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Geo-information systems in urban planning: A review of business and environmental implications

Abayomi Abraham Adesina [1], Azubuike Chukwudi Okwandu [2] and Zamathula Queen Sikhakhane Nwokediegwu [3,*]

[1] *Independent Researcher, Ohio, USA.*
[2] *Arkifill Resources Limited, Portharcourt, Rivers State Nigeria.*
[3] *Independent Researcher, Durban, South Africa.*

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Abstract

In an era where urban landscapes are rapidly evolving, the integration of Geographic Information Systems (GIS) in urban planning emerges as a pivotal tool for sustainable development. This paper delves into the multifaceted role of GIS, exploring its implications in the realms of business and environmental sustainability within urban contexts. The background of the study is rooted in the increasing complexity of urban challenges and the need for innovative solutions to address them effectively.

The aim of this paper is to provide a comprehensive analysis of GIS applications in urban planning, focusing on their impact on both business efficiency and environmental stewardship. The scope of the study encompasses an exploration of the historical evolution of GIS, its integration in various urban settings, and the interplay between commercial objectives and environmental sustainability.

Employing a methodological framework that includes a thorough review of relevant literature and case studies, the study illuminates the dynamic interplay between technological advancements in GIS and their practical applications in urban planning. This approach facilitates a panoramic view of GIS's multifarious implications, highlighting trends, patterns, and impacts of its adoption in diverse urban scenarios.

The main conclusions reveal that GIS is indispensable in modern urban development, adeptly addressing complex urban challenges, particularly in sustainable planning and balancing economic growth with environmental protection. However, the study also uncovers challenges such as the need for improved database construction and comprehensive information services.

Recommendations include tailoring policies to local contexts, focusing on multi-scalar GIS-based indicators, and prioritizing sustainable development goals. These strategies are crucial for enhancing the efficacy of GIS in urban planning, leading to more sustainable and well-managed urban environments.

Keywords: Geographic Information Systems (GIS); Urban Planning; Sustainable Development; Environmental Sustainability; Urban Landscapes; Technological Advancements

* Corresponding author: Zamathula Queen Sikhakhane Nwokediegwu

1. Introduction

1.1. Exploring the Role of GIS in Modern Urban Development

Geographical Information Systems (GIS) have become indispensable in modern urban development, offering a multifaceted tool for addressing the complex challenges of urban planning. Feng, Qianguo, and Peiji (2017) apply spatial analysis tools of GIS to explore the spatial-temporal evolution characteristics of residential, industrial, and public service land in Zhangye City since 1981. Their study provides effective development strategies for the sustainable development of oasis cities, revealing the internal characteristics of urban expansion and offering insights into the evolution of urban functional land as a spatial reflection of urban functional agglomeration and diffusion.

Van Maarseveen, Martinez, and Flacke (2019) delve into the functionalities of GIS in urban planning, emphasizing its role in land use and surface studies, which are crucial for sustainable development. GIS operates not just as a tool, but as a system or a group of systems, offering capabilities like database management, visualization, spatial analysis, and spatial modelling. These functionalities are essential for urban planners and decision-makers in managing the effects of urban change. The emergence of Spatial Decision Support Systems (SDSS) and Planning Support Systems (PSS) further enhances the role of GIS in spatial planning analysis (Van Maarseveen, Martinez, and Flacke, 2019).

The development of an intelligent management information system for urban planning based on GIS provides insights into the technological advancements in this field (Chen, Chen, and Chen, 2021). Their study demonstrates how GIS can be integrated with other technologies to create a more efficient and effective urban planning process. This integration includes the use of a spatial data model, database connectivity, multi-source data integration, and the application of fuzzy recognition modes for environmental impact assessment in urban planning.

Khayambashi (2018) discusses the strategic planning aspect of GIS in urban development. He emphasizes that GIS is not just a tool for data analysis but is instrumental in strategic schematization, which involves systematic methods incorporating internal strengths and weaknesses, as well as external opportunities and threats. This strategic approach is crucial for the optimal use of resources and achieving sustainable urban growth. Khayambashi also highlights the importance of new methods in strategic planning, such as SWOT analysis, for evaluating and analysing GIS needs in urban management (Khayambashi, 2018).

The role of GIS in modern urban development is multifaceted and evolving. It serves as a critical tool for sustainable planning, offering capabilities that extend beyond traditional mapping and data analysis. The challenges in adopting GIS, especially in developing countries, include resource limitations and technical dependencies. However, the integration of GIS with other technologies and its application in strategic urban planning present opportunities for more effective and sustainable urban development. The future of urban planning with GIS looks promising, with continuous technological advancements and strategic approaches paving the way for smarter, more sustainable cities.

1.2. Tracing the Development of GIS in Urban Planning History

The history of Geographic Information Systems (GIS) in urban planning is a rich tapestry that intertwines technological advancements with the evolving needs of urban development. Masser and Ottens (2019) trace the roots of GIS back to the sanitary maps of the 1830s and 1840s in Britain and the United States, highlighting how urban planning has long relied on geographic information. This reliance has evolved from simple map-making to the implementation of multi-purpose, multi-user GIS in modern cities. The foresight of early planners, like Lewis Keeble, who in 1952 advocated for overlay techniques and combination maps, prefigured the development of GIS, indicating a long-standing recognition of the need for sophisticated tools in urban planning (Masser and Ottens, 2019).

Kleshch (2017) provides a case study in the historical application of GIS through the examination of the urban landscape of Kharkiv. This study underscores the methodological evolution in urban planning, from traditional cartographic methods to the incorporation of GIS and geoinformation technologies. Kleshch's research demonstrates how GIS has been instrumental in modeling the development of urban territories, overcoming challenges and errors inherent in earlier methodologies. The integration of GIS in historical and geographical research has allowed for a more nuanced understanding of urban evolution, catering to various thematic interpretations by city historians, archaeologists, demographers, and economists (Kleshch, 2017).

The work of Namwamba provides a contemporary perspective on the use of GIS in urban planning, focusing on the analysis of historical changes in urban forest and land cover in Scotlandville, Louisiana, USA. Their study highlights the role of GIS and remote sensing in understanding the dynamics of urban sprawl and its impact on natural ecosystems.

By analysing land use history through GIS and remote sensing technologies, they were able to document significant changes in land cover over several decades, illustrating the power of GIS as a tool for decision-making in urban forestry and conservation planning (Namwamba, 2016).

The development of GIS in urban planning reflects a trajectory from basic cartographic tools to complex systems capable of handling multiple layers of urban data. This evolution has been driven by the growing complexity of urban challenges, from sanitary issues in the 19th century to the multifaceted demands of modern urban sprawl. The foresight of early urban planners, who recognized the potential of overlay techniques and combination maps, laid the groundwork for the development of GIS. Today, GIS is not just a tool for mapping and data analysis; it is an integral part of the urban planning process, enabling planners to model urban development scenarios, analyze historical land use changes, and make informed decisions about the future of urban landscapes.

The historical development of GIS in urban planning is a testament to the field's adaptability and foresight. From its early beginnings in sanitary mapping to its current role in modelling complex urban ecosystems, GIS has continually evolved to meet the changing needs of urban planners. This evolution underscores the importance of technological innovation in urban planning and the need for continuous adaptation to emerging urban challenges. As urban landscapes become increasingly complex, the role of GIS in urban planning is set to become even more pivotal, offering the tools and insights needed to create sustainable, liveable urban environments.

1.3. The Intersection of Commercial Objectives and Environmental Sustainability

The integration of commercial objectives with environmental sustainability in urban planning is a complex yet crucial endeavour. Geographic Information Systems (GIS) have emerged as pivotal tools in this integration, aiding in the assessment and planning of urban models that balance economic development with ecological preservation. Jiménez-Espada, García, and González-Escobar (2023) emphasize the role of GIS in evaluating urban sustainability indicators, demonstrating its effectiveness in a medium-sized Spanish city. Their research highlights how GIS, combined with open data and urban sustainability indicators, can assess various aspects of urban life, such as density, green areas, and public facilities, to ensure they meet regulatory requirements and sustainability standards (Jiménez-Espada, García and González-Escobar 2023).

In another study, Jiménez-Espada, García, and González-Escobar (2022) explore the interrelation between urban equity and sustainability in the context of Southern Europe's historic cities. They utilize GIS tools to analyse urban indicators across different fields, including land use, public space, mobility, and urban complexity. Their findings reveal correlations between historical zones and various sustainability indicators, such as density and compactness, suggesting that GIS can be a valuable tool for policymakers in achieving equitable urban quality conditions (Jiménez-Espada, García, and González-Escobar, 2022).

Akbulut, Ozcevik, and Carton (2018) present a method combining GIS with the Analytical Hierarchy Process (AHP) for sustainable urban and environmental planning. Applied to a case study in Istanbul, Turkey, this method evaluates urbanization patterns from the perspectives of urban planning principles and environmental sustainability. The GIS-AHP combined approach allows for a systematic assessment of metropolitan territories, highlighting the potential of GIS in balancing urban development with environmental considerations (Akbulut, Ozcevik, and Carton, 2018).

The intersection of commercial objectives and environmental sustainability in urban planning requires a nuanced approach that considers various factors influencing urban development. GIS emerges as a critical tool in this process, enabling the analysis and visualization of complex urban data. By integrating sustainability indicators with GIS, urban planners can assess the impact of commercial developments on the environment and vice versa. This integration facilitates informed decision-making, ensuring that urban development aligns with sustainability goals.

Furthermore, the application of GIS in historic cities underscores its versatility in addressing unique urban challenges. In such contexts, GIS helps balance the preservation of cultural heritage with the need for modern urban development. The ability of GIS to analyze spatial morphology and urban equity highlights its potential in creating sustainable and liveable urban environments that respect historical contexts.

The role of GIS in bridging commercial objectives and environmental sustainability in urban planning is increasingly vital. Its ability to process and analyse diverse urban data makes it an indispensable tool for urban planners and policymakers. As urban challenges become more complex, the integration of GIS in urban planning will be crucial in achieving sustainable and equitable urban development. The future of urban planning, therefore, lies in the effective

use of GIS to balance commercial growth with environmental stewardship, ensuring the long-term sustainability of urban environments.

1.4. Technological Advancements and Their Impact on GIS Applications in Urban Planning

The realm of urban planning has been significantly transformed by technological advancements, particularly in the application of Geographic Information Systems (GIS). These advancements have not only enhanced the capabilities of GIS but also broadened its applicability in various aspects of urban planning.

Deng and Zhang (2022) explore the integration of GIS in urban planning information systems, emphasizing the shift from traditional urban management methods to more advanced, technology-driven approaches. Their research highlights the use of modern WebGIS technology in designing urban planning information management systems, which significantly improves the efficiency and effectiveness of urban planning processes. This advancement in GIS technology facilitates better data management, analysis, and visualization, thereby enhancing decision-making in urban planning (Deng and Zhang, 2022).

Xie et al. (2023) delve into the application of GIS image systems and remote sensing technology in physical geography land planning. Their study demonstrates how these technologies enable comprehensive and systematic surveys of urban land use changes. By utilizing remote sensing data and GIS as supporting tools, urban planners can construct detailed spatial databases of the urban environment. This approach not only aids in the development of research but also guides the sustainable development and utilization of natural resources (Xie et al., 2023).

Quamar et al. (2023) review the advancements and applications of drone-integrated GIS technology, highlighting its revolutionary benefits in various fields, including urban planning. The integration of drones with GIS reduces costs and improves accessibility for geospatial data collection. Drones equipped with advanced cameras and AI software can efficiently replace traditional methods of aerial photography, making the process more economical and time-efficient. This integration is particularly beneficial in precision agriculture, emergency health response, disaster management, and the development of smart cities (Quamar et al., 2023).

The impact of these technological advancements on GIS applications in urban planning is profound. Modern GIS technologies, such as WebGIS, remote sensing, and drone integration, have expanded the scope and depth of urban planning. They enable planners to handle complex urban data more effectively, providing detailed insights into land use, urban morphology, and environmental impacts. These technologies also facilitate participatory planning by allowing easier access to planning information for the public.

Moreover, the integration of GIS with other technologies like AI and drones has led to the development of more sophisticated analytical tools. These tools can process large volumes of data quickly and accurately, providing urban planners with real-time insights into urban dynamics. This capability is crucial in managing rapid urbanization and addressing challenges such as environmental sustainability, land use efficiency, and urban equity.

Technological advancements have significantly enhanced the capabilities of GIS in urban planning. These advancements have not only improved the efficiency and accuracy of urban planning processes but also expanded the possibilities for innovative and sustainable urban development. As technology continues to evolve, the role of GIS in urban planning is expected to become even more integral, driving the creation of smarter, more sustainable, and liveable urban environments.

1.5. Examining Regulatory and Policy Contexts for GIS in Urban Planning

The integration of Geographic Information Systems (GIS) in urban planning is not just a technological advancement but also a regulatory and policy-driven process. Understanding the regulatory and policy contexts of GIS applications in urban planning is crucial for effective urban management and sustainable development.

Meenar, Morales, and Bonarek (2017) discuss the regulatory practices of urban agriculture, highlighting the role of GIS in connecting planning and policy. They observe that municipalities in the United States are increasingly recognizing urban agriculture within planning, land use, and zoning ordinances. The study reviews the regulatory practices of 40 metropolitan and 40 micropolitan municipalities, noting the adoption of enabling ordinances and regulations on urban agriculture production. GIS plays a critical role in these processes by providing data and tools for planning practitioners, urban agriculture practitioners, and researchers. This study underscores the importance of GIS in filling regulatory gaps and supporting decision-making in urban planning (Meenar, Morales, and Bonarek, 2017).

Maarseveen, Martinez, and Flacke (2018) explore the capacity of GIS in sustainable urban planning and management from a global perspective. Their work addresses the concept of sustainable urban development and the various frameworks for measuring sustainability. GIS is presented as a pivotal tool in informing practitioners and participants in urban planning processes. The book highlights the importance of GIS in understanding and solving urban problems, illustrating its role in analysing and evaluating the position of disadvantaged groups and areas in cities. This global perspective on GIS in urban planning emphasizes the need for regulatory frameworks that support sustainable urban development (Maarseveen, Martinez, and Flacke, 2018).

Chundeli (2017) examines the use of 3D GIS as a decision support tool in urban planning, particularly in the context of urbanization and suburbanization. The study generates a 3D information-rich model (3DIRM) of an urban area in Chennai, India, using ArcGIS and ArcScene. This model includes information such as land use, road width, building height, and zoning regulations. The classification of 3DIRM based on local zoning regulation highlights the potential of advanced geo-spatial tools like 3D GIS in enhancing decision-making processes and implementing zoning regulations. The study demonstrates that 3D GIS can help urban planners in managing rapid urbanization and ensuring compliance with development codes (Chundeli, 2017).

The regulatory and policy contexts of GIS in urban planning are multifaceted and crucial for sustainable urban development. GIS provides a platform for analyzing, visualizing, and managing urban data, which is essential for informed decision-making. The integration of GIS in urban planning processes supports the implementation of regulatory frameworks, facilitates sustainable development, and enhances the efficiency of urban management. As urban challenges continue to evolve, the role of GIS in shaping regulatory and policy contexts in urban planning will become increasingly significant, driving the creation of more sustainable, equitable, and well-managed urban environments.

1.6. Comparative Analysis of GIS Applications in Different Urban Contexts

The application of Geographic Information Systems (GIS) in urban planning varies significantly across different urban contexts. This variation is influenced by factors such as the rate of urban growth, planning objectives, and the technological capabilities of the region. A comparative analysis of GIS applications in diverse urban settings provides valuable insights into how this technology is adapted and utilized to meet specific urban planning needs.

Ouchra, Belangour, and Erraissi (2022) conducted a systematic review of the use of satellite data and GIS in urban planning, highlighting the necessity of these tools in managing accelerated urban growth. Their research underscores the importance of GIS and satellite imagery in updating land use and occupancy maps, a task that has become increasingly challenging due to rapid urbanization. The study demonstrates that GIS, combined with advanced methods of spatial analysis and machine learning, can significantly improve the urban planning process by enabling efficient data storage, manipulation, and analysis (Ouchra, Belangour, and Erraissi, 2022).

Posuk, Kajita, and Petchsasithon's study on Bangkok, Thailand, presents a compelling example of how remote sensing and GIS can be used for comparative analysis of city planning and land use change. Their research reveals that Bangkok's urban area expanded significantly over 21 years, with a corresponding decrease in rural and agricultural zones. This study suggests that GIS and remote sensing can provide solutions to urban land use problems by enabling the comparison of actual land use changes with comprehensive urban plans. The findings highlight the potential of GIS in controlling urban expansion and guiding sustainable city development (Posuk, Kajita, and Petchsasithon, 2018).

Sandu (2016) takes a different approach by analyzing the urban sprawl in post-socialist cities using GIS. This study focuses on the transition from vertical to horizontal spatial expansion in these cities and examines whether there is a tendency to control urban sprawl in the context of sustainable urban development. By employing GIS and a quantitative methodology, Sandu identifies the dynamics of urban form in post-socialist cities, providing insights into how these cities are managing their spatial expansion in the face of sustainability challenges (Sandu, 2016).

1.7. Stakeholder Perspectives on GIS in Urban Development

Understanding stakeholder perspectives is crucial in urban development, especially when integrating Geographic Information Systems (GIS) into planning and decision-making processes. Different stakeholders bring varied insights and concerns, shaping the way GIS tools are utilized and urban development is approached.

Miles, Esau, and Pettersson (2023) emphasize the importance of stakeholder understanding in sustainable urban development, particularly in relation to environmental factors like air quality and urban heat island effects. They propose the use of web GIS storytelling as an effective tool for communicating complex environmental information to

non-specialists. Their case study in Bergen, Norway, demonstrates how a web-based GIS platform can facilitate the dissemination of environmental data, enhancing stakeholder understanding and engagement in sustainable urban development. This approach underscores the potential of GIS as a medium for storytelling and information sharing, making complex data more accessible and comprehensible to a broader audience (Miles, Esau, and Pettersson, 2023).

Fitawok et al. (2023) analyze stakeholder perspectives on urban land-use changes, focusing on farmers' resistance in Bahir Dar, Ethiopia. Their study reveals that inadequate compensation during land expropriation, lack of good governance in urban expansion, and inaccessibility of infrastructure are primary reasons for farmers' resistance. This research provides valuable insights into the consequences of unplanned urban development and highlights the need for stakeholder-inclusive approaches in urban planning. It illustrates the importance of considering local community perspectives, especially in developing countries undergoing significant urban transformations (Fitawok et al., 2023).

Mourshed and Ameen (2016) investigate environmental, social, and economic challenges of urban development from stakeholder perspectives in a developing economy. Their nationwide survey in Iraq uses a structured questionnaire to explore stakeholder perceptions of urban indicators. The study identifies key components such as safety, water conservation, and preservation of historic buildings as crucial factors in urban development. This research highlights the necessity of understanding stakeholder perspectives to enhance participation in urban development processes, particularly in developing countries facing rapid urbanization (Mourshed and Ameen, 2016).

Stakeholder perspectives play a pivotal role in shaping GIS applications in urban development. The integration of GIS in urban planning must consider the diverse insights and concerns of various stakeholders, including local communities, urban planners, and environmental specialists. Effective communication and dissemination of information through tools like web GIS storytelling can enhance stakeholder understanding and engagement. Additionally, addressing the concerns of local communities and considering their perspectives in urban planning are essential for sustainable and inclusive urban development. As urban challenges continue to evolve, the role of GIS in facilitating stakeholder-inclusive urban planning will become increasingly significant, driving more effective and equitable urban development strategies.

1.8. Challenges and Opportunities in Implementing GIS Solutions

The implementation of Geographic Information Systems (GIS) in urban planning presents a unique set of challenges and opportunities. Understanding these aspects is crucial for leveraging GIS to its full potential in urban development.

Billger, Thuvander, and Wästberg (2017) explore the visualization challenges in urban planning, particularly in the development and implementation of digital visualization tools for dialogue. Their study, based on a thematic analysis of articles published between 2004 and 2014, reveals that while there is a range of visualization tools available, challenges persist in integrating qualitative and quantitative data, achieving appropriate levels of realism, and enhancing user experience. The study emphasizes the need for organizational preparedness, including clear ownership, resource allocation, and access to tools and technology, to fully realize the potential of visualization tools in urban planning (Billger, Thuvander, and Wästberg, 2017).

Karlina and Johan (2020) discuss the development of GIS for ecosystem-based Marine Spatial Planning, particularly focusing on the challenges faced in Indonesia. Their review highlights the essential role of GIS and remote sensing in accessing and summarizing spatial data for evaluating Marine Spatial Planning projects. The challenges identified include the need for effective tools to achieve the goals of Marine Spatial Planning and the difficulties in implementing GIS in the Indonesian context. This study underscores the opportunities and capabilities of GIS in future development and projections, particularly in marine and environmental planning (Karlina and Johan, 2020).

Bhatta and Joshi (2022) examine the role of GIS as a Planning Support System (PSS) in urban planning, with a focus on urban renewal processes in Hong Kong. Their archival research aims to explore the theoretical discourse underpinning GIS and PSS and their practical implications. The study identifies key opportunities and limitations of using GIS as a PSS in urban planning, emphasizing its role in promoting effective decision-making and efficient urban planning processes. The paper contributes to the theoretical discourse on the use of computer-based technologies like GIS in Planning Support Systems, highlighting their fundamental role in urban planning (Bhatta and Joshi, 2022).

The implementation of GIS solutions in urban planning presents both challenges and opportunities. Challenges include integrating diverse data types, achieving realistic visualizations, organizational preparedness, and adapting GIS tools to specific contexts like marine spatial planning. However, the opportunities are significant, with GIS enhancing dialogue, decision-making, and efficiency in urban planning processes. As urban challenges continue to evolve, the role of GIS in

urban planning will become increasingly crucial, driving more effective, sustainable, and inclusive urban development strategies.

1.8.1. Research Question to Guide the Study

In exploring the challenges and opportunities of implementing GIS in urban planning, it is essential to address key questions that can guide future research and practical applications. These questions aim to identify critical areas of focus, potential barriers, and strategies for effective implementation of GIS technologies in urban development. The following research questions are proposed:

What are the primary challenges faced by urban planners in integrating GIS technology into urban development projects?

How can GIS be effectively utilized to enhance stakeholder engagement and communication in urban planning processes?

What strategies can be implemented to overcome the technical and organizational barriers in the adoption of GIS for sustainable urban development?

1.9. Objectives and Scope of the Current Review Study

The primary objective of this review study is to comprehensively analyse the role of Geographic Information Systems (GIS) in urban planning, focusing on its business and environmental implications. The study aims to explore the multifaceted applications of GIS in urban development, tracing its historical evolution and examining its integration within various urban contexts. Key areas of focus include the technological advancements in GIS, their impact on urban planning practices, and the interplay between commercial objectives and environmental sustainability.

The scope of this study encompasses a critical examination of the regulatory and policy frameworks guiding GIS implementation in urban planning. It also involves a comparative analysis of GIS applications across different urban settings, considering the diverse challenges and opportunities encountered. Additionally, the study seeks to understand stakeholder perspectives on GIS in urban development, identifying their needs, concerns, and expectations.

Through this review, the study aims to provide valuable insights for urban planners, policymakers, and researchers, offering a nuanced understanding of GIS's potential in shaping sustainable and efficient urban landscapes. The findings are intended to inform future research directions and contribute to the development of more effective GIS-based urban planning strategies.

2. Methods

2.1. Criteria for Selecting Relevant Literature and Case Studies

The selection of literature and case studies for this review was guided by specific criteria to ensure relevance and comprehensiveness. Firstly, the focus was on sources that explicitly discuss the integration and application of GIS in urban planning. This included studies that provide insights into the technological aspects of GIS, its implementation challenges, and its impact on urban development. Secondly, priority was given to recent publications (from 2015 to 2023) to capture the latest advancements and trends in the field. Thirdly, the literature was chosen based on its methodological rigor and relevance to the study's objectives, including qualitative analyses and case studies that offer in-depth insights into the practical applications of GIS in diverse urban contexts. This approach ensured a balanced representation of theoretical and practical perspectives on GIS in urban planning (Ustaoğlu, 2022; Givi et al, 2015).

2.2. Analytical Framework for Assessing GIS Applications

The analytical framework for assessing GIS applications in urban planning was structured around several key dimensions. These included the technological capabilities of GIS, its adaptability to different urban planning scenarios, and the effectiveness of GIS in addressing specific urban challenges. The framework also considered the user experience and the ease of integrating GIS with other planning tools and methodologies. Additionally, the framework evaluated the role of GIS in facilitating stakeholder engagement and decision-making processes in urban planning. This comprehensive approach allowed for a nuanced analysis of GIS applications, highlighting both their strengths and areas for improvement in the context of urban development (Mansourihanis et al., 2023; Soltani et al., 2019).

2.3. Methodological Approaches for Balancing Business and Environmental Goals

The methodological approaches for balancing business and environmental goals in urban planning with GIS centered on qualitative analysis. This involved examining case studies and narratives that illustrate how GIS has been used to align economic development with environmental sustainability. The approaches included assessing GIS-based planning strategies that prioritize green space development, urban agriculture, and sustainable land use. Furthermore, the methodologies focused on exploring GIS applications that support environmentally conscious urban design and infrastructure planning. By analysing these qualitative aspects, the study aimed to uncover best practices and innovative GIS applications that successfully balance business interests with environmental considerations in urban planning (Ustaoğlu, 2022; Givi et al, 2015; Mansourihanis et al., 2023).

3. Results of the Study

3.1. Trends and Patterns in GIS Adoption for Urban Planning

The adoption of Geographic Information Systems (GIS) in urban planning has shown significant trends and patterns, reflecting its evolving role in shaping sustainable and efficient urban environments.

Liu et al. (2023) explore the current use and future potential of GIS models in sustainable urban mobility planning across Europe. Their survey reveals that while GIS models are deemed useful in supporting urban mobility planning, over 60% of surveyed cities have not yet adopted them. The study highlights a growing interest in GIS models that integrate social and environmental aspects, indicating a trend towards more holistic and sustainable urban planning approaches. However, challenges such as the need for increased user-friendliness and the limited availability of non-traditional data types like real-time or neighbourhood-level data are identified as barriers to wider adoption (Liu et al., 2023).

Mohammed's research presents a different perspective on urban planning, focusing on the topological analysis of city elements using GIS and Volunteered Geographic Information (VGI) techniques. The study finds that large cities exhibit a higher degree of hierarchical levels in their street networks compared to smaller cities. This suggests a trend in urban planning where GIS and VGI are used to understand and manage the complex spatial structures of cities, aiding in making more informed planning decisions (Mohammed, 2021).

Li, Zhao, and Zhong (2022) discuss the emergence of urban data science and its integration with GIS. They highlight the use of advanced spatial analytics and machine learning methods in exploring new patterns and phenomena in urban areas. This trend points towards a future where GIS and urban data science converge, offering more advanced computational capabilities and a global vision for urban-focused research. The study underscores the potential of GIS in addressing a wide range of urban challenges, from healthcare and transportation to economy and natural disasters (Li, Zhao, and Zhong, 2022).

The trends and patterns in GIS adoption for urban planning are characterized by a growing emphasis on sustainable and holistic approaches, the integration of advanced computational methods, and the exploration of new forms of urban data. These trends indicate a shift towards more sophisticated and comprehensive uses of GIS in urban planning, driven by the need to address complex urban challenges in an increasingly data-driven world.

3.2. Case Studies: Successful GIS Implementations in Urban Projects

The implementation of Geographic Information Systems (GIS) in urban planning has demonstrated significant success across various global contexts. This section explores four distinct case studies that exemplify the successful application of GIS in urban projects.

In China, the research by Dang, Shi, and Mao (2002) delves into the long-term development of urban GIS, offering insights into urban dynamic development. The study emphasizes the importance of GIS and remote sensing (RS) in understanding and managing urban growth, particularly in rapidly urbanizing areas. It highlights the role of GIS in analyzing quantitative and qualitative characteristics of urban development, which is crucial for sustainable urban development (Dang, Shi, and Mao, 2002).

The integration of GIS with the BREEAM community's sustainability assessment in Lisbon, as explored by Pedro, Silva, and Pinheiro (2019), presents a groundbreaking approach to urban planning. This innovative model successfully identified priority intervention areas within the city, such as attracting new businesses, implementing energy efficiency strategies, and improving public transport links. The case study demonstrates the potential of GIS in supporting urban planning policies by bridging the gap between urban sustainability assessment and spatial analysis.

Ghani, Sarkom, and Samadi (2018) offer a compelling example of GIS application in Malaysia through the development of a 3-D GIS model for Ampang Jaya, Selangor. This model facilitated the understanding of urban planning and design by translating complex spatial information into easily understandable formats. The case study underscores the importance of 3-D GIS models in empowering local councils in decision-making, improving transparency, and supporting spatial growth management.

Pallathadka et al. (2022) conducted a GIS-based spatial analysis in four American cities to determine urban greenspace accessibility for different racial groups during the COVID-19 pandemic. This study highlights the legacy of urban planning injustices and the role of GIS in addressing them. The research provides valuable insights from an environmental justice, public health management, and urban planning perspective, demonstrating the versatility of GIS in addressing contemporary urban challenges.

From enhancing sustainable development strategies to addressing public health and environmental justice issues, GIS proves to be an indispensable tool in modern urban planning. The success stories from different parts of the world provide a blueprint for future GIS implementations, showcasing the potential of this technology in creating more sustainable, efficient, and equitable urban environments.

3.3. Environmental Benefits Realized Through GIS in Urban Planning

The integration of Geographic Information Systems (GIS) in urban planning has led to significant environmental benefits, as evidenced by various studies and applications worldwide. This section explores the environmental impacts of GIS in urban planning through three key studies.

The rapid urbanization in India, particularly in its major cities, has been a significant concern for urban and town planners. The urban population has seen a dramatic increase, with major cities like Mumbai, Delhi, Kolkata, and Chennai experiencing substantial growth (Rahman, 2007). This urban expansion has brought about various challenges, including environmental management and the need for sustainable development, which have been increasingly addressed through the application of remote sensing and GIS techniques (Rahman, 2007).

Meerow and Newell (2017) research introduces the Green Infrastructure Spatial Planning (GISP) model, a GIS-based multi-criteria approach that integrates various benefits such as stormwater management, social vulnerability, green space, air quality, urban heat island amelioration, and landscape connectivity. This model, applied to Detroit, reveals that current green infrastructure projects are not optimally sited to maximize their potential benefits. The GISP model demonstrates the capability of GIS in identifying hotspots where green infrastructure benefits are needed most, thereby enhancing social and ecological resilience in urban areas.

Sturiale and Scuderi (2019) discuss the role of Green Infrastructures (GIs) in urban planning for climate change adaptation. Their study proposes a methodological approach to evaluate the social perception of citizens regarding urban green areas, integrating participatory planning with social multi-criteria evaluation methods. Applied to the urban green system of Catania, this approach underscores the importance of GIs in urban planning as a tool to satisfy environmental, social, and economic needs. The study exemplifies how GIS can be used to guide urban development towards resilience and sustainability, particularly in the face of climate change.

From enhancing urban landscapes and improving transportation safety to promoting resilience and climate change adaptation, GIS emerges as a crucial tool in creating sustainable urban environments. The ability of GIS to process and analyse complex spatial data enables urban planners to make informed decisions that positively impact the environment. As urban challenges continue to evolve, the role of GIS in fostering environmentally sustainable urban development will become increasingly vital.

3.4. Business Advantages and Economic Impacts of GIS Applications

The application of Geographic Information Systems (GIS) in urban planning has not only transformed the landscape of urban development but also brought significant business advantages and economic impacts. This section explores the economic benefits of GIS through three distinct studies.

Swetnam et al. (2011) developed a Geographic Information System (GIS) methodology to translate socio-economic scenarios, which are typically qualitatively expressed, into quantitative, map-based formats. This process involved three key steps:

(i) constructing scenarios with the input of local stakeholders and experts to determine potential changes in major land cover classes under varying driver sets; (ii) converting these scenarios into spatially explicit rules, such as restricting agricultural activities to specific soil types; (iii) generating future land cover maps, which are then utilized to model ecosystem services (Swetnam et al., 2011).

Zalloom (2022) explores the role of GIS in developing smart cities, particularly in urban infrastructure development in migration areas. The study focuses on Amman, Jordan, and highlights how GIS technology can improve the utilization of existing infrastructure, enhance the quality of life, and provide guidance on mobility and service use. The research underscores the importance of GIS in creating more inclusive urban plans, reducing the vulnerability of both refugees and host communities, and enhancing social sustainability. This study confirms the essential need for smart cities with GIS technology to address the challenges posed by waves of immigration and their impact on infrastructure and socio-economic conditions.

Droj et al. (2023) demonstrate the benefits of integrating real-time traffic data with GIS technology for urban traffic assessment in Oradea, Romania. Their case study, focused on the historical centre of Oradea, utilized remote sensing data collected before, during, and after traffic restrictions to analyse the impact of infrastructure works and COVID-19 on traffic. The study shows the necessity of using GIS and crowdsourcing-based applications in traffic analysis and planning, highlighting GIS's role in solving complex planning problems and enhancing the feasibility and consistency of proposed infrastructure with sustainable city requirements.

Through innovative applications in diverse urban contexts, GIS proves to be an indispensable asset in navigating the complexities of modern urban development, offering solutions that are both sustainable and economically beneficial. As we continue to face urban challenges, the strategic integration of GIS technology stands as a key driver in shaping the future of urban landscapes, aligning economic growth with sustainable urban practices.

3.5. Limitations and Shortcomings of Current GIS Technologies

Despite the widespread adoption and numerous benefits of Geographic Information Systems (GIS) in urban planning, there are inherent limitations and shortcomings that need to be addressed. This section explores these challenges through the lens of three distinct studies.

The research by Jingfeng and Shen (2022) delves into the application of GIS in urban planning informatization, highlighting the main shortcomings of current GIS technology. The study emphasizes the need for a comprehensive GIS-based urban digital planning system, addressing the challenges in modelling known geographical phenomena and establishing geographic data models. The research points out the necessity of an object-oriented approach in GIS and underscores the importance of GIS in providing more scientific and quantitative methods for urban planning and construction, moving beyond the reliance on subjective experience by planners.

Zhang and Wang (2022) explore the application of GIS in the construction of Smart Cities, particularly in the context of street data analysis and information construction. Their study identifies the shortcomings of traditional design methods and the challenges faced in integrating GIS with intelligent technologies. The research emphasizes the need for a more in-depth understanding of the practicality and advantages of GIS in urban planning, particularly in addressing the limitations of traditional design methods and enhancing the construction of Smart Cities.

Alhaj and Abdalla (2022) discuss the usage of GIS in system planning and management of infrastructure projects, highlighting the challenges faced by governmental and private institutions in service management and emergency and crisis management. The paper reviews various research areas where GIS has been used to address problems and find appropriate solutions. It recommends the future use of GIS programs in service management and distribution techniques due to their potential in presenting problems, shortcomings, and providing ideal solutions.

4. Discussion of the Results

4.1. . Analyzing GIS's Impact on Urban Development Dynamics

The impact of Geographic Information Systems (GIS) on urban development dynamics is a multifaceted subject, as evidenced by recent studies. Shrestha (2012) explores the ecological impact of exurban development, a form of residential development outside urban areas, using GIS and remote sensing. This study highlights the significant role of GIS in mapping and analysing the spatial pattern of urban growth, particularly in areas experiencing rapid exurban

development. The research underscores the importance of GIS in understanding the ecological implications of urban expansion, thereby contributing to more informed decision-making processes in urban planning.

Arabadzhieva and Toteva (2023) focus on the impact of urban environments on surface and groundwater recharge in Sofia, Bulgaria, using a GIS-based approach. Their study integrates geospatial data and land use analysis to assess the complex interplay between urban development and water recharge. The findings reveal the challenges posed by urbanization to water resource management and the potential of GIS in providing insights for sustainable water management strategies. This research exemplifies the critical role of GIS in enhancing our understanding of urban hydrological systems and informing water resource sustainability in urban settings.

Kindu et al. (2020) conduct a comprehensive study to monitor urban growth patterns in Bahir Dar, a rapidly growing city in northwest Ethiopia, using a 30-year record of Landsat imagery. Their research employs object-based image analysis and GIS for post-classification comparison, analysing changes in land use and land cover over time. The results reveal significant urban expansion and changes in natural landscapes, demonstrating the effectiveness of GIS and satellite imagery in understanding urban dynamics and informing sustainable urban development (Kindu et al., 2020).

From ecological assessments to water resource management and urban growth modelling, GIS emerges as an indispensable tool in urban planning and development, offering valuable insights for sustainable and informed urban management strategies.

4.2. Balancing Commercial Interests with Environmental Sustainability

The challenge of balancing commercial interests with environmental sustainability in urban planning is a complex yet crucial endeavour. Stigt, Driessen, and Spit (2013) explore the integration of environmental interests in urban planning, emphasizing the concept of 'decision windows'. Their study suggests that recognizing and manipulating decision windows is key to integrating environmental interests in urban planning. The research highlights the dynamic nature of decision-making in urban planning, involving diverse stakeholders and policy networks, and underscores the importance of framing issues within decision-making arenas to achieve sustainable solutions.

Rahman and Szabó (2022) present a GIS-based multicriteria decision-making approach to optimize urban land use, considering sustainability dimensions (social, economic, and environmental benefits). Their case study in Rajshahi City, Bangladesh, demonstrates how GIS can be used to define sustainability criteria and optimize residential land allocation. The study reveals that a GIS-MCDM approach can yield significantly more sustainability benefits, showcasing the potential of GIS in balancing urban development with sustainability goals.

Akyol, et al. (2018) discuss the assessment of environmental urbanization using GIS and multicriteria decision analysis, focusing on a case study in Denizli, Turkey. Their research develops a framework for evaluating urbanization quality, considering various geographic and urbanization parameters. The study emphasizes the importance of integrating GIS with multicriteria analysis to assess urban environmental quality, which is crucial for sustainable urban development (Akyol et al., 2018).

These studies illuminate the intricate process of balancing commercial interests with environmental sustainability in urban planning. They demonstrate the pivotal role of GIS and decision-making frameworks in navigating the complexities of sustainable urban development, ensuring that economic growth does not compromise environmental and social well-being.

4.3. Policy Recommendations for Enhancing GIS in Urban Planning

The enhancement of Geographic Information Systems (GIS) in urban planning requires strategic policy interventions. In China, the research by Dang, Shi, and Mao (2002) delves into the long-term development of urban GIS, offering insights into urban dynamic development. The study emphasizes the importance of GIS and remote sensing (RS) in understanding and managing urban growth, particularly in rapidly urbanizing areas. It highlights the role of GIS in analysing quantitative and qualitative characteristics of urban development, which is crucial for sustainable urban development (Dang, Shi, and Mao, 2002).

Opadeyi and Brown (2008) work focuses on the application of GIS in urban planning and management in the Caribbean. They argue that implementation policies and strategies must be tailored to the local context for effective use of GIS tools. The study uses Campbell and Masser's distinction between technological determinism, managerial rationalism, and social interactionism to assess GIS experiences in the Caribbean. The paper concludes with policy recommendations to support more effective use of GIS tools in urban planning and management in the region (Opadeyi and Brown, 2008).

Ghose and Huxhold (2017) discuss the value of using multi-scalar GIS-based indicators in urban planning. Their research, conducted in conjunction with neighbourhood stakeholders in Milwaukee, Wisconsin, examines inner-city neighbourhood conditions using GIS-based indicators. The study finds that such studies are helpful for monitoring neighbourhood conditions, assessing past successes and failures, and formulating new planning policies. The use of a multi-scalar approach is particularly valuable, and the responses from stakeholders indicate that these studies are beneficial for urban planning policy-making activities (Ghose and Huxhold, 2017).

Tailoring policies to local contexts, focusing on multi-scalar GIS-based indicators, and prioritizing sustainable development goals are crucial steps in this direction. The integration of these policy recommendations can significantly improve the effectiveness of GIS in urban planning, leading to more sustainable and well-managed urban environments.

4.4. The Role of Technology and Innovation in Shaping Future GIS Applications

The integration of technology and innovation in Geographic Information Systems (GIS) is revolutionizing urban planning. The research by Jingfeng and Shen (2022) delves into the application of GIS in urban planning informatization, highlighting the main shortcomings of current GIS technology. The study emphasizes the need for a comprehensive GIS-based urban digital planning system, addressing the challenges in modelling known geographical phenomena and establishing geographic data models. The research points out the necessity of an object-oriented approach in GIS and underscores the importance of GIS in providing more scientific and quantitative methods for urban planning and construction, moving beyond the reliance on subjective experience by planners.

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Karlina and Johan (2020) discuss the application of GIS in ecosystem-based marine spatial planning, particularly focusing on the challenges faced in Indonesia. The study highlights the importance of GIS and remote sensing in effectively accessing and summarizing spatial data for evaluating marine spatial planning projects. It emphasizes GIS's essential role in managing and analysing spatial data and supporting decision-making processes in marine environment management (Karlina and Johan, 2020).

Yin (2023) discusses the design scheme of urban and rural planning management systems based on GIS. The study focuses on the integration of computer technology, information technology, and CGI technology in urban planning and management. It proposes innovative solutions to improve the effectiveness of traditional urban planning and management methods. The research emphasizes the importance of GIS technology in the planning management collaborative operation system, highlighting its role in providing management information operation carriers for urban planning managers.

The ability of GIS to process and analyse complex spatial data enables urban planners and policymakers to make informed decisions that positively impact the economy and society. As urban challenges continue to evolve, the role of GIS in driving economic growth and sustainability in urban development will become increasingly vital.

5. Conclusion

Embarking on a comprehensive exploration of Geographic Information Systems (GIS) within the realm of urban planning, this study meticulously navigated through the intricate interplay of GIS's business and environmental facets. The endeavour was not merely to map out its applications but to delve deeper into how these applications sculpt the ever-evolving urban landscape.

Employing a robust methodological approach, the study meticulously sifted through a plethora of scholarly literature and case studies. This approach was pivotal in distilling the essence of GIS's role in urban development, shedding light on its transformative impact across diverse urban scenarios. The methodology, both rigorous and reflective, served as a beacon, guiding the study through the complex terrain of urban planning and GIS integration.

The revelations of this inquiry are manifold. GIS has emerged as a cornerstone in the edifice of urban planning, a tool indispensable for navigating the labyrinth of modern urban challenges. It stands at the forefront of sustainable planning,

adeptly balancing the scales of economic vitality and environmental guardianship. However, this journey also uncovered the hurdles that GIS faces – challenges in database sophistication, the quest for comprehensive information services, and the seamless melding with smart technologies.

In synthesizing these insights, the study presents a tapestry of recommendations, each thread woven with the intent to bolster GIS's role in urban planning. These recommendations, ranging from the customization of policies to the local milieu, to harnessing the power of multi-scalar GIS-based indicators, chart a course towards a future where urban planning is not only more effective but also more attuned to the rhythms of sustainable development.

As the urban canvas continues to evolve, the imprint of GIS in shaping its contours is poised to deepen. This scholarly endeavour contributes a rich palette of insights, offering urban planners, policymakers, and academicians a nuanced perspective on the transformative potential of GIS. It is a narrative that not only celebrates the achievements of GIS in urban planning but also serves as a clarion call for continued innovation and strategic foresight in harnessing its full potential. The study, in its essence, is both a reflection of GIS's journey in urban planning and a roadmap for its future trajectory – a trajectory aimed at crafting more sustainable, efficient, and vibrant urban landscapes.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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