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ARTICLE

Smart City Transformation through IoT in Indonesia: A Bibliometric Review of Local Government Strategy

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ABSTRACT

This study aims to analyze how implementing the Internet of Things (IoT) can accelerate the transformation of smart cities in Indonesia, particularly by improving the efficiency of public services in the transportation, security, and environmental sectors. The study also identifies strategies and challenges faced by local governments in adopting IoT, including infrastructure limitations, data security, and human resource readiness. The method used was bibliometric analysis with data retrieved from the Scopus database covering publications from 2014 to 2023. A total of 187 documents were selected through a systematic screening process and analyzed using VOSviewer software to explore trends, keywords, and collaboration networks. The results show that global IoT implementation continues to grow and positively impacts cities' operational efficiency. However, in Indonesia, barriers remain, including digital infrastructure inequality and weak regulatory frameworks. The analysis also shows a shift in research focus from technical aspects to issues of governance, data protection, and system interoperability. Recommendations from this study include the importance of collaboration among the government, the private sector, and academia, the improvement of digital infrastructure, and the development of adaptive policies and national cybersecurity standards. The findings contribute to the development of academic discourse and the formulation of digital transformation policies. The limitation of this study lies in the nature of bibliometric analysis, which does not evaluate the qualitative depth of each publication and may overlook contextual nuances in local policy implementation. Future research should combine a bibliometric approach with field studies to improve contextual understanding and policy relevance.

A. INTRODUCTION

Urban transformation through a digital approach is a strategic response to the increasing complexity of urban area management (Garg et al., 2021). According to data from the United Nations (2018), in 2023, about 57% of the world's population lived in urban areas, and this share is expected to increase to 68% by 2050. In Indonesia, a similar trend is evident in the report (Badan Pusat Statistik, 2023), which shows that the urban population accounted for 57.6% of the total population. This growth requires cities to transform from conventional

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management systems to a more responsive, efficient, and sustainable direction (Kaginalkar et al., 2021).

In Indonesia, the need for digitally based urban transformation becomes more evident as cities face challenges related to mobility, environmental quality, public safety, and the integration of public infrastructure. One of the national initiatives responding to these challenges is the 100 Smart City Movement, launched by the Ministry of Communication and Information Technology in 2017, which aims to guide cities/regencies in preparing smart city master plans tailored to local contexts (Kemkominfo, 2018). However, disparities in digital infrastructure, uneven human resource capacity, and limited interoperability across government agencies show that the transformation toward smart cities still faces significant obstacles.

Despite the global recognition of the Internet of Things (IoT) as a key technology supporting smart city development (Borgogno & Colangelo, 2019), the implementation of IoT in Indonesia varies significantly across regions (Mantelero & Esposito, 2021). Some cities have begun integrating IoT-based systems to improve transportation, environmental monitoring, and public safety. Yet, many local governments continue to struggle with infrastructure limitations, data security issues, and weak regulatory frameworks (Bappenas., 2020). These conditions highlight that the success of IoT-based transformation depends not only on technological readiness but also on local governments' strategic capacity to manage, regulate, and integrate digital systems effectively.

Although the literature on smart cities and IoT continues to grow (Fatima et al., 2019), there remains a gap in studies that systematically map how these research trends address the strategic issues faced by local governments in Indonesia (Javed et al., 2022). A bibliometric approach is needed to identify dominant themes, keyword connections, and the alignment of global research with Indonesia's local challenges. This study aims to provide a comprehensive mapping of scientific publications on IoT-based smart city transformation, with a focus on local government roles, strategies, and adaptive capacities.

The concept of a smart city emerged as the answer, by utilizing the Internet of Things (IoT), a network of devices that are interconnected and capable of collecting and exchanging data in real-time to optimize various aspects of public services (Kaginalkar et al., 2021) ranging from transportation, energy, and the environment to city security. In Indonesia, tangible progress is evident in the 100 Smart City Movement, launched by the Ministry of Communication and Information Technology in 2017, which aims to help 100 cities/districts prepare smart city master plans tailored to local potential.

Based on this background, this study aims to answer one key question: How do the trends and research focus on IoT-based smart city transformation in Indonesia reflect the strategies and challenges faced by local governments? To answer this question, a bibliometric analysis of scientific publications from the Scopus database over the last decade is used. The findings of this study are expected to make an empirical contribution that is not only useful for advancing academic research but also for better formulating public policies adapted to urban digital transformation at the local level.

B. LITERATURE REVIEW

The Role of Internet of Things (IoT) in Smart City Development

The Internet of Things plays a central role in the development of smart cities by integrating real-time data from diverse sources to support evidence-based decision-making (Montanaro et al., 2022). This technology enables cities to dynamically adapt to changing conditions through efficient monitoring and response to urban dynamics (Strielkowski et al., 2022). In practice, IoT devices are interconnected through sensors installed in various public facilities, such as

streetlights, vehicles, power grids, environmental monitoring systems, and even medical devices (Naiki, 2024). Data from these sensors is processed and analyzed to optimize public services, reduce energy waste, and improve citizen safety and comfort (Hassan & Alkinani, 2022).

The use of IoT enables city management systems to be more intelligent, responsive, and citizen-centric (Motta et al., 2018). For example, in the transportation sector, IoT enables automatic traffic light settings based on real-time vehicle volumes (Farooq et al., 2022). In the energy sector, this technology is used to monitor household energy consumption, detect leaks, and manage power distribution efficiently (Tundys & Bretyn, 2023). According to (Zhang et al., 2021), with this approach, cities can manage resources such as clean water and electricity more optimally. Maximum utilization of IoT also contributes to achieving the Sustainable Development Goals (SDGs), especially in environmental sustainability and infrastructure efficiency (Senthilkumar, 2019). However, the successful utilization of IoT is highly dependent on the readiness of digital infrastructure and adequate policy support from local governments (Perera et al., 2014).

In the past two years, academic attention to the implementation of IoT in the context of smart cities has increased (Fatima et al., 2019). A study shows that implementing IoT-based systems significantly improves the efficiency of transportation services and the city's health system, especially during emergencies (Javed et al., 2022). Arora et al., (2023) emphasizing the importance of strengthening inclusive smart governance to ensure that IoT technology truly supports city governments' strategic decisions. Meanwhile, Hossain et al., (2024) highlight that the biggest challenge lies not only in the technology itself, but also in the institutional readiness of local governments to manage data (O'Dwyer et al., 2020), build sectoral interoperability, and ensure cybersecurity. Globally, IoT devices are expected to reach more than 15.14 billion units by 2023 and will grow to 29.42 billion units by 2030 (Badan Pusat Statistik, 2023). In Indonesia, IoT adoption still varies widely across regions, mainly due to disparities in digital infrastructure and uneven human resource capacity (Bappenas., 2020).

Data Security and Privacy Challenges in IoT

Despite its many benefits, implementing IoT poses significant challenges for data security and user privacy (Abosaq, 2019). IoT devices collect highly sensitive data, such as location, activity, and user preferences, which can be easy targets for cyberattacks if not protected by adequate security systems (S. Wang et al., 2019). Nita et al. (2018) emphasize that many IoT systems are designed with minimal security features, leaving them vulnerable to data theft and privacy breaches. This is a major concern for city governments and technology developers looking to implement IoT on a large scale (Khan et al., 2022).

In Indonesia, this challenge is even more complicated because personal data protection regulations are still in transition, despite the Personal Data Protection Law (PDP Law) being passed in 2022. The implementation of this law still requires strengthening the legal and institutional infrastructure and improving public digital literacy (Yang et al., 2020). Hossain et al. (2024) mentioned that many local governments lack adequate information security management capacity, which could erode public trust in smart city systems. Therefore, privacy protection is not merely a technical issue but also a policy and social concern that must be addressed systematically and inclusively (Falco et al., 2018). Developing a comprehensive IoT security architecture is essential to enabling safe, trustworthy digital transformation.

Multi-Stakeholder Collaboration in IoT Implementation

The success of IoT implementation in smart cities depends heavily on the extent to which the actors involved can build solid, coordinated, and sustainable collaboration (Sharma et al., 2019). Central and local governments play a key role as regulators and facilitators in developing legal and policy frameworks to encourage technology integration (Bibri & Krogstie, 2017). Meanwhile, the private sector provides innovative infrastructure and technology (Kundu, 2019), and academics contribute to research and development aligned with local needs (Khan et al., 2022). This collaboration requires clear role sharing and dialogue among parties to ensure the success of a holistic and sustainable smart city program (Varshney et al., 2021).

Leroux & Pupion (2022) emphasize the importance of community involvement at every stage of IoT system development, from planning and testing to service evaluation. Without the trust and active participation of citizens, the digital transformation of cities will be difficult to achieve comprehensively (Stellios et al., 2022). Angelov et al. (2021) also highlight that the ideal multi-stakeholder collaboration should be inclusive, sustainable, and grounded in the real needs of citizens, rather than a top-down approach (Alaeddini et al., 2023). IoT implementation strategies need to explicitly include cross-sector coordination mechanisms as an integral part of every stage of smart city development (Axelsson & Granath, 2018). This collaborative model also needs to ensure program sustainability through strengthening local institutions and meaningful citizen participation (Li, 2022).

Regulations and Policies for IoT Implementation

Regulations and policies are important foundations that ensure the implementation of IoT technology can run safely (Bhuvana et al., 2024), efficiently, and sustainably in the context of smart cities (Ng et al., 2017). Without clear rules, the collection and use of data by IoT systems can lead to ethical and legal conflicts, such as data misuse or privacy violations (Kochetkov et al., 2019). Governments need to develop policies that not only regulate the technical aspects of technology use (Sujata et al., 2019), but also guarantee the protection of citizens' rights, including data security, transparency, and accountability in information management (F. Wang, 2024).

In Indonesia, despite progress in formulating digital policies, their implementation remains suboptimal at the regional level (Javed et al., 2022). Leroux & Pupion (2022) notes that most local governments do not yet have specific regional regulations governing IoT technology, either from a technical or data protection perspective (Boustani et al., 2022). Fiore (2020) emphasizes the importance of developing policies that adapt to technological dynamics to avoid hindering innovation. In addition, regular security audits and increased digital literacy among public service providers are part of a strategy to strengthen regulations that are not only law-based but also capacity-based (Yang et al., 2020). These efforts will strengthen a digital transformation ecosystem that is better prepared in terms of regulations and technology (Doohan et al., 2022), as well as responsive to global challenges (Mijwil et al., 2022).

Although the concepts of smart cities and IoT have been widely discussed in the literature, there are still gaps in studies that systematically map how existing research addresses the strategic issues faced by local governments in Indonesia. The bibliometric approach is essential for tracing the development of academic studies, identifying dominant themes, and assessing whether current research aligns with local needs and challenges. This study provides a comprehensive mapping of IoT-based smart city literature in Indonesia, emphasizing local government engagement, strategic approaches, and adaptive capacity. In doing so, it establishes a foundation for developing a more contextual and data-driven research and policy agenda. The novelty of this study lies in integrating bibliometric analysis with an examination of the practical challenges and strategic responses of Indonesian local governments, an aspect that

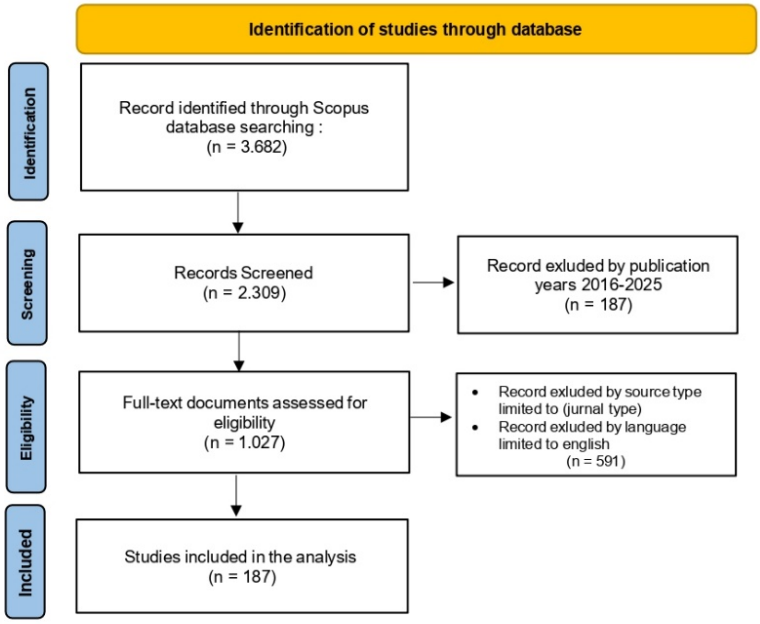
remains underexplored in previous research, thereby offering new insights for both scholars and policymakers in shaping IoT-based smart city initiatives in Indonesia.

C. METHOD

This study uses a bibliometric analysis approach to examine the development and application of the Internet of Things (IoT) in smart city management. This approach was chosen because it can identify research trends, dominant topics, and the influence of scientific publications in the field (Huo et al., 2022; Farhan HR & Nurmandi, 2022). Compared with thematic or framework-based review approaches, bibliometric analysis offers advantages in objectivity, scalability, and reproducibility, as it relies on citation data and scientific networks rather than solely on researchers' manual interpretation. Therefore, the bibliometric approach is considered the most appropriate for examining the interdisciplinary nature and dynamics of IoT-based smart city research development.

Data were obtained from the Scopus database, comprising 187 documents published between 2014 and 2023 (Parasol, 2018). The document includes publications such as journal articles, conference proceedings, literature reviews, and book chapters, all relevant to the IoT and smart cities (Zhao & Liu, 2021).

The data collection process begins with a search using keywords such as "Internet of Things," "Smart City," and "Governance" (Ashraf et al., 2021; Hamm, 2020; Sudarmani et al., 2022). The data selection procedure is carried out systematically through several stages, as shown in Figure 1. In the initial stage, 3,682 documents were found. After filtering by publication year (2016-2025), 2,309 documents are further screened. Furthermore, 1,027 documents were reviewed during the feasibility assessment stage. At this stage, screening is based on two main criteria: publication type (only peer-reviewed journal articles are selected) and language (limited to English). A total of 591 documents were excluded from the analysis because they did not meet these criteria. Finally, 187 documents were selected for analysis in this study.



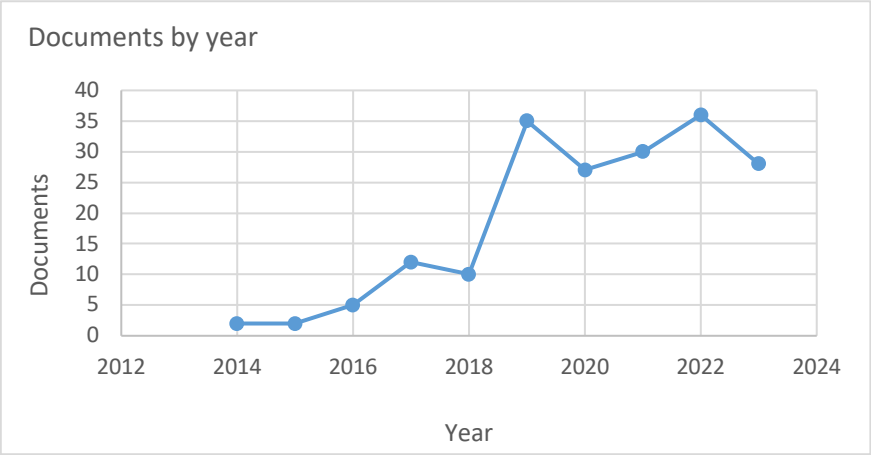
Source: (Wang et al., 2019)

Figure 1. Analyzed Documents by year

The filtered data are then analyzed using VOSviewer, a commonly used software for bibliometric network mapping. The analysis includes co-citation and co-authorship relationships among authors and institutions, as well as mapping *keyword co-occurrences* to identify key themes and conceptual linkages in the literature (Elahi et al., 2022; Rajyalakshmi & Lakshmanna, 2023). To maintain validity and reliability, only documents from reputable journals indexed in Scopus are included in the analysis, in line with best practices in bibliometric analysis (Seyhan & Akleylek, 2022).

The results of this analysis are presented in visualizations, such as trend graphs and network maps, to provide a comprehensive overview of research developments in IoT and smart cities. This visualization supports the identification of dominant keywords, author collaboration patterns, and thematic developments throughout the period studied (Lawelai et al., 2023; Puritat, 2019), thus providing a strong basis for further interpretation and discussion.

D. RESULT AND DISCUSSION



(Source: Scopus Database, 2024)

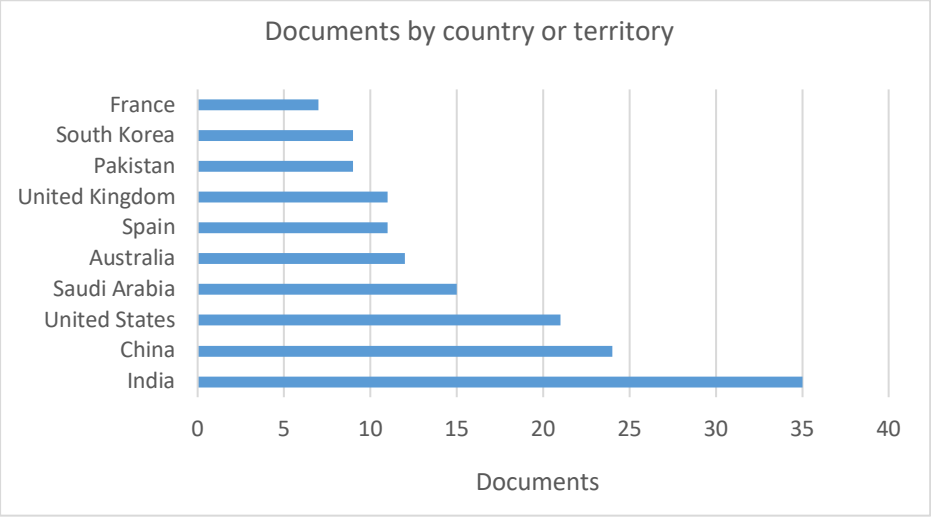
Figure 2. Analyzed Documents by year

Figure 2 shows the trend in the number of publications on *the Internet of Things* (IoT) and *smart cities,* indexed in Scopus, from 2014 to 2023. At the beginning of the period (2014-2015), the number of publications was still low, averaging fewer than 5 per year. This indicates that the topic has not yet become the main focus in academic discourse. The increase was first seen in 2016-2018, alongside growing global interest in the digitalization of cities. The first peak occurred in 2019, with more than 35 publications. This surge coincides with the intensification of digital transformation in the public sector and the emergence of national and global policies that encourage the use of IoT in urban management.

However, the number of publications declined significantly in 2020, most likely due to the COVID-19 pandemic, which hampered research activities and fieldwork. However, the trend increased again in 2021 and peaked in 2022. A slight decline occurred again in 2023, with a total of around 25 documents. Overall, the trend shows a consistent growth in academic interest in IoT and smart city topics. This data reinforces the urgency of conducting a bibliometric analysis, as conducted in this study, to understand the direction of research development in the (Hamamah et al., 2019), the dominant themes, and how the strategies and challenges of local governments in adopting IoT are reflected in the scientific literature, especially in the Indonesian context.

Reports from the World Bank indicate that digital transformation in cities accelerated significantly after 2018, driven by increased investments in smart infrastructure and strengthened data-driven governance. This global momentum contributed to the rise in

academic studies during the same period, as researchers became more focused on examining how technological advancements support urban management. Likewise, the expansion of digital public services has prompted scholars to explore IoT not only as a technological breakthrough but also as a strategic tool to enhance public-sector performance. Thus, the surge in academic attention shown in the publication trend is consistent with international developments that place IoT at the center of smart city innovation and governance transformation.



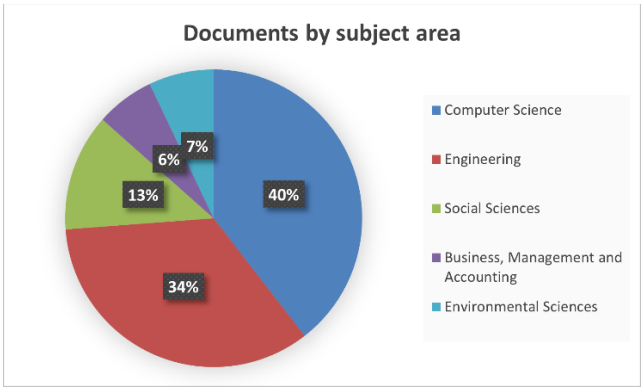
(Source: Scopus Database, 2024)

Figure 3. Analyzed Documents by country or territory

Figure 3 shows the 10 countries with the highest number of publications in the fields of the *Internet of Things* (IoT) and *smart cities*, based on data from the Scopus Database (2024). India ranks first with nearly 40 documents, followed by China and the United States, which also make significant contributions to the development and dissemination of knowledge in this field. The three countries exhibit strong dominance, reflecting high research capacity, substantial investments in digital transformation, and a supportive technology ecosystem (Lee-Geiller & Lee, 2019).

The dominance of these countries also reflects the continued concentration of global centers of technological research and innovation in Asia and North America. The strong contribution of publications from India, China, and the US shows that smart cities and IoT have become a strategic agenda in their national innovation policies (Wirtz et al., 2019). This pattern reinforces the relevance of the bibliometric study in this article, as it provides a comparative reference point for understanding how global research trends evolve and which countries are setting the pace for innovation.

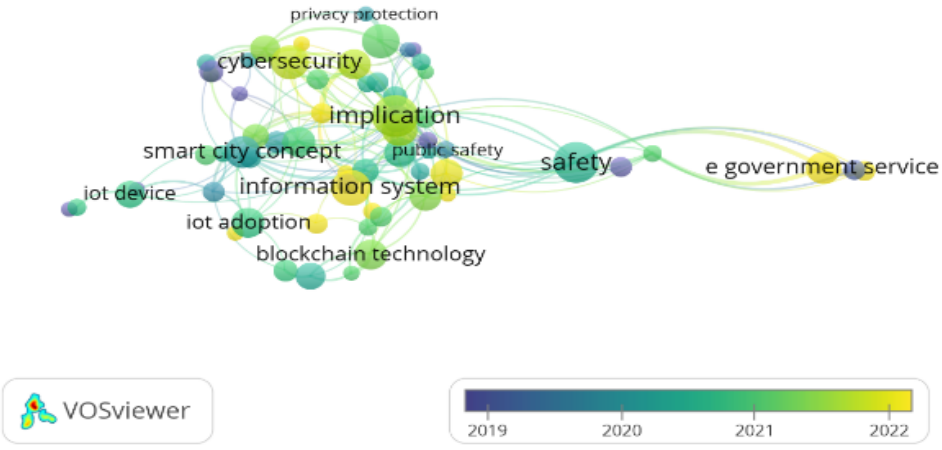
In contrast, Indonesia has not yet appeared among the top 10 contributing countries, highlighting the need to strengthen its academic engagement in this field. Policy documents from Bappenas indicate that Indonesia's research landscape continues to face structural challenges, including disparities in digital infrastructure and fragmented institutional coordination. Therefore, strengthening collaboration among universities, local governments, and research institutions is essential to enhance Indonesia's academic contributions and support more systematic, competitive research on IoT adoption for smart city development.



(Source: Scopus Database, 2024)
Figure 4. Analyzed Documents by Subject Area

Figure 4 shows the distribution of documents indexed in Scopus by subject area addressing the topic of the Internet of Things (IoT) and smart cities after applying a subject-area filter to exclude non-relevant fields. The results indicate that Computer Science (40%) and Engineering (34%) dominate the literature, reflecting a strong emphasis on technological development, including computing systems, network infrastructures, and IoT-based applications for smart city implementation (Javed et al., 2022). In contrast, Social Sciences (13%), Environmental Sciences (7%), and Business, Management, and Accounting (6%) contribute a smaller share, indicating that governance, policy, sustainability, and organizational perspectives remain underrepresented. This imbalance highlights a gap in the literature, particularly regarding the strategic role of local governments in shaping and implementing IoT-based smart city initiatives.

Reports from the OECD show that many smart city initiatives face obstacles not due to technological shortcomings but to governance-related challenges, such as the absence of standardized data-sharing frameworks, limited digital literacy among civil servants, and weak inter-institutional coordination. These global findings resonate with the patterns observed in Figure 4, indicating that the dominance of technical disciplines and the limited contribution of governance-oriented research are not only academic trends but also real-world barriers to implementing integrated and sustainable smart city initiatives, including in Indonesia.



(Source: Data Processing Using VOSviewer, 2024)
Figure 5. Overlay Visualization

Figure 5 shows the relationship between research topics in the field of smart cities and Internet of Things (IoT) from 2019 to 2022. The colors on each node indicate the time of

dominance of the topic's appearance, with purple (2019) at the bottom and yellow (2022) at the top. The size of the node represents the frequency of the keyword's occurrence, while the connecting line indicates the strength of the linkage between the topics. Keywords such as *information system*, *cybersecurity*, and *the smart city concept appear dominant and closely interconnected, suggesting that information technology and security are the main foundations in academic discourse on* smart cities.

Topics such as *e-government services*, *safety*, and *privacy protection* emerged more strongly in the latest literature, indicating a shift in research attention towards strengthening digital public services and data protection. This aligns with the context of smart city transformation in Indonesia, where local governments face serious challenges in information system readiness, sensitive data management, and the need for adequate cybersecurity regulations (Z. Khan et al., 2017). This visualization provides a clear picture of trends in strategic issues and serves as an important basis for formulating regional IoT implementation policies.

The findings also indicate that IoT implementation is closely tied to the need for stronger institutional frameworks, integrated information systems, and consistent digital regulations. Global literature highlights similar concerns, with reports from the World Bank emphasizing the urgency of addressing cybersecurity vulnerabilities in cities adopting IoT technologies. These insights reinforce the need for a solid foundation of digital governance to ensure the secure and sustainable development of smart cities.

The bibliometric findings indicate that topics such as *information systems*, *cybersecurity*, and *e-government services* are taking center stage in recent global publications related to smart cities and the Internet of Things (IoT). These issues mark a shift in research from solely technology development to governance, data security, and the quality of digital public services (Ali et al., 2020). In the Indonesian context, this shows that the transformation of smart cities cannot be separated from local governments' institutional readiness, the availability of digital infrastructure, and regulations that are adaptive to technological developments.

IoT and smart city research has expanded significantly and become more thematically diverse. However, technological studies still dominate the literature, while governance-oriented research remains limited. This imbalance reveals a critical gap, especially in countries where administrative capacity and policy coordination play decisive roles in determining the success of digital transformation efforts.

Insights from international and national policy analyses further emphasize these challenges. Reports from the World Bank and Bappenas point to persistent issues in local governance, including limited institutional capacity, shortages of skilled personnel, and uneven development of digital infrastructure across regions. These findings align with bibliometric trends showing that governance-related themes appear less prominently than technical ones.

The evolving research landscape reflects a growing emphasis on privacy protection, public safety, and digital governance areas that international bodies such as the OECD identify as essential for ensuring sustainable smart city development. As digital systems expand, concerns about cybersecurity, data management, and citizen engagement become increasingly central to policy formulation and implementation.

For Indonesia, these insights underscore the need for a structured and context-sensitive smart city roadmap. Such a roadmap should prioritize service integration, national cybersecurity and interoperability standards, and capacity building within local governments. Strong coordination among central authorities, regional governments, private-sector actors, and academic institutions is vital for addressing the complex technical and governance challenges associated with IoT-driven smart city development. With a well-coordinated and governance-

centered approach, Indonesia can advance toward a smarter, more adaptive, and more accountable digital public service ecosystem.

E. CONCLUSION

The findings of this study show that trends and research focus on IoT-based smart city transformation increasingly highlight both technical and governance-related challenges faced by local governments in Indonesia. While early studies predominantly focused on sensors, connectivity, and operational efficiency, more recent literature emphasizes cybersecurity, data governance, system interoperability, and digital readiness. These trends reflect the strategic challenges local governments face, particularly disparities in digital capacity, limited regulatory frameworks, and uneven institutional preparedness to adopt and manage IoT-driven public services.

These findings confirm that IoT adoption for smart city development is not merely a technological issue but a governance challenge that requires strengthening institutional capacity, improving digital infrastructure, and enhancing coordination across levels of government. In the Indonesian context, the effectiveness of IoT implementation depends heavily on how well local governments can design data-driven strategies, ensure secure information management, and adapt to technological changes. Therefore, achieving smart, efficient, and citizen-oriented public service transformation requires a holistic approach that integrates technological innovation with governance reform.

As policy recommendations, local governments should develop structured, context-specific smart city roadmaps that prioritize essential public service sectors, integrate information systems across agencies, and strengthen institutional capacity through continuous digital skills development. At the national level, standardized guidelines on cybersecurity, data protection, and system interoperability are crucial to ensure secure, efficient, and coordinated IoT implementation. The central government should also provide regulatory support, technical guidance, and targeted funding to reduce regional disparities in digital readiness. Furthermore, strengthening multi-stakeholder collaboration among government institutions, the private sector, academia, and communities is essential to ensure that IoT-based smart city transformation becomes more effective, inclusive, and sustainable in the long term.

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