (LSTM) did not outperform the statistical models in this case – likely due to the short history available (only two years of data) and the strong regularity in the series which classical models handle well.

TABLE II. FORECAST ACCURACY FOR DAILY AFFINITY INDEX (JAN–FEB 2025 TEST PERIOD)

Model	**Metrics**

	MAE	***RMSE***	***MAPE***
ARIMA	30.5	52.0	10.8 %
ETS	32.1	55.0	11.4 %
Prophet	37.4	64.7	13.0 %
LSTM	35.8	59.8	12.5 %

For confidentiality, the absolute values have been rounded, but the relative performance of models is as shown. Figure 1 illustrates the actual vs. forecasted daily values for each model over the 8-week test period. The plot shows that all models track the overall trend and weekly swings reasonably well.

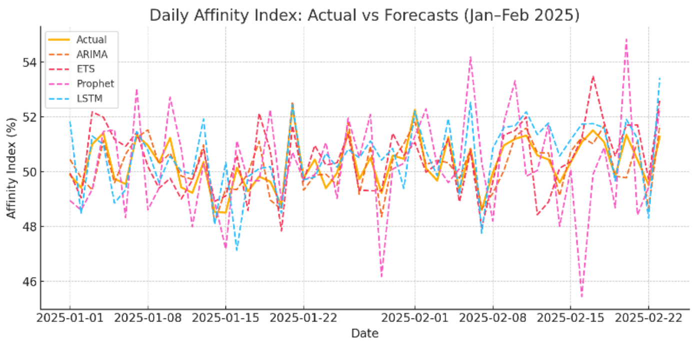

Figure 1. Daily Affinity Index: Actual Vs Forecasts (Jan–Feb 2025)

Conclusion

In this paper, we present an end-to-end, data-science pipeline for forecasting TV metrics. After detailing the panel-meter system and key indicators (Rating, GRP, TRP, Affinity), we benchmarked four models—ARIMA, ETS, Prophet and an LSTM—on two years of data. ARIMA and ETS best captured weekly seasonality, but Prophet and LSTM also delivered solid results once tuned. Forecasts of target and base EqGRPs were combined to generate a daily affinity index, whose error stayed near 1 % MAPE—good enough for day-by-day media-buy decisions. In practice, separately forecasting TRPs and GRPs, then taking their ratio, provides advertisers with a stable, high-precision view of how well each day's schedule will reach the desired audience.

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State Registers as Data Sources for Innovations in E-Government

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Abstract: Electronic Government (E-Government) has evolved into one of the principal avenues of public administration modernization worldwide, as it enhances both the efficiency and transparency of governmental operations. In an era of rapid digitalization, E-Government facilitates the online delivery of public services, ensures data openness, and encourages citizens to actively participate in policymaking. This approach not only mitigates bureaucratic barriers and corruption risks but also accelerates socio-economic development.
Keywords: e-government, government registers, open data, digital transformation, public services, interoperability, data-driven innovation

Introduction

Today, many governments worldwide prioritize the development of Electronic Government (E-Government), investing in the creation of unified digital platforms, enhancing interoperability, and promoting the disclosure of public registries [2], [4]. In Ukraine, the active implementation of E-Government similarly aims to bring public services closer to citizens and strengthen governmental accountability, particularly through the launch of portals such as "Diia." Moreover, there has been notable progress in introducing electronic services (e.g., electronic document management systems, digital signatures, the Diia portal), which underscores the continued relevance of this trend at the national level [4].

State registers as a key data source for digital services

The role of state registries in the development of Electronic Government (E-Government) is pivotal, as they contain large volumes of structured and up-to-date information on business entities, the population, property, resources, and more [3]. These registries form the foundation for creating electronic services by enabling citizens to promptly obtain certificates or verify data without having to re-enter information [5]. The "once-only principle," widely adopted in EU countries, stipulates that a citizen or business provides the necessary data to the government only once, while all other authorities communicate internally through shared registries [2]. This approach makes service provision more convenient and transparent, preventing duplication of documentation. High-quality, comprehensive data in state registries is essential for developing innovative services, including analytical systems, monitoring platforms, and online transactions [6].

Currently, there are over 300 state registries in Ukraine, maintained by various executive authorities [4]. The most important ones are administered by the Ministry of Justice (e.g., the Unified State Register of Legal Entities, the State Register of Proprietary Rights to Real Estate), the Ministry of Internal Affairs (the Demographic Register), the Ministry of Finance, the State Tax Service, and others [7]. Each registry is established on the basis of a specific legislative act and may be either open or restricted, depending on the nature of the data it contains (e.g., personal or official information) [8].

According to the open data strategy, a substantial portion of state registries is made publicly accessible on the national open data portal (data.gov.ua), allowing businesses and the public to freely utilize official information [4], [5]. Open registries—such as the Unified State Register of Legal Entities and Individual Entrepreneurs, the public cadastral map, and the register of court decisions—enable citizens to quickly verify business partners, obtain property-related information, and retrieve necessary certificates online [2], [6]. However, several registries remain restricted due to the sensitive nature of their data; these include databases maintained by law enforcement agencies, the defense sector, or those containing personal information [4]. While this ensures a balance between openness and security, it also poses challenges for interagency cooperation if technical and organizational mechanisms for data exchange are not adequately developed [2], [8].

The availability and use of government data foster the growth of both commercial and non-commercial services that build on open registries [3]. Platforms such as YouControl, Opendatabot, and Clarity Project aggregate information from dozens of registries, providing comprehensive analytical solutions for due diligence, investigative journalism, and public procurement analysis [6]. This demonstrates the synergy between government open data policies and the IT sector’s capacity to create value-added services. Such tools not only enhance transparency but also help popularize E-Government by facilitating citizens’ interactions with government agencies [7].

Initiative to create a “register of registers” in Ukraine

Active efforts are underway in Ukraine to launch a centralized catalog of all state registries, commonly referred to as the “registry of registries” [8]. The concept involves creating a single database where any citizen or professional can find information about the available registries, their purpose, the authority responsible for them, and access conditions [4]. The project is intended to increase transparency, eliminate duplication, and standardize requirements for managing registries across different agencies [8]. The "registry of registries" is also expected to become a key component in advancing interagency electronic interaction, as it will simplify integration and data exchange among government bodies [5]. The launch of such a catalog will further Ukraine's digitalization and enhance the efficiency of processes for developing new electronic services by providing a "map" of available data and helping to avoid duplicating databases [1], [7].

State registers in electronic procurement: a case study

One example of the practical use of state registries within Electronic Government (E-Government) is the electronic public procurement system. Data from registries of legal entities, taxpayer registers, court decision databases, and other official sources make it possible to create comprehensive profiles of tender participants, thereby significantly increasing process transparency [2], [3], [6].

The authors is developing a recommendation system that applies multi-criteria evaluation methods for public procurement participants based on data from various open and restricted registries. The system provides automated data collection about a company (its financial statements, court rulings, affiliated individuals, history of violations, and so forth) and integrates these data into a model that generates a weighted reliability rating or integrity index for each participant [9]. Here, registries serve as the source of factual information that is subsequently processed by the respective multi-criteria analysis algorithms. Consequently, the synergy between official databases and multi-criteria recommendation systems yields user-friendly analytical tools for contracting authorities and oversight agencies. This approach underscores the critical importance of state registries as an informational foundation for digital innovations in the field of electronic public procurement—one of the key components of E-Government.

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Data Science-Based Diagnostic Technology Development for Medical Imaging

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Abstract: Manual interpretation of chest radiographs is time-consuming and often delayed due to the global shortage of qualified radiologists. This study presents a data-driven diagnostic system based on convolutional neural networks (CNNs) for automatic detection of thoracic abnormalities. Using the publicly available ChestX-ray14 dataset, we benchmarked three CNN architectures—ResNet50, EfficientNetB0, and MobileNetV2—evaluating their performance in terms of classification accuracy, AUC-ROC, and interpretability via Grad-CAM heatmaps. This system can be integrated into clinical workflows to improve diagnostic efficiency and support radiologists in emergency and resource-limited settings.

Keywords: medical imaging; deep learning; CNN; EfficientNet; radiology; AI healthcare systems

Introduction

Chest radiography is the most common imaging technique used for the detection of thoracic pathologies. However, the growing volume of medical data and a global shortage of radiology professionals have made timely diagnosis increasingly difficult. In emergency departments, delayed interpretation of chest X-rays can lead to critical delays in treatment. Artificial intelligence (AI), particularly deep learning, offers promising solutions to support medical professionals by automating image analysis and triage. This research aims to develop and evaluate a CNN-based system for detecting abnormalities in chest X-ray images, ultimately improving diagnostic speed and reliability.

Methodology

The development of the diagnostic system was based on the ChestX-ray14 dataset provided by the NIH Clinical Center. It includes 112,120 frontal chest X-ray images labeled with one or more thoracic disease categories. The dataset presents real-world clinical complexity, including overlapping pathologies, imbalanced class distribution, and variable image quality.

To prepare the images for model training, preprocessing steps included grayscale conversion, resizing to 224×224 pixels, pixel normalization, and contrast enhancement. Data augmentation was applied during training to improve generalization and simulate variability found in clinical imaging: random rotations, zooming, and horizontal flips were introduced with controlled probabilities.

We implemented and evaluated three convolutional neural network architectures:

- ResNet50, which uses residual connections to enable deep learning without degradation.
- EfficientNetB0, optimized for high accuracy with fewer parameters through compound scaling.
- MobileNetV2, a compact and efficient architecture designed for fast inference in limited-resource environments.

All models were initialized with pre-trained ImageNet weights and fine-tuned on the prepared dataset. Hyperparameter optimization was performed using a grid search strategy, tuning learning rates (0.001, 0.01, 0.1), dropout values (0.2–0.4), and batch sizes (16–64). The Adam optimizer was chosen due to its proven convergence speed and adaptability. We used early stopping to prevent overfitting and saved the best-performing model based on validation performance.

Model performance was evaluated using accuracy, AUC-ROC, F1-score, and confusion matrices to assess the correctness of predictions across different conditions. For model explainability, we employed Grad-CAM to visualize regions within the X-rays that contributed most to the model's decision-making process — supporting clinical interpretation and building trust in the system.

Results

Across all experiments, EfficientNetB0 demonstrated the highest performance with a classification accuracy of 88% and an AUC-ROC of 0.91. It provided a strong balance between predictive accuracy, training efficiency, and generalization capability. ResNet50 also showed strong performance, particularly on more visually complex pathologies. However, it required significantly more computational resources and exhibited slightly slower convergence. MobileNetV2, while more compact, maintained a respectable accuracy of 84% and an AUC-ROC of 0.87, showing potential for deployment in mobile health applications and in settings with limited infrastructure.

The confusion matrices (Fig. 1) illustrate that all three models performed reliably in distinguishing between normal and abnormal chest X-rays.

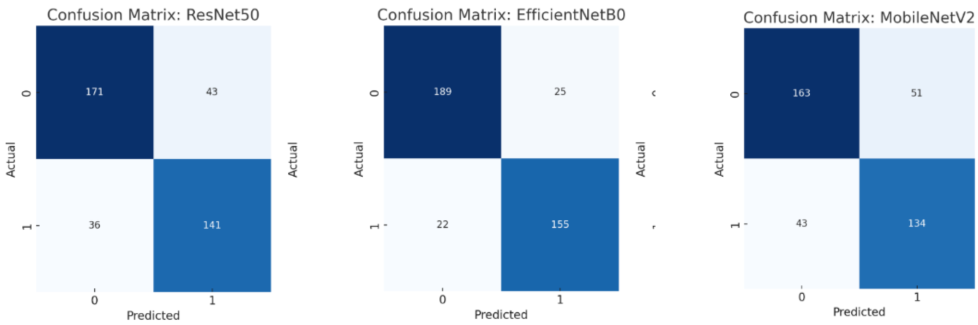

Figure 1. Confusion matrices for ResNet50, EfficientNetB0, and MobileNetV2

Importantly, Grad-CAM visualizations confirmed that the networks focused on relevant thoracic regions, often aligning with known clinical indicators. This interpretability plays a critical role in potential real-world adoption by medical professionals.

Conclusion

We designed and evaluated a convolutional neural network–based system for automated detection of thoracic abnormalities in chest radiographs. Among the tested architectures, EfficientNetB0 demonstrated the most favorable balance between predictive accuracy and computational efficiency.

The integration of explainability through Grad-CAM enhances model transparency, facilitating trust and potential deployment within clinical environments such as PACS.

Overall, the results indicate that AI-driven diagnostic tools can effectively support radiologists, reduce interpretation delays, and streamline medical imaging workflows.

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Development of a fake news classification system using Data Science methods

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Abstract: This research addresses the critical challenge of fake news detection within smart city environments. The study presents a comprehensive system that combines traditional machine learning approaches with advanced data science methods to identify and classify fake news. Our implementation utilizes TF-IDF vectorization coupled with Naive Bayes classification, enhanced by transformer-based models. The system demonstrates significant accuracy, achieving 89% overall accuracy in news classification, with 92% precision in fake news detection. Testing on a diverse dataset of over 70,000 news articles validates the system's reliability and scalability. The proposed solution offers practical integration capabilities with existing smart city infrastructure, supporting data-driven decision-making processes and enhancing urban information security. This research contributes to developing resilient smart city ecosystems by providing an efficient tool for maintaining information integrity in urban digital spaces.

Keywords: smart cities, fake news detection, machine learning, data science, urban information security, text classification

Introduction

The rapid digitalization of urban environments and the emergence of smart cities have transformed how communities interact with information. As cities become increasingly dependent on data-driven systems, the integrity of information flow becomes crucial for effective urban governance. Recent studies indicate that approximately 45% of urban decision-making processes are influenced by digital information channels, making the detection of fake news a critical component of smart city infrastructure.

The challenge of fake news detection in smart city environments is particularly complex due to:

1. The high volume of real-time information flow
2. The immediate impact on urban decision-making processes

3. The diversity of information sources
4. The potential effects on public safety

This research addresses these challenges by developing an automated system for fake news detection that integrates with smart city infrastructure. Our approach combines traditional machine learning techniques with advanced transformer models, providing a robust solution for maintaining information integrity in urban digital spaces.

The main objectives of this study include:

- Development of an efficient fake news detection algorithm using modern data science methods
- Integration of the detection system within smart city digital infrastructure
- Enhancement of urban information verification processes

The significance of this research lies in its practical application within smart city frameworks, where accurate information is crucial for emergency response systems, public transportation management, and urban planning decisions.

Methodology

The proposed fake news detection system employs a hybrid approach, combining traditional machine learning techniques with advanced neural network architectures for smart city environments. Our methodology focuses on system architecture and data processing techniques.

The research is based on a comprehensive dataset of over 70,000 news articles, encompassing both authentic and fake news content. Initial data analysis revealed distinct patterns in text structure and content distribution between genuine and fabricated news articles.

Text preprocessing methodology includes several stages of data preparation. Our approach focuses on tokenization, cleaning, and normalization processes, with special attention to both headlines and article content. The analysis showed optimal processing ranges for different types of content, allowing for efficient information extraction while maintaining semantic integrity “Fig. 1”.

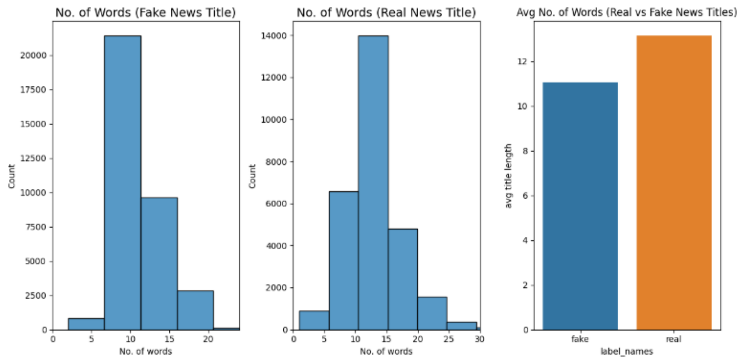

Figure 1. Distribution of Text Length in Real and Fake News Titles

The core system architecture implements a sophisticated pipeline approach combining multiple processing stages. The primary component utilizes TF-IDF (Term Frequency-Inverse Document Frequency) vectorization, transforming textual data into numerical features while preserving important word relationships and contextual information.

For the classification stage, we implemented a Multinomial Naive Bayes algorithm (1), selected for its efficiency in text classification tasks and ability to handle high-dimensional news data. The system architecture ensures scalability and real-time processing capabilities, crucial for smart city applications.

$$P(A|B) = (P(B|A) \cdot P(A)) / P(B) \quad (1)$$

Where P(A|B) is the probability of news being fake given its features, P(B|A) is the likelihood of features occurring in fake news, P(A) is the prior probability of fake news, and P(B) is the probability of features occurring in all news.

The implementation leverages specialized Python libraries for natural language processing and machine learning, ensuring robust performance and maintainability within urban information systems.

Results

Our fake news detection system demonstrated high effectiveness in smart city applications, achieving 89% overall accuracy in news classification. The confusion matrix analysis reveals precise performance metrics: 92% accuracy in fake news detection with 6,400 correctly identified fake news articles, and only 550 false positives out of 70,000 analyzed pieces “Fig. 2”.

Figure 2. Classification Performance - Confusion Matrix Key performance indicators showed:

- x <500ms for full articles

Implementation in urban systems demonstrated immediate practical benefits through rapid integration with city information dashboards and emergency response systems. Testing confirmed system scalability under varying loads while maintaining consistent accuracy levels, making it viable for large-scale urban deployment.

Conclusion

This research successfully developed and implemented an efficient fake news detection system specifically designed for smart city environments. The achieved 89% accuracy rate, combined with rapid processing capabilities, demonstrates the system's practical viability for urban information management.

The key contributions of this work include:

- Development of a scalable classification system integrating TF-IDF and Naive Bayes methods
- Implementation of real-time processing for urban information flows
- Proven effectiveness in reducing misinformation spread in smart city environments

Future development directions should focus on expanding the system's capabilities to handle multilingual content and adapting to emerging types of misinformation. The integration of this system with existing smart city infrastructure provides a foundation for enhanced urban information security and reliable decision-making processes.

The research outcomes suggest that similar approaches could be effectively implemented in other smart city applications, particularly in areas requiring rapid information verification and decision support systems.

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Deterministic Factor Analysis and Internal Audit in Climate Change Assessment

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Abstract: This study examines the evolving role of internal audit in assessing the environmental impact of business activities in the context of accelerating climate change. Emphasis is placed on the growing importance of environmental, social and governance (ESG) factors audit in the context of rapid climate change and environmental disruption. The study highlights the use of deterministic factor analysis as a tool for decomposing changes in environmental performance into measurable factors, such as production volume, raw material composition, or technological changes. Internal audit is positioned not only as a compliance mechanism, but also as a strategic function that supports climate risk management, transparency and sustainable development

Keywords: Internal audit, ESG factors, climate risk, deterministic factor analysis, sustainability, non-financial reporting, governance

Introduction

The global climate is undergoing unprecedented changes: 2024 was the warmest year on record, and March 2025 set a new temperature record in Europe. According to the Copernicus Climate Change Service, the average global temperature exceeded pre-industrial levels by 1.5°C, which is equal to the critical limit set as the desired threshold of the Paris Climate Agreement and indicates that we are approaching the medium-term limit. With these transformations on the background, social and regulatory pressure is growing on business entities that may neglect the environmental and social impacts of their operations. There is an urgent need for institutional control to identify, analyze, and prevent the negative impact of business on the environment.

The Global Internal Audit Standards (2024) established by the Institute of Internal Auditors for the first time enshrine at the regulatory level the need to consider Environmental, Social, and Governance (ESG) factors in assessing the effectiveness, ethics and sustainability of management systems. This requires not only the adaptation of audit methods to new challenges, but also the formation of an integrated system of analytical support within corporate governance.

I. Methodology and Analytical Tools of ESG Audit

Modern ESG audit practice is based on a multidisciplinary approach that combines economic analysis, accounting, statistics, non-financial reporting, and digital technologies. Internal audit, which performs an analytical function in the area of climate responsibility, relies on a number of tools. Here are the key methodologies and analytical tools: Life Cycle Assessment (LCA), ESG- Key performance indicators (KPIs), Scenario analysis and stress testing, Clustering of firms based on environmental, social, and governance ratings, Big Data and automated ESG analytics.

II. **Application of deterministic factor analysis in ESG factors audit**

In the scope of internal audit, the methods of deterministic factor analysis are increasingly used to identify sources of influence on changes in the environmental profile of an enterprise. It allows to quantify the contribution of certain managerial, technological or production factors to changes in the environmental performance of the enterprise. In particular, deterministic factor analysis is used to decompose the dynamics of greenhouse gas emissions, energy consumption or resource intensity into the impact of production volume, changes in the structure of raw materials or the transition to new technologies. These allow the auditor not only to record the change in indicators but also to explain its causes reasonably.

The analyst can determine what share of the increase in the total carbon footprint was caused by changes in production volumes, what impact changes in the structure of raw materials or energy sources had, and how investments in environmentally friendly technologies affected emissions intensity.

III. Conclusions and Future Perspectives

According to empirical studies, companies with a high level of transparency and confirmed ESG data show better financial stability, reduce risks and increase investor confidence. The analytical function of internal audit in the ESG area goes beyond the classical audit: it is transformed into a systemic tool for managing climate risks, assessing environmental responsibility and ensuring transparency of companies' activities. Thus demonstrates, that internal audit is not only an also a source of value that creates sustainable competitive advantages for the company, but it also plays a strategic role in shaping sustainable development policy.

In order to fully realize the potential of ESG audits, it is necessary to provide:

- institutional integration of environmental and social aspects into audit planning
- improving the professional competence of auditors in the field of climate risks, sustainable reporting and environmental law

- developing and implementing unified methodological approaches to verifying ESG indicators in accordance with international standards
- digitalization of audit procedures using automated data collection, processing and verification systems
- public access to the results of internal ESG audits, especially for companies with a high level of environmental or social impact, as an element of public accountability

The development of internal ESG audit is not only a matter of compliance with new standards, but also an urgent need of the time, which allows harmonizing the interests of business, society and the environment. Providing a strong analytical and control function in this area will contribute to the long-term sustainability of enterprises and the achievement of climate-neutral economic development goals.

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