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Review

Exploring the Roles, Future Impacts, and Strategic Integration of Artificial Intelligence in the Optimization of Smart City—From Systematic Literature Review to Conceptual Model

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Abstract: Artificial Intelligence (AI) is one of the science fields with huge potential to create a cognitive and tech-leaping type of future smart city design/development. However, extant studies lag behind recent applications, potential growth areas, and the challenges associated with AI implementation. This study examines AI's current role, trend, and future potential impacts in enhancing smart city drivers. The methodology entails conducting a Systematic Literature Review (SLR) of publications from 2022 onwards. The approach involves qualitative deductive coding methods, descriptive statistical analysis, and thematic analysis. The findings revealed the impacts of AI in (i) public services and connectivity, (ii) improving accessibility and efficiency, (iii) quality healthcare, (iv) education, and (v) public safety. Likewise, strategies, such as collaborative ecosystems, digital infrastructure, capacity building, and clear guidelines and ethical framework, were proposed for fostering the integration of AI in potential future smart cities. This research fills a notable gap in the current understanding of AI's specific contributions to smart cities, offering insights for stakeholders in urban planning, computer science, sociology, economics, environmental science, and smart city initiatives. It serves as a strategic guideline and scholarly research output for enhancing smart city design. It also underscores the potential of AI in creating dynamic, sustainable, and efficient urban environments.

Keywords: Artificial Intelligence; smart cities; smart city drivers; sustainable development; environmental sustainability; quality of life

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1. Introduction

"*Smart cities*" is a catchphrase that is currently receiving attention from diverse disciplines, including but not limited to computer science [1–3], environmental science, sociology [4], economics [5], and urban planning [6,7]. From a sociological perspective, smart tools have been utilized within the public domain to enrich citizens' immediate and long-term learning/knowledge acquisition relating to their social domain in a European nation [4]. Likewise, computer scientists' understanding of the concept ranges from transferring the smart city application to virtual storage and energy management to the crypto-based Internet of Things (IoT) [1–3]. Various economic models have been utilized during smart city construction implementation [5]. In urban planning, the smart city concept is being utilized to integrate information and communication technology, and various physical devices connected to the IoT network [8].

Smart cities optimize the efficiency of city operations/services and connect to citizens. Smart cities use data from various sources, i.e., citizens, devices, buildings, and assets [9]. These data are processed and analyzed to manage/optimize traffic and transportation systems, power plants, water supply networks, waste management, information systems, and other community services [10]. The overarching goal of smart cities is to enhance residents' quality of life (QoL) through smart technology, thereby creating an urban environment that is not only technologically advanced but also sustainable and efficient. Several key factors drive the development of smart cities. A paramount driver is sustainability and environmental stewardship—focusing on minimizing waste, reducing pollution, and efficiently managing resources [11]. This is achieved by implementing green technologies and practices, such as renewable energy sources, sustainable building materials, and efficient waste management systems [12].

Another crucial driver is the need for technological innovation, which involves deploying advanced technologies such as the IoT, AI, and big data analytics. These technologies are used to improve urban infrastructure and services, making them more responsive, efficient, and adaptable to the needs of the city's inhabitants [13]. Furthermore, enhancing public services and connectivity significantly drives smart cities [14]. This involves using technology to improve the accessibility, efficiency, and quality of various public services, i.e., healthcare, education, and public safety [15]. For instance, smart healthcare systems use technology to monitor patients remotely, while innovative education initiatives leverage digital tools to enhance learning experiences. Additionally, smart cities emphasize improved connectivity and mobility, employing technology to develop intelligent transportation systems and enhance digital connectivity [16]. This includes optimizing traffic flow, reducing congestion, and providing real-time information to residents and commuters. By integrating these elements, smart cities improve residents' day-to-day lives and prepare them for future challenges and opportunities, creating a dynamic and sustainable urban environment [17].

Furthermore, AI plays a transformative role in enhancing the critical drivers of smart cities, fundamentally altering how urban areas operate and serve their residents [18]. In the context of sustainability, AI contributes significantly by optimizing resource management. It enables smart cities to analyze large datasets from various sources, such as traffic patterns, energy usage, and waste production, to identify trends and make data-driven decisions [19]. For instance, AI algorithms can predict peak energy demand times and adjust the supply accordingly, reducing waste and increasing efficiency [20]. In environmental monitoring, AI aids in detecting and managing pollution levels, contributing to healthier urban environments [21]. Moreover, AI-driven systems are integral in managing water resources, predicting maintenance needs in infrastructure, and automating recycling processes, thereby promoting a more sustainable urban ecosystem [22].

In the field of public services and connectivity, AI's impact is equally profound. Smart healthcare systems powered using AI can predict outbreaks, personalize patient care, and streamline hospital operations [23]. AI enhances learning experiences through personalized learning paths and predictive analytics to identify areas where students need additional support. Public safety is another area where AI makes a substantial difference—it is used in surveillance systems to enhance security, emergency response systems to improve efficiency, and traffic management to reduce accidents and congestion [24]. AI also revolutionizes transportation in smart cities by powering autonomous vehicles, optimizing traffic flow, and providing predictive maintenance for public transport systems. By integrating AI into these aspects of urban life, smart cities are becoming more efficient, responsive, inclusive, and accessible, ultimately enhancing inhabitants' QoL [25].

This research focuses on filling a notable gap in understanding how AI explicitly contributes to smart city development. Existing studies recognize the broad role of AI in urban environments but lack a detailed exploration of its impact on crucial aspects of smart cities, such as sustainability and efficiency. Moreover, there is a need for a more comprehensive, data-driven analysis that identifies emerging trends and potential areas for the future application of AI in these urban settings [26]. With the rapid evolution of AI technology, these gaps are significant, as they hinder informed decision-making and strategic planning for advancing smart cities. Additionally, recent extant literature has not adequately addressed the challenges and ethical considerations unique to implementing AI in different sectors of smart city development. This study aimed to explore the integration and impact of AI in developing and optimizing smart city drivers. In ensuring the successful actualization of the stated aim, the objectives of this study were as follows:

(i) Identify the key drivers of smart cities and examine the current role of AI in enhancing these drivers;
(ii) Conduct a statistical analysis and trend identification of AI applications within smart cities, focusing on areas with the most significant AI influence;
(iii) Identify the potential future impact of AI on smart city drivers;
(iv) Identify strategies for addressing challenges and ethical considerations in AI implementation.

In order to achieve the objectives of this research, the following research questions (RQs) were designed:

(i) How is AI currently influencing the critical drivers of smart city development?
(ii) Based on current statistical data and analysis, what are the emerging trends and potential growth areas for AI applications in smart cities?
(iii) What challenges and ethical considerations arise in implementing AI in smart cities, and how can they be effectively addressed?

These objectives and RQs were designed to provide a structured approach to understanding AI applications' current and future role in smart cities and the broader implications of their integration. This research significantly enhances the theoretical understanding of AI and its practical application in the evolving interdisciplinary computer, sociology, economics, environmental sciences, and urban planning landscape by addressing the identified shortcomings. This study's findings will provide valuable insights for interdisciplinary stakeholders planning and implementing smart cities. This study acknowledges the limitations inherent to SLR, such as potential biases in article selection and the possibility of missing relevant studies not indexed in the chosen databases. The rapid evolution of AI technology also means that the most recent developments might not be fully captured in the literature.

The next section highlights the utilized research methodology. This is followed by this study's qualitative and quantitative research findings. In Section 4, the discussion of the research findings is presented in line with the proposed conceptual model, RQs, and a comparison with related extant studies. The summary of the study and the direction for future research is presented in the Conclusion section.

2. Methods

This study adopted the SLR approach to explore AI's integration and impact in smart cities. The SLR methodology was chosen for its systematic, transparent, and reproducible approach [27], enabling a comprehensive synthesis of existing research findings related to AI's role in smart city development. The overall architecture of the proposed methodology is provided in Figure 1.

This research approach was used to provide diverse perspectives and findings, contributing to a well-rounded understanding of AI in the context of smart cities, particularly in identifying potential growth areas and strategies to address challenges and ethical considerations in AI implementation, in line with this study's research objectives. By adhering to this structured SLR methodology, its significance is the offering of a detailed and comprehensive understanding of AI's current state and prospects in smart city development, directly addressing the research objectives and providing valuable insights for stakeholders involved in sociology, economic development, cognitive computing, urban planning, smart and sustainable city initiatives, and cognitive cities development. The detailed research procedures of this study are provided in the following sub-sections.

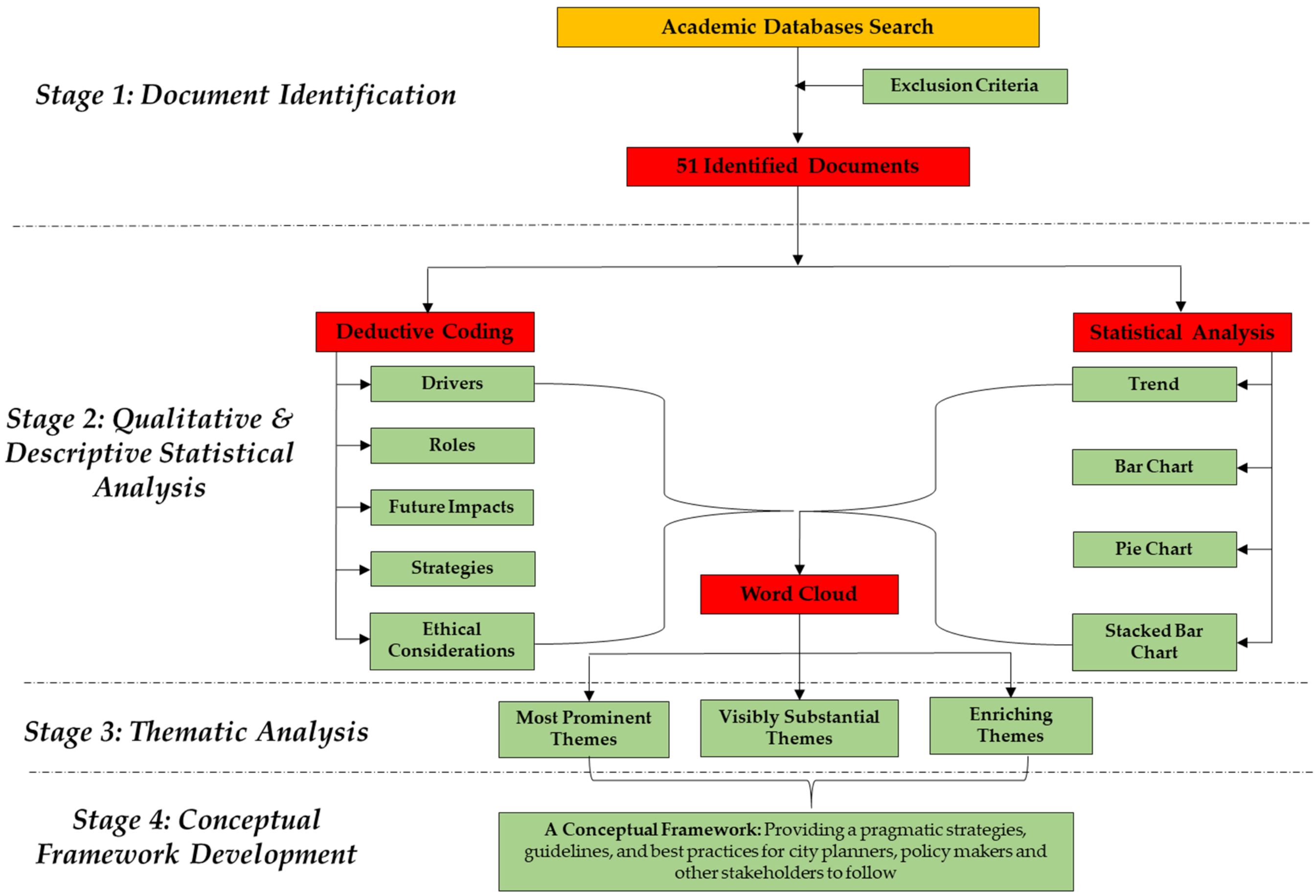

Figure 1. Research approach depicting the stages and methods utilized.

2.1. *Selection/Identification Process, Inclusion and Exclusion Criteria*

In conducting SLR that aligns with the defined research objectives, the methodology encompassed a structured approach to the literature search, selection, and analysis processes. The literature search was conducted across several academic databases, including IEEE Xplore, ScienceDirect, Springer, Nature, JSTOR, and Google Scholar, focusing on AI-related publications on smart cities. This search mainly targeted peer-reviewed articles and conference papers published in English from 2022 onwards to ensure the relevance and currentness of the information. Keywords and phrases such as "Artificial Intelligence", "AI", "Smart Cities", "Urban Development", "AI in Urban Planning", "Smart City Drivers", and "AI Impact in Smart Cities" were utilized in the search. The inclusion criteria for the literature involved publications focusing on AI applications in smart cities, specifically those addressing the key drivers of smart cities, to align with the first research objective and first RQ. The exclusion criteria included non-peer-reviewed articles, unrelated topics, and outdated studies, ensuring the focus remained tightly aligned with the research objectives. The process leading to the final selection of the reviewed documents is illustrated in Figure 2 below.

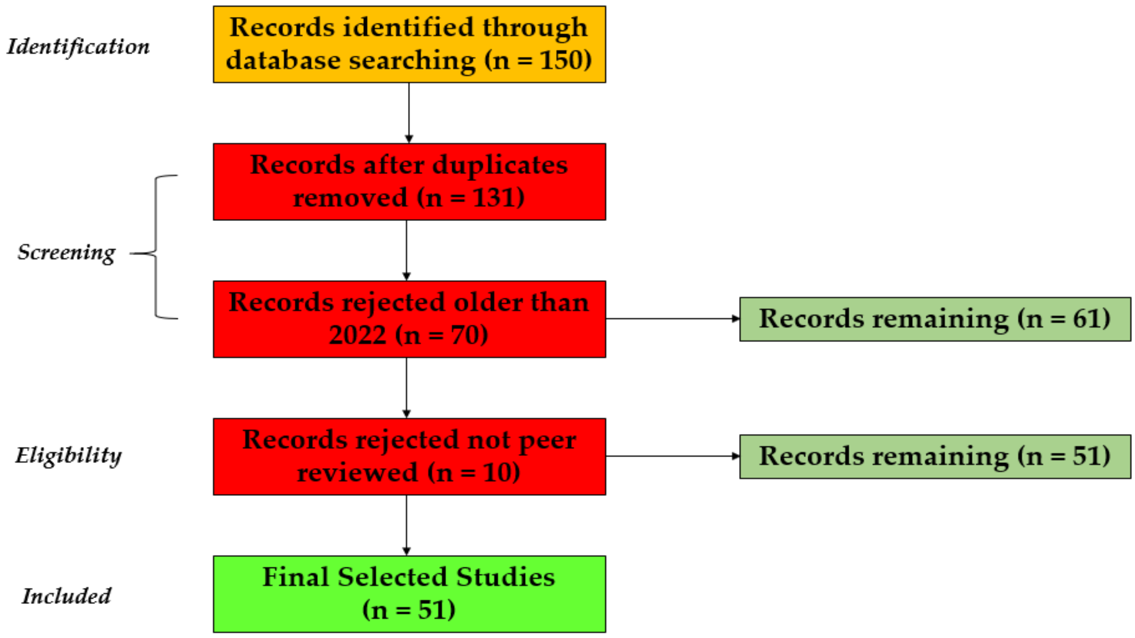

Figure 2. Document search selection process.

2.2. Qualitative Coding, Descriptive Analysis, and Thematic Analysis

Once the relevant literature was identified, a detailed data extraction process commenced. In this process we systematically recorded vital information such as study objectives, methodologies, findings, and conclusions from each selected study/document. The data extraction was explicitly tailored to gather information that contributed to (i) understanding the current role of AI in smart city drivers, (ii) identifying trends and significant areas of AI influence in smart cities, and (iii) gaining insights into the potential future impact of AI. To achieve this, a qualitative coding method was utilized. The utilized deductive codes and their corresponding definitions are contained in Table 1 below.

Table 1. Deductive codes used for data collection and analysis.

Codes	Definition
Drivers	The key drivers of smart cities (i.e., playing pivotal role in shaping the development of urban areas)
Roles	Understanding the current role of AI in smart city drivers
Future impacts	Insights into the potential future impact of AI
Strategies	The strategies for fostering the integration of AI in potential future
Ethical consideration	The challenges and ethical considerations in AI implementation of smart cities

In addition to the qualitative analysis of the extracted relevant information, quantitative data analysis was also utilized. This study used descriptive statistical analysis involving annual trend analysis, bar chart, pie chart, and stacked bar to visualize and quantitatively illustrate the analyzed results. This process aligned with the second research objective of conducting a statistical analysis and trend identification. The extracted data were further synthesized through thematic analysis to identify common themes, patterns, and gaps in the existing literature [28]. This thematic analysis is instrumental in understanding the various dimensions of AI's application in smart cities, particularly the key drivers identified in the research objectives. The final selection included 51 papers, ensuring focused yet comprehensive topic coverage.

2.3. Limitations of Research

While comprehensive in its approach to exploring the role of AI in smart cities, this research encountered several limitations that must be acknowledged. Firstly, this study's focus on articles exclusively from 2022 and 2023, though beneficial for obtaining the most current insights, potentially overlooks the continuity and evolution of ideas from earlier research. This temporal scope might limit understanding the progression and historical context of AI's integration in smart cities. Secondly, the reliance on published academic literature and peer-reviewed articles, although ensuring scholarly rigor, may omit practical insights and real-world experiences found in grey literature, industry reports, and case studies. Such sources could provide a more nuanced understanding of how AI is implemented in urban environments.

Additionally, the quantitative analysis, primarily represented through a word cloud and stacked bar charts, offers insights based on the frequency of topics but lacks depth regarding AI's qualitative richness and practical implications in smart cities. This methodological choice may not fully capture the complexities and subtleties of AI's impact on urban life. Furthermore, the study's focus on English language publications could introduce a language bias, potentially overlooking significant research and developments documented in other languages.

Lastly, this research acknowledges the rapid pace of technological advancement in AI and smart cities. The findings and conclusions drawn in this study are subject to the fast-evolving nature of technology, which may lead to the rapid obsolescence of the insights provided. This dynamic nature of the field presents a challenge in maintaining the relevance and applicability of the research findings over time. Despite these limitations, this study provides valuable insights and a foundational understanding of AI's role in developing smart cities, offering a platform for future research to build upon and expand.

3. Results and Conceptual Model Development

3.1. Quantitative Research Findings

3.1.1. Yearly Trend of AI Smart Cities-Focused Studies

These research findings reflect this study's second research objective. The line chart in Figure 3 presents a comprehensive visualization of the temporal distribution of studies in the SLR focusing on smart cities and AI prior to the specific inclusion criteria of selected papers from 2022 and 2023. Commencing with the '*Pre-2005*' era, the chart indicates a foundational phase in the field with 13 studies, setting a baseline for early research activities. A significant uptrend was observed in the '*2005–2010*' period, marked by an increase to 24 studies, reflecting a burgeoning academic interest and potential advancements in smart cities and AI technologies. The '*2011–2015*' timeframe shows a plateau with 13 studies, suggesting a period of research consolidation and possibly a maturation in the thematic focus of the studies.

However, the '*2016–2019*' period exhibits a slight decline to nine studies, indicative of a potential shift in research paradigms or priorities within the field. This trend reverses notably in the '*2020–2021*' segment, where the count escalates to 21 studies, aligning with a global upsurge in smart technologies and AI driven by technological advancements and heightened societal interest. The most recent years, '2022' and '2023', continue this upward trajectory with 29 and 22 studies, respectively, underlining the increasing importance, relevance, and urgency of research in this domain. With its ascending trend in the latter years, the line chart effectively encapsulates scholarly work's dynamic and evolving nature in smart cities and AI, highlighting the progressive emphasis on contemporary developments and innovations in the field. This visual representation charts the historical progression of research and underscores the growing academic focus on cutting-edge technologies in urban development and AI.

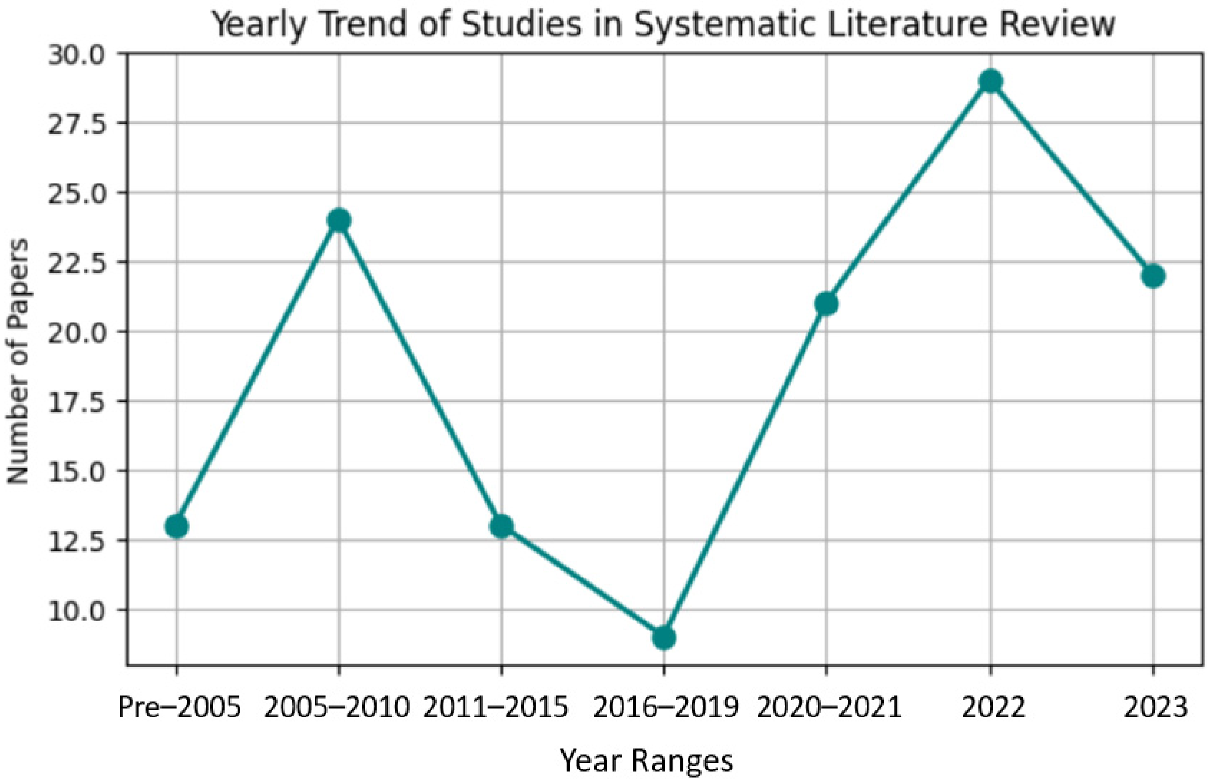

Figure 3. Yearly trend in SLR.

3.1.2. AI Smart Cities Document Selection Analysis

The bar chart in Figure 4 succinctly illustrates the selection process undertaken in the SLR concerning research papers related to smart cities and AI. Initially, a comprehensive collection of 150 papers was considered for the review. However, a rigorous screening process led to the exclusion of many papers based on specific criteria: 70 papers were excluded due to their publication date being before 2022, ensuring this review's focus on recent and relevant findings. Additionally, ten papers were discarded as they lacked proper peer review or predominantly consisted of grey literature, thereby maintaining the academic rigor of this review. Furthermore, 19 papers were identified as duplicates and removed to avoid redundancy. The meticulous filtration process included 51 papers deemed suitable for review based on their relevance, recency, and academic credibility. This quantitative representation underscores the thorough and selective approach employed in this research, ensuring a focus on quality and pertinent literature on smart cities and AI.

3.1.3. Yearly AI Smart Cities Study Distribution

The pie chart in Figure 5 vividly delineates the distribution of studies within the SLR based on their publication year, explicitly differentiating between 2022 and 2023 and the cumulative period preceding 2022. The segment representing 2022 is a substantial portion of the total studies, emphasizing the significant emphasis of research contributions made during this year. The 2023 segment underlines the ongoing relevance and vitality of current research endeavors. In contrast, the '*Pre-2022*' segment occupies the most significant proportion of the chart, encapsulating a comprehensive range of foundational and developmental studies that have collectively shaped the current landscape of smart cities and AI research.

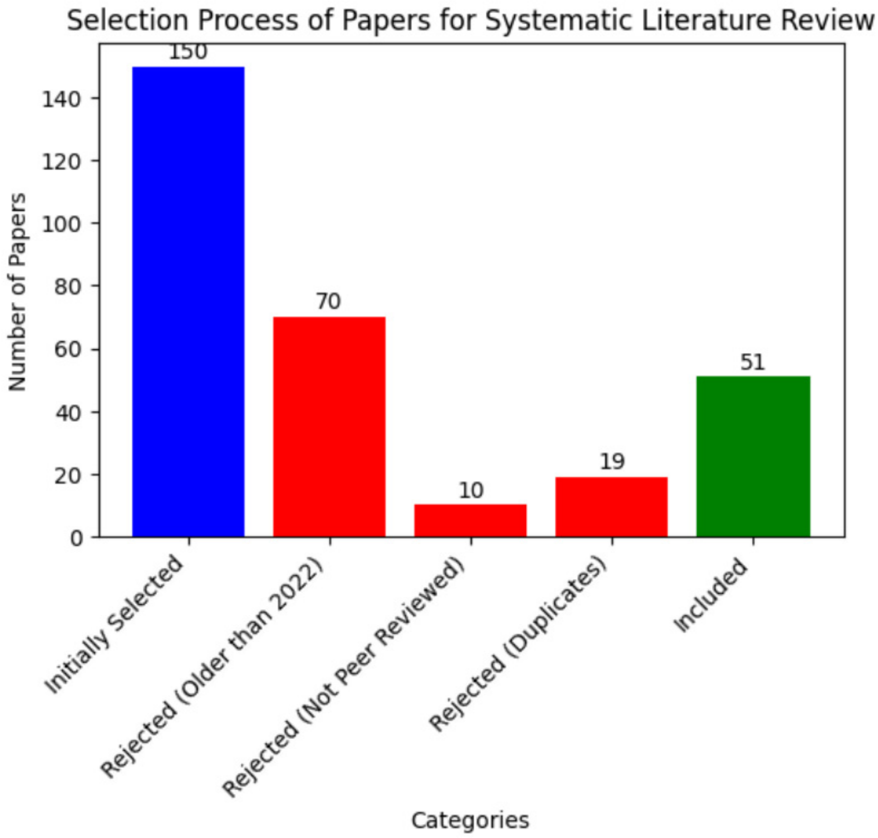

Figure 4. Selection process of proposed SLR.

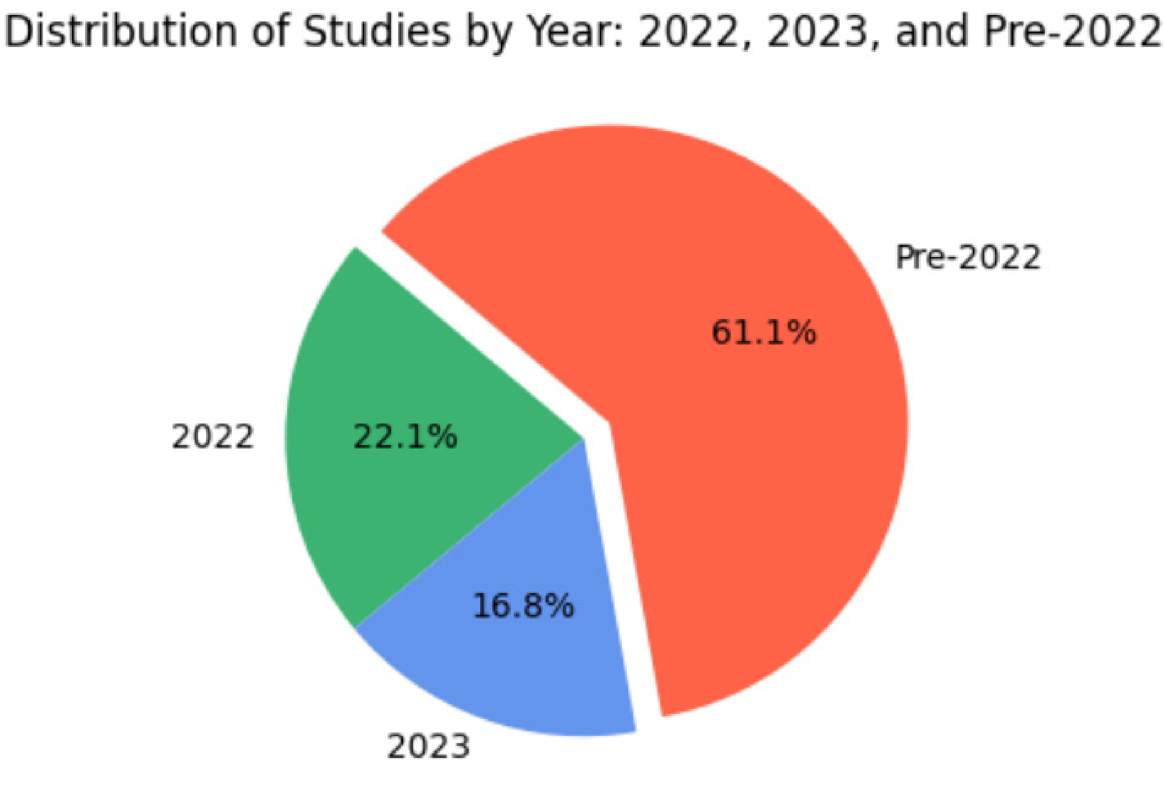

Figure 5. Distribution of studies by the year.

3.1.4. Distribution of AI-Related Topics in Smart Cities

The stacked bar chart in Figure 6 methodically delineates the distribution of AI-related studies within the smart cities domain for 2022 and 2023. Each bar in the chart corresponds to one of these years and is segmented into various components, each representing a specific research topic where AI integration is prominent. For 2022, the chart shows a comprehensive engagement across multiple facets of smart cities, highlighted by significant contributions in topics such as AI in sustainability, AI in efficiency, AI in connectivity, AI in citizen engagement, AI in public health, AI in public utilities, AI in urban planning, and AI in environmental monitoring. The total number of studies on each topic collectively forms the height of the bar for 2022, indicating an extensive focus on AI's role in advancing smart city initiatives. For 2023, a similar distribution of topics is observed, although with a slight variation in the number of studies per topic. This variation reflects the dynamic nature of the research focus and the evolving priorities within the field. Each topic maintains a presence, underlining the continued importance of AI in shaping various aspects of smart city development.

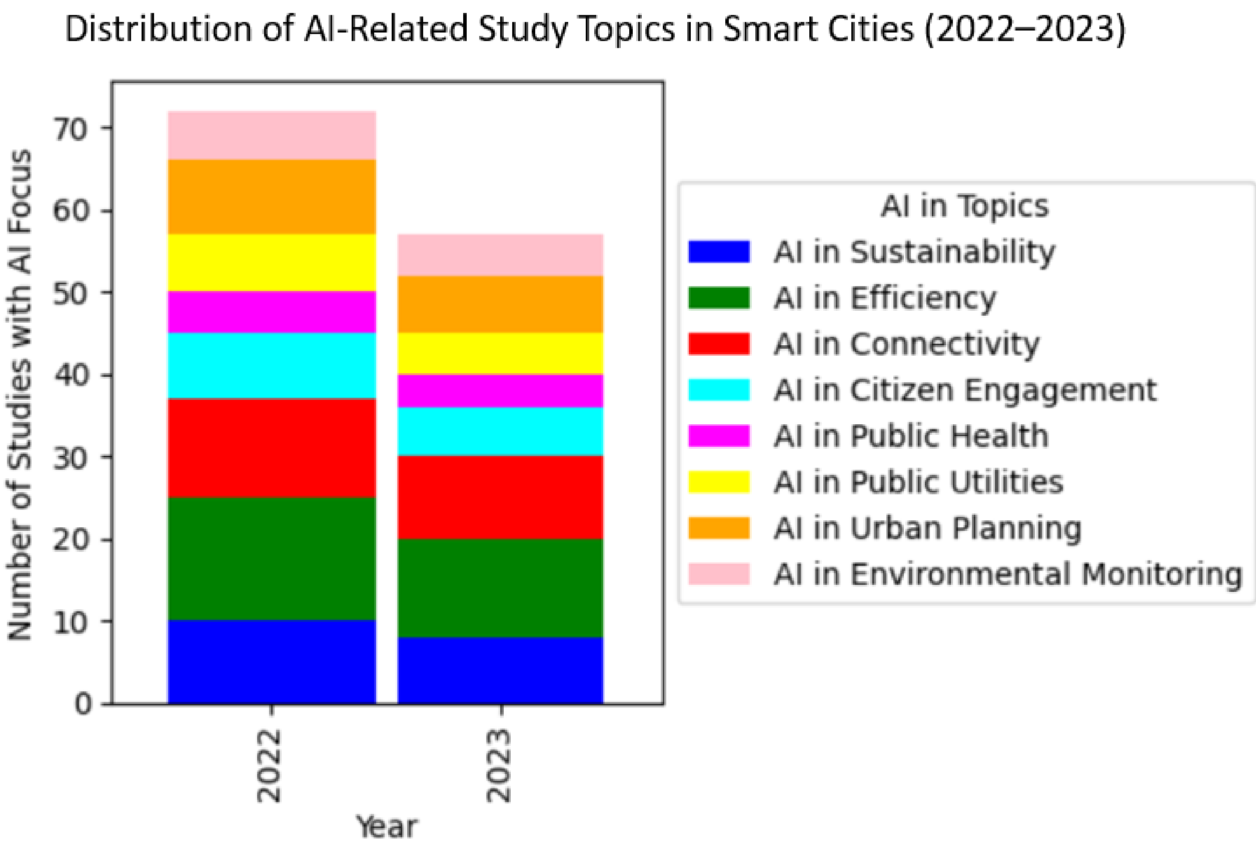

Figure 6. AI-related topics count concerning the year.

3.1.5. Predominant Themes and Concepts in AI-related Smart Cities Research

The word cloud in Figure 7 visualizes the predominant themes and concepts in AI-related smart cities research, illustrating the areas of focus and their relative importance based on their occurrence across studies. In this depiction, terms such as "Sustainability", "Efficiency", and "Connectivity" emerge as the most prominent, indicating their significant role and frequent discussion in the context of smart cities. The prominence of "Artificial Intelligence" and "Smart Cities" in the cloud underscores their central position in the research narrative, reflecting the integral role of AI in the evolution and functioning of urban environments. Additionally, terms such as "Urban Development", "Technology", "Innovation", and "IoT" (Internet of Things) are also visibly substantial, highlighting the diverse facets and technological underpinnings of smart cities. The inclusion of terms such as "Data Analysis", "Digital Infrastructure", "AI Integration", "Urban Operations", "Quality of Life", and "Resource Management" further enriches the depiction, revealing the multifaceted approach to studying smart cities. These various elements collectively denote a comprehensive exploration of how AI technologies intersect with urban development to enhance efficiency, connectivity, and overall QoL, painting a vivid picture of the current research landscape in this dynamic and evolving field.

Figure 7. Word cloud representing the count of each mentioned word.

3.2. *Qualitative Research Findings*

This section presents the qualitative research findings of the deductive coding analysis. The breakdown of the qualitative findings based on the research objectives and RQs are as follows: (i) identified key drivers of smart cities, (ii) current roles of AI in enhancing key smart cities drivers, (iii) potential future impact of AI in smart cities, (iv) strategies for fostering of AI in potential future smart cities drivers, and (v) challenges and ethical considerations. The qualitative findings are discussed in the following sub-section.

3.2.1. Identified Key Drivers of Smart Cities and the Current Roles of AI in Their Enhancement

These research findings align with the first research objective. Smart cities are distinguished by their ability to leverage technology to enhance the QoL of their inhabitants and the efficiency of urban operations [29]. In this study, four key drivers of smart cities were identified. These are (i) sustainability, (ii) efficiency, (iii) connectivity, and (iv) citizen engagement. These key drivers play a pivotal role in shaping the development of these urban areas.

Sustainability in smart cities involves using technology to manage resources more efficiently, reduce carbon footprints, and promote environmentally friendly practices [21]. This driver is not just about conserving energy or reducing waste; it is about creating a city that can sustain its growth and development without depleting its resources or harming the environment [22].

Efficiency in smart cities refers to optimizing urban operations and services [12]. The goal is to use technology to make city services more efficient, reduce costs, and improve the overall functionality of the city. This could mean anything from smart traffic lights that reduce congestion to digital platforms that streamline government services [30].

Connectivity in smart cities is about creating a networked urban environment where data and information are freely and efficiently exchanged [31]. This driver ensures that all parts of the city are connected, enabling seamless communication and data exchange, which are essential for the efficient functioning of various city services.

Citizen engagement in smart cities involves leveraging technology to improve the city's and its residents' interaction [32]. This involves using digital platforms to facilitate communication, engage citizens in decision-making processes, and ensure that the city's development aligns with its inhabitants' needs and preferences. It is about creating a two-way dialogue where citizens are not just passive recipients of city services but active participants in the city's development [33]. Table 2 reveals the current roles of AI in enhancing the four identified key drivers with examples. The findings revealed that AI is significantly transforming the drivers of smart cities, bringing about remarkable improvements in urban life.

Table 2. Current roles of AI in enhancing key smart cities drivers.

Key Drivers	AI Roles	Examples
Sustainability	(i) Analyze large datasets related to energy consumption, waste management, and resource allocation [25]; (ii) Optimize energy grids, predict power demand, and reduce energy wastage [34] and resource management [35].	Examples include but are not limited to (i) *Azure IoT Central*—an AI solution developed by Microsoft for energy efficiency; (ii) *Nest Thermostat*—acquired by Google for thermal optimization; and (iii) *Predix*—created by GE Digital for predictive maintenance.
Efficiency	(i) Automating and optimizing city operations; (ii) Predictive maintenance of urban infrastructure [36,37].	Smart traffic management systems powered using AI are a prime example [38]. Other real examples are (i) Waymo's autonomous taxi service in Phoenix, Arizona; (ii) Singapore's Urban Redevelopment Authority's predictive analytics for urban planning; and (iii) Barcelona's smart waste bins.
Connectivity	Process large volumes of data from various IoT devices, improving the connectivity and integration of different city services [39].	In Dubai, United Arab Emirates, autonomous AI-based drones are being used to monitor traffic gridlock and respond quickly to emergencies.
Citizen Engagement	Powering smart applications that allow residents to interact with city officials, report issues, and provide feedback [40].	A real-life example is the *MyLA311*, which the City of Los Angeles invented as a virtual assistant for citizen services.

In each of these drivers, AI is not just a tool for improvement; it is a transformative force redefining how cities operate and serve their residents. Integrating AI into smart city drivers is paving the way for more responsive, efficient, and sustainable urban environments, where technology works hand in hand with human insight to create better living spaces.

3.2.2. The Potential Future Impact of AI in Smart Cities

These research findings relate to the third research objective. Within the domain of smart cities, AI has the potential to profoundly influence several key drivers that have not yet been fully capitalized upon [41]. In this study, the following four areas with potential AI impacts in the future were identified.

Firstly, **public health**. This study's first identified future area is public health, where AI can monitor and predict public health issues, improve healthcare delivery, and facilitate proactive health management [42]. AI could analyze vast amounts of health data to identify patterns that human analysts might miss, predicting outbreaks or health crises before they occur [43,44]. This prescient ability of AI could enable cities to allocate healthcare resources more effectively, potentially saving lives and reducing healthcare costs [45].

Secondly, **public utility management**. Another promising growth area for AI in smart cities is managing public utilities, such as water and electricity. AI can enhance the efficiency of these utilities by predicting usage patterns and optimizing distribution [46]. For example, AI systems can anticipate peak demand times for electricity and adjust the supply dynamically, leading to a more balanced and sustainable energy consumption pattern. Similarly, AI can detect leaks and inefficiencies in the water supply network, ensuring this vital resource is managed judiciously and sustainably [47].

Thirdly, **smart and sustainable city design and development**. Urban planning and development are additional areas where AI's potential has only begun to be explored. AI can process and analyze data from various sources, including satellite imagery, traffic patterns, and demographic information, to assist in the planning of more efficient, livable, and sustainable cities [48]. By simulating different urban development scenarios, AI can help city planners visualize the potential impact of their decisions, leading to more informed and strategic urban development [49].

Lastly, **environmental monitoring and protection**. These areas are ripe for AI interventions. AI can monitor air and water quality, analyze environmental data to identify pollution sources, and even predict the environmental impact of various activities. Such applications of AI would contribute to the sustainability of the urban environment and the health and well-being of its citizens, ensuring that smart cities remain habitable and pleasant places to live for generations to come [50].

3.2.3. The Strategies for Fostering the Integration of AI in Potential Future Smart Cities Drivers

These research findings are in line with the fourth research objective. To enhance the role of AI in less explored drivers of smart cities, it is crucial to adopt strategies that foster the integration of AI technologies [18]. The identified strategies are presented in the following paragraphs.

First, **creating collaborative ecosystems that unite government agencies, technology providers, academic institutions, and citizens**. These ecosystems can facilitate the sharing of data and insights, which is vital for developing and implementing AI solutions that address specific urban challenges [51].

Second, **investing in the digital infrastructure necessary for AI to flourish**. This includes physical infrastructure, such as sensors and connectivity networks, and the data architecture, allowing efficient data processing and analysis. A robust digital infrastructure will enable cities to leverage AI for various applications, from traffic management to environmental monitoring [52].

Third, **capacity building within city administrations and among citizens**. Training programs that improve the AI literacy of city officials and the general populace can demystify AI and encourage its adoption. Such programs can also help to identify new opportunities for AI applications within the city, fostering innovation and creativity [53].

Lastly, **establishing clear guidelines and ethical frameworks for using AI in smart cities**. This will address concerns related to privacy and security and ensure that AI's benefits are distributed equitably among all citizens [54]. By setting standards for the responsible use of AI, cities can build trust and encourage the acceptance of AI technologies among their residents, thereby closing the gap between current applications and AI's vast potential to transform urban living [55].

3.2.4. The Challenges and Ethical Considerations in AI Implementation

Similar to the identified findings in the sub-section above, the findings reported in this section are also in line with the fourth objective of this study. Various challenges and ethical considerations arise in integrating AI into smart cities, necessitating careful deliberation [56]. The identified challenges and ethical considerations are discussed in the following paragraphs.

First, **ensuring the privacy and security of the vast amounts of data that smart cities generate and collect**. As AI systems rely heavily on data for effective functioning, there is an inherent risk of breaches that could compromise personal and sensitive information [57]. The challenge lies in implementing robust data protection measures while allowing for the free flow of information necessary for AI systems to operate efficiently. This balancing act requires advanced technological solutions and strict governance policies to safeguard against unauthorized access or misuse of data.

Second, **the potential for bias in AI algorithms**. AI systems are only as unbiased as the data they are trained on, and if these data are skewed or non-representative, the AI's decisions and predictions can be inherently biased [58]. This can lead to unfair or discriminatory outcomes, particularly in sensitive areas such as law enforcement, employment, and social services. Addressing this challenge involves carefully designing and continuously monitoring AI systems to ensure they operate fairly and impartially. It also calls for diverse and inclusive data sets accurately reflecting the city's population [59].

Third, **the potential for AI to exacerbate social inequalities**. The ethical considerations in deploying AI in smart cities extend beyond privacy and bias to include broader societal impacts. One concern is the potential for AI to exacerbate social inequalities. While AI can improve efficiency and convenience, its benefits might not be evenly distributed across all sections of society [60]. For example, AI-driven services could primarily cater to those with digital access and literacy, leaving behind those less technologically equipped. This digital divide could deepen socio-economic disparities, making it crucial for smart city initiatives to include strategies promoting inclusive access to AI technologies.

Fourth, **the ethical imperative to consider the long-term implications of AI on human autonomy and decision-making**. As AI systems become more sophisticated and integral to city operations, there is a risk of over-reliance on these systems, potentially eroding human skills and judgment [61]. This raises questions about how much decision-making should be delegated to AI, especially in critical public welfare areas. The challenge is to strike a balance where AI complements human decision-making, enhancing rather than replacing human judgment. Ensuring that AI is a tool for human empowerment rather than a substitute for human agency will be crucial as smart cities evolve [17].

3.3. Conceptual Model

Based on the identified challenges and ethical considerations, the best strategies for fostering AI, the critical drivers of smart cities, the roles of AI in enhancing the smart cities' key driers, and the pragmatic impact/contributions of AI, a conceptual model was proposed to serve as a framework/guideline for successful smart cities design implementation. The framework is illustrated in Figure 8. If adopted, the conceptual model will be a strategic template for effectively leveraging AI to optimize smart cities. It outlines practical strategies, guidelines, and best practices for city planners, policymakers, and other stakeholders to follow. The conceptual model is grounded in theoretical concepts without compromising actionable insights for implementation.

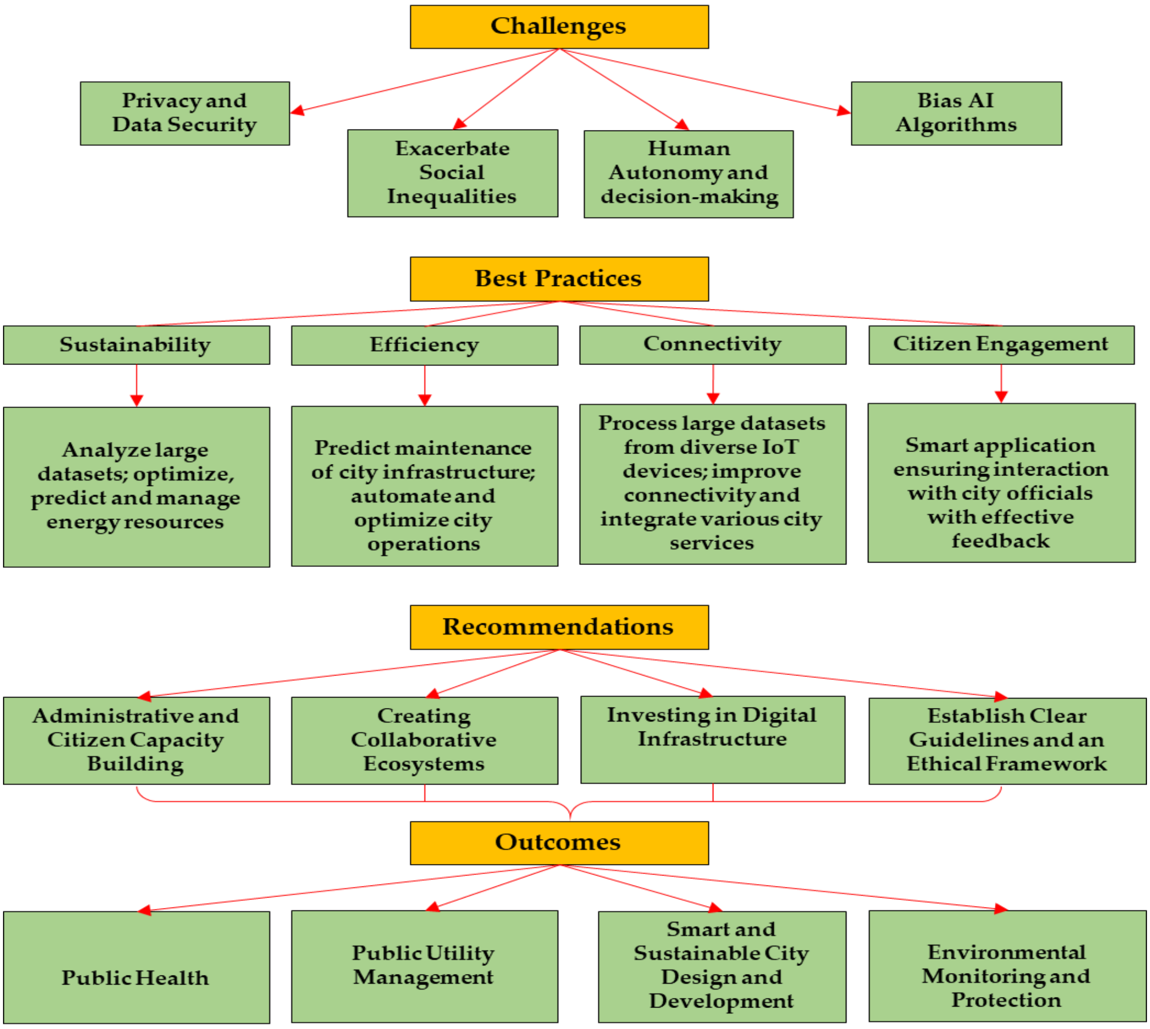

Figure 8. A strategic integrated AI-based conceptual model for smart city driver's optimization.

4. Discussion

This article proposed a conceptual framework based on the best strategies for fostering AI derived from extant studies from theoretical and practical perspectives. The conceptual framework was proposed as a strategic tool for effectively and efficiently actualizing AI impacts on future smart cities' design and overcoming potential barriers and ethical considerations. A Scopus database search revealed more than fifty documents on smart cities with either a conceptual framework or a model between 2015 and 2023. However, only two extant studies considered the relevance of developing conceptual frameworks from the perspective of the literature review [62,63]. In the extant studies, while one concentrated on sustainable mobility governance, the other research focused on the challenges of smart city development. These differ entirely from this study's proposed conceptual framework, which centers on a strategic integration framework for effectively leveraging AI in optimizing smart cities.

This study's conceptual framework outlines pragmatic guidelines for city planners, policymakers, and other stakeholders in computer science, sociology, economics, and environmental sciences. In another study [63], the authors proposed a conceptual framework to address barriers confronting government and non-governmental institutions with a pilot survey among Pakistani respondents. Furthermore, in their sustainable mobility governance model [62], the authors proposed selected key performance indicators for sustainable assessment. In contrast to these existing studies, the conceptual model proposed in this study is not channeled to transportation governance and nor does it address selected smart cities challenges in certain parts of the world. This study proposed a conceptual framework focused on AI's challenges and ethical considerations to ensure the smooth implementation of AI roles in advancing critical drivers in smart cities. Likewise, this study's proposed conceptual framework addresses the broad potential future impact of AI on smart city development, including sustainability (economic, social, and environmental) aspects, efficiency, connectivity, and citizen engagement.

In this study, the challenges and ethical considerations in AI concerning (i) privacy and data security, (ii) biased AI algorithms, (iii) exacerbating social inequalities, and (iv) human and decision-making were identified. While these findings agree with some extant studies, several other challenges of AI in different application scenarios not reported in this study have been published by diverse scholars. An explanation for this aberration could be attributed to the selection/document identification process and the keywords and phrases used when searching the selected databases. While this study identified smart cities and AI challenges in public health, there are several other challenges of AI in the field of medicine (i.e., neuro-oncology, neurosurgery, and radiology), tropical cyclones, edge computing, etc.

A comprehensive review of extant studies revealed that scholars in the field of AI application within the built environment have studied the broad role of AI in an urban environment. In 2023, Cugurullo and colleagues conducted a study that extensively explored the nature of urbanism in the rise in the utilization of AI [64]. The lead author conducted a similar study, exploring the juxtaposition from both practical and theoretical perspectives in AI and city planning [65]. In another report, the European Commission compiled the correlation between AI and urban development [66]. This current study explores the impact of AI in developing and optimizing smart city drivers and has contributed immensely to the body of knowledge in the field of AI and smart cities. Extant studies lack a comprehensive review of AI impacts on crucial aspects of smart cities, such as sustainability and efficiency.

The review of extant studies also revealed a scarcity of detailed, data-driven analyses to identify emerging trends and potential areas for the future utilization of AI in these urban settings. Likewise, unlike this study, which explicitly reviewed the barriers and ethical issues surrounding the utilization of AI within the context of smart cities, the extant literature has not adequately addressed the challenges and ethical considerations unique to implementing AI in different sectors of smart city development. The following paragraphs present a discussion of the findings in line with the study's RQs. The findings from the SLR, incorporating both qualitative and quantitative analyses, provide insightful answers to the RQs posed in this study on AI in smart cities. These findings bridge the gap between a theoretical understanding and the practical implications of AI in urban development.

Regarding the RQ "*How is AI currently influencing the critical drivers of smart city development, such as Sustainability, Efficiency, and Connectivity*"? The qualitative analysis highlighted that AI plays a transformative role in enhancing the critical drivers of smart cities. AI's contribution to sustainability is marked by its ability to optimize resource management, reduce energy wastage, and aid in environmental monitoring. In terms of efficiency, AI has been instrumental in automating and optimizing city operations, notably in traffic management and predictive maintenance of infrastructure. The influence of AI on connectivity is evident through its role in creating networked urban environments where data and information are seamlessly exchanged, facilitating efficient city services. The quantitative analysis, represented in the word cloud, reaffirms the centrality of these themes, with terms including "Sustainability", "Efficiency", and "Connectivity" featuring prominently, underscoring their frequent discussion and importance in the literature.

Concerning the RQ "*Based on current statistical data and analysis, what are the emerging trends and potential growth areas for AI applications in smart cities*"? The quantitative analysis revealed a significant focus on public health, urban planning, and public utilities management, indicating emerging trends and potential growth areas for AI in smart cities. Public health, in particular, has emerged as a critical area where AI can significantly contribute, especially in monitoring and predicting health issues and improving healthcare delivery. The trend analysis also pointed to the growing importance of AI in urban planning and the management of public utilities such as water and electricity. The stacked bar chart shows that the distribution of study topics over 2022 and 2023 highlighted these growing areas of interest.

Lastly, for the RQ "*What challenges and ethical considerations arise in implementing AI in smart cities, and how can they be effectively addressed*"? The qualitative research findings emphasized several challenges and ethical considerations in implementing AI in smart cities. Key challenges include ensuring the privacy and security of data, addressing potential biases in AI algorithms, and managing the risk of exacerbating social inequalities. Ethical considerations extend to the long-term implications of AI on human autonomy and decision-making. Strategies to address these challenges include establishing robust data protection measures, designing diverse and inclusive datasets, and developing clear guidelines and ethical frameworks for using AI in smart cities. The quantitative analysis supported these findings by highlighting the importance of "*Data Analysis*" and "*Digital Infrastructure*", indicating the need for a strong focus on ethical and responsible AI implementation.

The findings from both the qualitative and quantitative analyses provide a comprehensive understanding of AI's current and potential impact on smart cities, the emerging trends in this domain, and the challenges and ethical considerations that need to be addressed. These insights are crucial for stakeholders involved in planning and implementing smart cities, offering guidance for harnessing AI's potential while navigating its complexities and challenges.

5. Conclusions and Future Research Direction

This research provides a comprehensive analysis of the integration and impact of AI in developing smart cities, focusing on 2022 and 2023. This study successfully delineated how AI significantly enhances critical aspects of urban innovation, such as sustainability, efficiency, and connectivity, while identifying emerging trends and potential growth areas. A nuanced understanding of AI's role in urban environments was achieved through SLR, encompassing qualitative and quantitative methodologies. The research underscores the transformative potential of AI in reshaping urban landscapes, making them more efficient, sustainable, and responsive to the needs of their inhabitants. It highlights the importance of AI in various domains of computer science, sociology, economics, environmental science, and urban planning, from resource management and urban planning to public health and environmental monitoring. The findings also reveal the challenges and ethical considerations inherent in implementing AI in urban settings, emphasizing the need for robust data protection measures, unbiased algorithmic design, and inclusive approaches to technology deployment.

However, this research has limitations, including its narrow temporal focus and reliance on academic literature, which may restrict the scope of the insights gained. Despite these constraints, this study lays a solid foundation for future research, suggesting avenues such as broadening the historical scope, incorporating diverse literature sources, and exploring the qualitative impacts of AI in more depth. As smart cities evolve rapidly, driven by technological advancements, this research will be a crucial reference point for urban planners, computer scientists, sociologists, economics, environmental scientists, policymakers, and technologists. It provides them with a deeper understanding of AI's capabilities and challenges, guiding them in harnessing this powerful technology to create socio-economic environments, urban centers, and eco-cities that are not only technologically advanced but also equitable, sustainable, and conducive to enhancing the QoL of all residents. The development of smart cities must be approached with a multifaceted, interdisciplinary, and balanced perspective, considering both the immense possibilities and the ethical responsibilities of integrating AI into the urban fabric.

The future directions of research in the realm of AI in smart cities are manifold and hold significant potential for further exploration. One critical area for future research lies in extending the temporal scope of the study. Investigating a broader range of publications, including those from earlier years, would provide a more comprehensive understanding of the evolution and long-term trends in AI applications within urban environments. This expanded historical perspective would offer valuable insights into how the challenges and strategies in implementing AI have evolved. Another promising direction is including the research framework's grey literature, industry reports, and case studies. Such sources can offer practical insights, real-world applications, and the experiences of practitioners in the field, complementing the academic perspective with a more applied viewpoint. This approach would bridge the gap between theoretical research and practical implementation, providing a more holistic understanding of AI in smart cities.

Additionally, expanding the research to include publications in languages other than English could uncover valuable insights and developments in AI that are not represented in the English-language literature. This would provide a global perspective, accounting for diverse cultural and urban contexts in applying AI in smart cities. Further research could also delve deeper into the qualitative aspects of AI's impact on urban life, exploring the socio-economic, cultural, and ethical dimensions in more detail. This could involve more in-depth case studies, interviews with key stakeholders, or participatory research methods to gather nuanced understandings of the implications of AI in different urban settings.

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