Heliyon 10 (2024) e30367

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Exploring diverse interests of collaborators in smart cities: A topic analysis using LDA and BERT

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A R T I C L E I N F O

Keywords:
Smart city
Quadruple helix
Hype cycle
Google trends
LDA
BERT

A B S T R A C T

Smart cities have emerged as a promising solution to the problems associated with urbanization. However, research that holistically considers diverse stakeholders in smart cities is scarce. This study utilizes data from four types of collaborators (academia, public sector, industry, and civil society actors) to identify key topics and suggest research areas for developing smart cities. We used latent Dirichlet allocation and Bidirectional Encoder Representations from Transformers for topic extraction and analysis. The analysis reveals that sustainability and digital platform have received similar levels of interest from academia, industry, and government, whereas governance, resource, and green space are less frequently mentioned than technology-related topics. Hype cycle analysis, which considers public and media expectations, reveals that smart cities experienced rapid growth from 2015 to 2021, but the growth rate has slowed since 2022. This means that a breakthrough improvement in the current situation is required. Accordingly, we propose resolving the unbalanced distribution of topic interests among collaborators, especially in the areas of governance, environment, economy, and healthcare. We expect that our findings will help researchers, policymakers, and industry stakeholders in understanding which topics are underdeveloped in their fields and taking active measures for the future development of smart cities.

1. Introduction

The United Nations recommends that local and national governments strengthen intersectoral collaboration (sharing knowledge, expertise, technology, and financial resources) to achieve the Sustainable Development Goals [1]. Smart cities are more than sophisticated cities with high-level technology. They involve a new approach to using technology to solve various urban problems, improve the quality of life, and optimize government performance [2,3]. Due to the complexity and variability of smart city initiatives, collaboration and smart governance within smart cities remain a major challenge for local governments [4]. Smart urban collaboration involving multiple stakeholders at different levels is a characteristic of recent developments in smart city governance [5]. Specifically, cross-sectoral collaboration has a dynamic nature, which is determined by the context [6]. Therefore, the success of smart cities necessitates considering their various stakeholders in planning and decision-making. By exploring the interests of smart city collaborators, this study aims to enhance collaboration and ultimately contribute to the development of smart cities. The research questions are as follows.

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https://doi.org/10.1016/j.heliyon.2024.e30367
Received 10 December 2023; Received in revised form 21 April 2024; Accepted 24 April 2024
Available online 25 April 2024
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RQ1. What are the main concerns of smart city collaborators?

RQ2. What is the current status of smart cities, and what are the directions for future development?

In this study, data collected from four collaborator sectors (academia, public sector, industry, and civil society actors) of smart cities were used to identify major themes and suggest research areas for further development. For topic extraction and analysis, latent dirichlet allocation (LDA), a representative topic modeling technique, and Bidirectional Encoder Representations from Transformers (BERT), a deep learning technique, were combined to leverage the unique advantages of each. Through LDA, we extracted 20, 13, and 5 topics for papers, patents, and plans, respectively. The extracted topics were matched by paper topics, and their relationships were analyzed.

Regarding the first research question, sustainability and digital platform were of shared interest among academia, industry, and government. On the other hand, governance, resource, and green space received less attention than technology-related topics. Additionally, we examined the characteristics of government plans by classifying them as goals- and means-oriented and analyzed their relationship with population density, one of the main determinants of urban planning.

In terms of the second research question, the hype cycle analysis revealed that the rapid growth of smart cities began in 2015, but the growth rate has slowed down slightly since 2022. This means that the present is critical for progress, and a breakthrough is needed. Therefore, this study proposes resolving the imbalance of interest between collaborators' topics mentioned in the topic relation matrix. In particular, the areas that need future attention are governance, environment, economy, and healthcare.

This research aims to provide stakeholders with insights into how smart cities can overcome the challenge associated with this critical period to achieve the goal of 'a plateau of productivity' without a peak of inflated expectations or trough of disillusionment. Therefore, we identified and suggested future research streams necessary for the development of smart cities. The findings of this study can assist researchers, policy makers, and industry stakeholders in identifying the topics receiving insufficient attention in their field, based on which they can take active steps to shape the future development of smart cities. They will also help governments, who are planning smart cities, to find their own benchmarking models and build and operate cities efficiently under time and resource constraints.

The remainder of this paper is structured as follows. Section 2 discusses related literature and methodology, including smart cities, the quadruple helix model, the hype cycle, and LDA and BERT. Section 3 presents the used datasets and describes our methodology. Section 4 shows the final results of the analysis and we conclude in Section 5. The research flow is shown in Fig. 1.

2. Background

2.1. Smart cities

Smart cities are the most attractive solution to urban problems, but they are difficult to define and categorize due to different perceptions of smart cities across countries, cities, and sectors [3],[7]. Since the first smart city paper [8], various studies on the definition, classification, and conceptualization of smart cities have been conducted. The two most cited definitions of smart cities are as follows. Hall et al. described a smart city as a city that monitors and integrates the status of all major infrastructures to maximize citizen services through resource optimization, maintenance activity planning, and security monitoring [9]. Lazaroiu and Roscia defined it as a model of cities that utilizes technology to help people improve their economic and social quality of life [10]. While the use of technology in cities is a common aspect in the definition, there are differences regarding what is important from an expert's perspective.

In terms of categorization, Mora et al. conducted the first bibliometrics study in the field of smart cities by considering related topics and arguing that much of the knowledge generated was related to technology [11]. Yigitcanlar et al. categorized smart city drivers into policy (including laws, regulations, and governance environments), community, and technology [12]. However, they explained that the focus of most of the content has been on the technical aspects. Soomro et al. classified smart city topics into governance, economy, environment, transportation, and energy through literature analysis [13]. Van der Hoogen et al. identified the components of a smart city as a smart economy, smart citizens, smart governance, smart environment, smart mobility, and smart living [14]. Lim et al., the

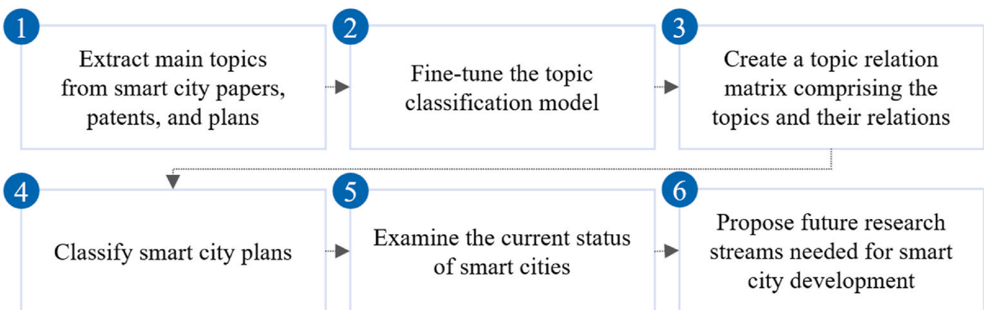

Fig. 1. Research flow diagram.

first to apply machine learning (text mining) to literature analysis, defined three research categories: smart city policies, city technologies, and smart city services [15]. Kim broadly categorized prior research on smart city structure into infrastructure, data, service, and device and specified that infrastructure and service provision had been focal in the past, whereas the focus in recent years has been on big data technology and device development [7]. Sharma et al. also found that much of the information generated in the research was on technology (e.g., security, connectivity, and decentralization) [16].

The interest in exploring the development of smart cities has persisted, and various literature reviews have been conducted, including a bibliometric analysis [17] (Table 1). Mora et al. identified five smart city development paths and their underlying strategic principles through a bibliometric analysis of the research literature [18]. Zheng et al. identified evolutionary patterns and emerging trends in smart city research to reveal the fundamental knowledge structure, and they highlighted technological innovation acceptance, people, urban governance, and sustainable development as important key points [17]. Bajdor and Starostka-Patyk identified keywords closely related to smart cities through bibliometric analysis and identified key dimensions and domains [19]. Okafor et al. conducted a bibliometric analysis to identify the relationship between smart city models and social equity to highlight that social equity is important for realizing smart cities [20]. Okafor et al. also highlighted the scarcity of studies discussing social equity in the context of smart cities and suggested that social equity policies should be established and implemented to solve the problem of increasing inequality caused by the technology gap [20]. Qiu et al. identified four urban concepts (sponge, low carbon, resilient, and inclusive city) that emerged in the 21st century with the rapid increase in the number of papers by analyzing the literature [21]. Moreover, they argued that these concepts are closely related and integrated with smart cities in terms of theory and technology and should be continuously expanded by integrating other urban concepts to build low-carbon, inclusive, and resilient smart cities. Through a literature review, van Twist et al. comprehensively analyzed citizens' dissatisfaction with smart cities (reasons and expressions and government responses) and identified two perspectives (active and passive discontent) [22]. They noted the importance of studying citizens who are passive or absent from the smart city debate (the invisible citizen) and explained the need to include citizens not only as optimistic users of smart technologies but also as political actors with different perspectives in the smart city debate.

Because each smart city collaborator has different opinions and perspectives depending on the context, it is necessary to systematically analyze the relationship holistically. Various stakeholder groups (e.g., agendas, expectations, problem-solving styles, and organizational culture) influence collaborative network dynamics and outcomes [23]. Therefore, further research is needed on the characteristics of the different actors that collaborate and how the collaboration composition changes across project phases [24]. However, comprehensive summaries examining each actor in a smart city are lacking, especially the interests of collaborators. Therefore, we based this research on the premise that an in-depth analysis and understanding of collaborators can facilitate a successful smart city transition. This study aims to suggest the direction of future smart cities by extracting topics from each field and connecting them to determine the interrelationships and gaps between them. This study is novel, as it identifies and interprets trends in key smart city interests across four collaborators.

2.1.1. *Smart city planning*

Smart city development strategies can be found globally, and there have been many studies analyzing the design and implementation process [25]. The goals, types, and approaches to smart city development vary widely [26]. Komninos et al. stated that smart city planning is neither detailed nor rigid; in contrast, it is an evolutionary process in which multiple organizations interact with each other to create a city under uncertainty [27]. Factors that influence smart city strategies also vary from geography to population density and related issues (e.g., traffic congestion and air pollution) [28].

Urban planning is characterized by high uncertainty, complexity, and subjectivity, which requires tacit and specialized knowledge. However, this makes it difficult for stakeholders to obtain clear and explicit knowledge [29]. Thus, an approach that can help them retrieve and find the right information for decision-making is needed [30]. To resolve ambiguities related to smart city planning, it is important to collect, organize, and share knowledge based on actual plans, which can be used to support decision-making for urban planning and implementation [25]. Therefore, this study conducts a topic analysis of government planning and related literature and provides guidelines for cities that governments can benchmark and areas that need further research.

Table 1
Comparison of previous literature reviews.

Article	Research objectives	Findings
[17]	To explore the evolution of the disciplines engaged in smart city research and reveal the development paths and research topics	ICT and urban planning field are the two pivotal axes in promoting SC development. People and governance have received increasing interest.
[18]	To analyze the development paths of smart cities, making them visible and understandable	The analysis revealed five main development paths (experimental, ubiquitous, corporate, European, and holistic).
[19]	To examine what areas related to the smart city concept are the most valuable and stimulating their implementation	The most critical areas and research trends include urbanization, sustainable development, city, technology, and Internet of Things.
[20]	To assess the current research focus on social equity in relation to smart city development	Most of the studies did not focus on social equity. The nine determinants of social equity were obtained.
[21]	To explore the origins and definitions of five urban concepts (smart, resilient, low-carbon, sponge, and inclusive cities) and the correlation between smart cities and the other four city concepts	The four city concepts are conceptually or technically related to the smart city. Smart cities acquire and absorb more advanced models from other urban concepts to enrich themselves.
[22]	To review academic research addressing citizen discontent with the smart city	Two perspectives on citizens' discontent are identified: active and passive discontent

2.1.2. Smart city collaboration

Complex challenges in science and business have led to numerous organizations collaborating in networks [31]. Numerous network types that differ in their diversity and number of stakeholders exist [23]. Organizational theory interprets cross-sector collaboration as a dynamic process whose composition changes over time [6]. Partnerships are crucial in smart city transitions, which are a collaborative process [32], and rely on dynamic and complex multistakeholder collaboration [33]. Dolmans et al. called for collaborative models for smart city development that consider the context-specific nature of collaboration, the complexity of reality, and the dynamic nature of collaboration while emphasizing the evolving nature of collaboration (dynamic shifts in stakeholder configurations, relationships, and interests) [34]. White and Burger also introduced a framework for smart city development and demonstrated that the configuration is not fixed, changing instead with context and time [35]. Collaborative dynamics is one of the most relevant factors in smart cities [36], but much of it is still unknown [37]. Specifically, Thabit and Mora determined that common collaboration models do not adequately account for the complexity of real-world cases [24]. The functioning of a collaborative ecosystem depends on its economic and political aspects and multilevel configuration [24]. Each phase of a smart city (design, implementation, and maintenance) has different characteristics [38], and the composition of collaborating actors should also change accordingly [24]. Because different types of partnerships are needed depending on the local characteristics and context of the city [24], researchers should take a flexible approach to collaboration-related research.

Moreover, the body of research on citizens as collaborators is growing. Spicer et al. introduced a resident perspective to smart city performance evaluation to analyze the extent to which smart city design and technology adoption meet residents' needs and preferences [39]. Spicer et al. also observed a mismatch between the types of projects cities are pursuing and resident preferences and indicated the need for broader and deeper community engagement [39]. Ruijer et al. demonstrated that although the number of tools for smart governance is increasing, only a few are available to citizens and NGOs [33].

The collaborative governance literature emphasizes that stakeholders may have different or similar interests, goals, and expectations [33]. This can lead to conflict in collaboration [36]. However, information on how to properly organize cross-sector partnerships in smart city projects is limited [5]. Thabit and Mora stated the importance of focusing on how the collaboration is implemented and the capabilities of the participants rather than the types of actors involved in the collaboration [24]. By analyzing what stakeholders are interested in, the capabilities and expectations of actors and how collaboration works can be directly and indirectly understood. Therefore, this study aims to improve the understanding of cross-sectoral collaboration in the smart city context by analyzing the interests of each collaborator in depth.

2.1.3. Population density

A variety of socioeconomic and political factors influence city categorization [40]. Increasing population density is a useful urban planning means to control urban sprawl and protect valuable land from development [41]. However, excessively high density is a problem for urban development because it can increase congestion-related problems in physical infrastructure (e.g., energy distribution and transportation) [28].

Population density is an important dimension for assessing trends in smart cities [42]. Population density has a positive impact on smart city transformation readiness [43] and on hard domains (e.g., energy grids, public lighting, waste management), including transportation and mobility, and buildings [28]. Financial requirements are also important in determining the roadmaps for high-tech urban development [26]. The implementation of smart city initiatives requires budget and resources [43], and high population density can contribute to the affordability of smart city investments [44]. Moreover, high population density has benefits for creating more vibrant, innovative, and sustainable communities [43] and the potential to increase knowledge sharing and innovation [45]. Consequently, increased innovation can contribute to smart city readiness [46]. For this reason, this study examines the relationship between population density and smart city plans.

2.2. Quadruple helix model

Because cities are living organisms in which human activities occur, a comprehensive multidisciplinary approach that considers the perspectives of different actors and the environment is needed [3]. However, because each actor has a different perspective, a holistic framework that can bring them together is necessary. The quadruple helix model (QH) is well-suited to efforts to consider both social and technological contexts, such as smart cities, because it can explain how social innovation is fostered and the role of communities [47,48]. QH categorizes collaborators as academia (university), public sector (government), industry, and civil society actors [49]. Notably, Paskaleva et al. proposed a framework for engaging all smart city stakeholders by applying the QH innovation approach to smart city impact assessment [50].

Hybrid organizations are increasingly emerging at the intersection of sectors [24]. Furthermore, even actors in the same sector can have different positions depending on the political and economic context [51]. The adoption of a particular model (e.g., triple- or quadruple-helix collaborative models) does not necessarily impact the public value of a smart city project [52]. However, exploring the interests of each collaborator based on QH is helpful for smart city planning and operation. Furthermore, because the QH approach varies depending on the type of innovation and its stage of development and guidance on how it should be implemented and managed by different stakeholders is scarce [32], a deep analytical study of each stakeholder is needed to develop the relevant details. Moreover, identifying a study in the literature that systematically analyzes the topic by simultaneously considering various smart city collaborators is difficult. Therefore, this study applied QH as a framework for simultaneously considering collaborators. Data from each actor were collected and integrated to explore different domains. This allows us to examine the interests of academia, industry, government, and civil society in the topic of smart cities and the progress of each.

2.3. Hype cycle

The hype cycle concept, introduced by Gartner in 1995, focuses on the dynamics of expectations in technological innovations [53]. Hype is caused by a surge in shared positive expectations or the social acceptance of rhetorical justifications [54]. It is used to study innovation processes, and understanding hype patterns can help collaborators improve their ability to respond to hype [55]. The emergence of technology can be understood from the perspective of the five stages of the hype cycle [56]: technology trigger, where a technological innovation and product launch receive significant media attention; peak of inflated expectations, a phase of excessive enthusiasm; trough of disillusionment, where the technology fails to meet expectations and media attention declines; slope of enlightenment, where experimentation with the practical application of the technology takes place; and plateau of productivity, where the benefits of the technology are demonstrated and accepted [27]. In other words, emerging technologies initially go through a phase of increased expectation, followed by a trough of disillusionment, and then a plateau of productivity [55]. The cycle is illustrated in Fig. 2. Shi and Herniman argued that high positive expectations in the early stages of the cycle were more likely to be associated with emotional expectations [53], whereas subsequent drops in expectation were associated with "emotional expectation decreases" and "logical expectation increases." The convergence field of the smart city simultaneously involves various fields, but technology is at its center. In addition, a timely introduction of emerging technologies is crucial. Accordingly, we discuss the current status of smart cities based on the hype cycle concept and suggest solutions and future directions.

2.4. LDA and BERT

Topic analysis is useful for identifying emerging topics, hot spots, and knowledge transfer in scientific domains [57]. Various approaches to topic extraction exist, but a recently popular method involves applying topic modeling to the collected publications [58]. Notably, LDA is the most widely used topic modeling method [3,59], and it has been frequently used to identify topics in academia [60]. The number of topics is an important parameter in LDA for obtaining reliable results, and increasing this number tends to increase the predictive power of the model, but it decreases the semantic consistency [61]. Researchers generally make qualitative decisions [3], trying different numbers of topics and analyzing them together with related words. LDA has been actively applied in the field of smart cities [3]. For instance, Sharma et al. applied LDA to smart city IoT-related articles to perform topic modeling analysis and extracted 10 topics [16]. Kim et al. used dynamic topic model, an extended LDA concept, to build a classification model for citizen opinions regarding smart cities [2]. Kim and Kim used LDA to group patents and categorize smart city-related technologies [62]. Oh et al. extracted six topics from the research literature related to smart cities and COVID-19 and proposed the development direction of smart cities in the postpandemic era [3].

Topic modeling is commonly utilized for topic analysis [58]. However, LDA is limited by its focus on keyword analysis without considering the context in which keywords appear. Therefore, BERT, which considers contextual information as well, is increasingly being used [60]. BERT is a natural language processing model that Google trained on 3.3 billion words from the Internet [63]. BERT efficiently processes large corpora and ensures accuracy and efficiency in text classification tasks [64]. Text classification is the assignment of text to multiple categories, and topic classification, which is the subject of this paper, is one of its subfields [65]. Khadhraoui et al. used a pretrained language model (PLM) to design a model to multiclassify patents and found that among several PLMs (ELMo, OpenAI GPT, and BERT), BERT was the most suitable [66]. Li et al. pointed out that the classification of a vast and diverse set of policies is mainly performed manually, which is neither objective, reproducible, nor efficient, so they proposed a BERT-based model [64]. Saheb et al. combined three algorithms (clustering, LDA, and BERT) to extract eight academic topics (such as convergent IoT and AI for smart city development) on sustainable AI in the energy sector to compensate for the shortcomings of existing topic modeling approaches [60].

Manual categorization of various research materials (e.g., web and datasets) by researchers is not only time-consuming and energy-intensive but also increasingly infeasible in the era of big data [65]. However, there are not many studies on topic analysis using PLMs

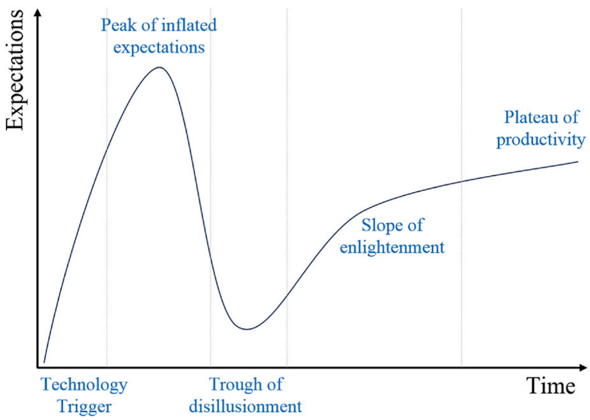

Fig. 2. Gartner hype cycle [55].

[58]. Therefore, in this study, a BERT model was fine-tuned using a corpus of smart city papers and applied to plan and patent topic classification. With this approach, BERT can learn the smart city context and achieve high-performance classification with its language processing capabilities. To the best of our knowledge, this paper is the first study to combine LDA and BERT for use in a varied text corpus for a smart city topic analysis task. We developed a topic analysis method for smart city-related text data and examined the hidden relationship between each collaborator's interest.

3. Method

3.1. Data collection plan

Duwe et al. studied innovative technologies and explained that patents and publications can be used on the technology side, and Google Trends data can be used on the market side [67]. Google Trends is the most widely used tool for behavioral analysis using web-based data [68] and provides relative search volumes regarding how often certain search terms are entered compared to others [69]. Search traffic is highly correlated with social phenomena because internet searches immediately reflect users' needs and interests [70]. Google Trends data provide important information for forecasting macroeconomic variables [71] and can be used to analyze public interest in policies [72]. Therefore, many studies have been conducted in the economic and policy fields that use Google trends data to understand people and society and predict behavior [70]. Regarding civil society in the study of smart cities, an emotional analysis using social network service data was performed to analyze public interest [73], and Kim et al. identified public needs by analyzing civic query data for a city [2]. However, quantitative analysis using Google Trends has rarely been performed. Therefore, this study uses publications, patents, plans, and Google Trends search volume to represent academia, industry, the public sector, and data, respectively, to analyze civil society.

3.2. Topic classification model

To systematically compare and analyze the differences in collaborators' interests, we conducted LDA on the academic literature with the largest number of data points to extract topics and set them as a baseline topic list. Using the academic literature text data and extracted topics as training data, we trained the BERT model as a topic classification model and used it to classify the other two data types (patents and plans) based on the academic literature topics. Topics can be extracted through LDA by simultaneously using academic literature, patents, and plans as data. However, due to the characteristics of each text corpus, each data type may be represented as a single topic, and it may not be possible to analyze the similarities and differences in interest among collaborators. The BERT-classification model, trained on academic literature, allows topics in each field to be extracted with consistent criteria and what stakeholders are interested in to be compared.

The methodology consists of two main steps. Fig. 3 shows the overall steps, where the bottom is step 1 and the top is step 2. In the first step, we built a topic classification model to classify the topics of the smart city-related corpus. Manually categorizing each text

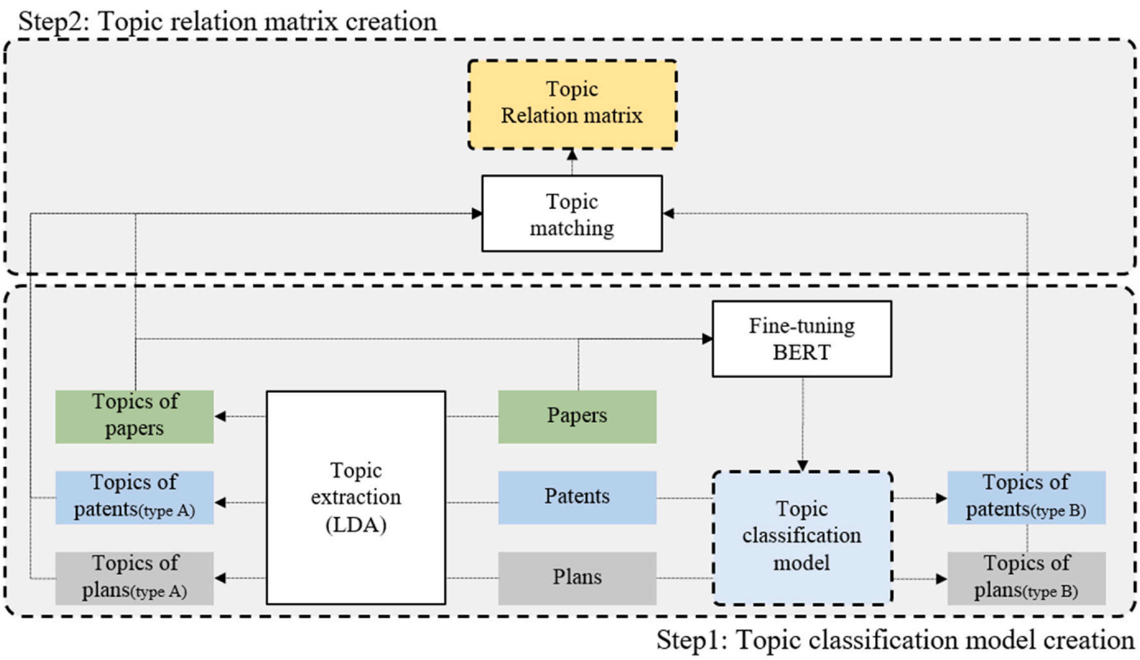

Fig. 3. Research method framework.

when heterogeneity exists in the data collected from different sources is difficult [65]. Therefore, we used LDA and BERT models to classify the smart city-related corpus. First, LDA was applied to the text data of research papers, patents, and plans to extract each topic (typeA). Second, we fine-tuned BERT using paper topics and text to create a topic classification model. For fine-tuning, we used the BERT-base-cased model of Hugging Face. Third, we extracted the typeB topic again by inputting the text data of patents and plans into the created classification model.

3.3. Topic relation matrix

In the second step, we matched the paper topics, patent topics (typeA and typeB), and plan topics (typeA and typeB) extracted in the first step before finally generating a topic relation matrix comprising the topics and their relations. Fig. 4 shows how the topics of papers, patents, and plans are matched. For example, when the text of *Patent_i* was classified using LDA with patent corpus, topic 12 (typeA) was extracted, and when topic classification was performed using BERT-based topic classification model trained on the paper corpus, topic 17 (typeB) was extracted. In this case, patent topic 12 can be explained as being related to paper topic 17. Accordingly, we counted the connections between the entire patent (or plan) topics and the paper topics, aligned the plan and patent topics based on the paper topics, and finally generated a topic relation matrix.

4. Results

4.1. Data collection

Table 2 summarizes the data collected based on QH. Because Google Trends data have been available since 2004 (Jun et al., 2018), we collected monthly data from 2004 to September 2023. Academic data were retrieved from Web of Science papers (search string = *"smart city" or "smart cities" (Title) or "smart city" or "smart cities" (Abstract) and Article (Document Types) and English (Languages))*. A total of 10,400 papers were collected, and 9401 papers were finally selected after excluding papers without abstracts and irrelevant papers. For industry data, we searched Google Patents (search string = *"TAC=("smart city" OR "smart cities") language:ENGLISH")* and collected 8519 patents. We only included granted patents, resulting in a final dataset of 3846 patents. Government data were collected from smart city plans (including master plan, roadmap, blueprint, and strategy) published by the government or related official websites (including official organizations). The cities for collecting government plans were initially selected from the world's top 50 smart cities [74], as cited by Ref. [7]. However, many city plans could not be found because the language was limited to English, and most plans were not publicly available. Therefore, we also included smart city-related plans searched on Google. Accordingly, we collected government descriptions for 51 cities. The number of countries and cities collected are listed in Table 3. The maximum length of a single text allowed by the BERT model is 512 [63], so the full text of the plan could not be used as model input. Therefore, we manually excerpted the parts that summarized the entire plan (such as the summary and introduction). The collected texts were preprocessed (including through lowercasing, tokenization, cleaning, and lemmatization) [3,65]. For the paper corpus, we split 90 % of the total data into training sets and 10 % into test sets for fine-tuning the BERT model.

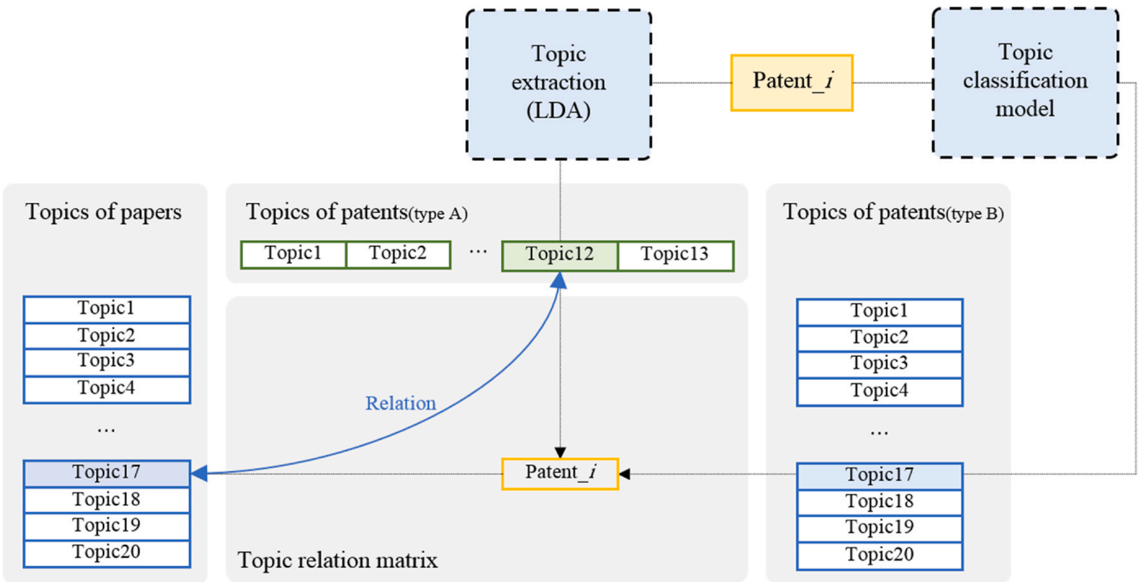

Fig. 4. Example of patent topic extraction and matching.

Table 2
Collected data sets.

Dimensions	Data		Source
Civil society actors	Search volume (monthly)	(2004–2023)	Google Trends
Academia	Title & abstract of 9401 papers	(1999–2023)	Web of Science
Industry	Title & abstract of 3846 granted patents	(2008–2023)	Google Patents
Government	Summary from 51 city plans		Government website

Table 3
Number of countries and cities.

Europe		Asia		North America		Oceania	
Country	Cities	Country	Cities	Country	Cities	Country	Cities
Austria	1	China	1	Canada	3	Australia	12
Czech Republic	1	Israel	1	USA	6	New Zealand	1
Denmark	2	Malaysia	2				
Finland	2	Singapore	1				
France	1	South Korea	3				
Germany	2	Taiwan	1				
Iceland	1	UAE	1				
Italy	1						
Netherlands	1						
Norway	2						
Sweden	1						
Switzerland	2						
United Kingdom	2						

4.2. Google Trends

The term smart city has been confused with various terms (e.g., creative, intelligent, knowledge, digital, sustainable, and ubiquitous city) [12]. Therefore, in this study, we compared the Google search volume of related words, and the results are shown in Fig. 5. Google sets the maximum search volume for a query to 100 and provides the relative search volume tracked over the entire period [70]. Over the past decade, "smart city" has been the dominant search term, with other terms having a very small share. This suggests that the public is most familiar with and interested in the term. Table 4 lists the changes in search volume for each word over time. The graphs for "smart," "knowledge," and "sustainable city" show an overall upward trend, whereas "digital," "intelligent," "ubiquitous,"

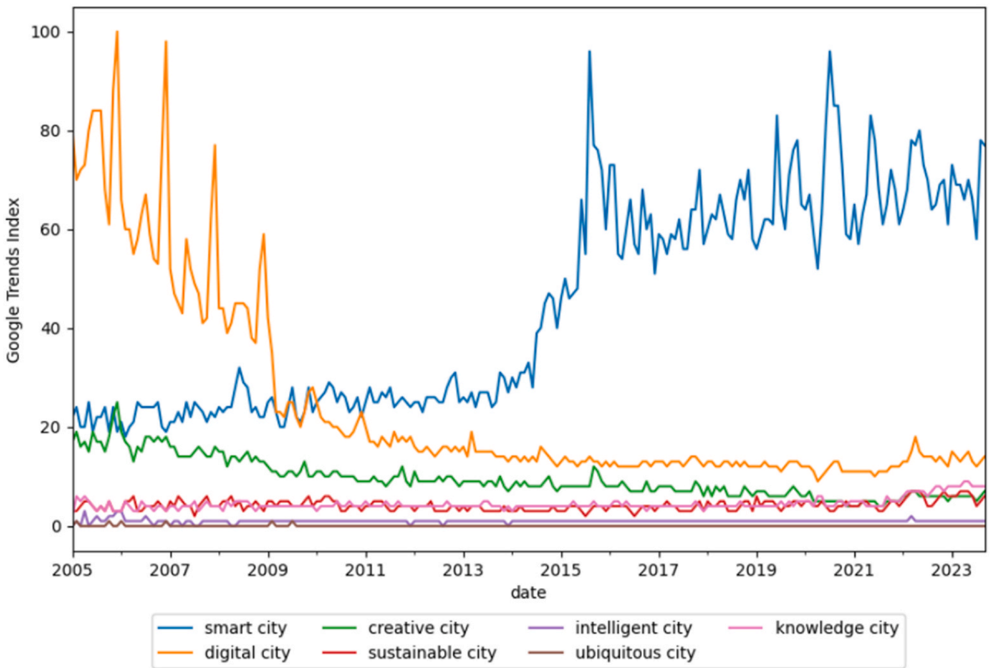

Fig. 5. Search volume comparison between smart city and six related words.

and “creative city” exhibit a decrease in search volume.

4.3. Topics extraction

Using LDA, we extracted 20, 13, and 5 topics for papers, patents, and plans, respectively. Table 5 lists the extraction results for each type of data (a number is randomly assigned by the LDA model and has no meaning). Regarding papers, topics in various fields, such as governance, security and privacy, and mobility, were extracted. The results of categorizing the extracted topics based on six areas of smart cities [75] are listed in Table 6. Consistent with previous research, topics related to smart mobility (e.g., fog and edge computing, object detection, blockchain, sensors, IoT, and attack detection) were the most common, followed by smart environment and smart living. In contrast, no paper topics were related to smart economy and smart people, and they were underrepresented in patents and plans. These two areas have a real impact on city residents, so it is necessary to actively research and develop solutions in the future. In the patent corpus, topics such as computing, detection, and transportation emerged. Regarding plans, topics that consider livability and sustainability, which are related to the quality of life of urban residents, were extracted. The research topic of smart city services has been popular over the past decade [42], and it has been extracted as a topic of interest in government plans.

4.4. Topic classification model creation

We fine-tuned the BERT model using the text of the articles and 20 paper topics. We used the default hyperparameters and set the training epoch to six. We used accuracy, F1 score, precision, and recall as metrics, calculated using TP (the positive class correctly predicted by the models), FP (the positive class incorrectly predicted by the models), TN (the false class correctly predicted by the models), and FN (the false class incorrectly predicted by the models) values [65]. On average, the metric scores were approximately 82 %, so we categorized the classification result as significant. Therefore, we used the model to extract the typeB topics of patents and plans in the next step. The detailed evaluation results are listed in Table 7.

4.5. Topic relation matrix creation

We extracted the topics on patents and plans (typeB) using the topic classification model fine-tuned with the topics and corpus from papers. The two types of topics (typeA, typeB) of patents and plans were matched to finally fill the topic relation matrix based on paper topics. The results are shown in Fig. 6 and are sorted by the number of articles in each topic.

Sustainability and digital platform were covered in all three types of datasets, meaning they are of interest to academia, industry, and government. Specifically, sustainability was related to all five plan topics. Plans were mostly related to the future and service, such as sustainability and digital platforms, whereas patents were mostly matched to technology-related research areas. Governance, resource, and green space continue to be of interest in academia but are relatively under-represented compared to technology-related topics in academia, industry, and government. The lower the research publication volume, the fewer the patents and plans, suggesting that research interests are aligned with patents and plans. The fields behind the topics of IoT, traffic, and sensors are being driven by industry. For example, the topic “sensor” was highly related to patent topic 6, namely street lamp. “Sensor” was the second most researched topic in academia, and many sensor-related lamp patents are filed in the industry.

The topics of “security and privacy” were of interest to both academia and industry, but their share was relatively small. In particular, this topic has received relatively little attention in the plan topic classification, which aligns with the results of [76], who analyzed the characteristics of 15 smart city plans and found that most strategies vaguely address security and privacy issues. Privacy and security issues have been studied in the literature on open and data-based innovation, but they need further exploration in the context of smart city transformation [32]. Information exposure and damage to individuals and organizations is an important issue to be addressed in smart city planning and implementation [77], and further research and attention are needed in this area.

Moreover, the inclusion of a participatory approach (i.e., governance) by citizens and companies is important, but many city strategies do not address it in detail. Citizen participation is a major goal of smart city strategies, but the process of empowering citizens is not simple [76], so developing the governance field is deemed slower in terms of practical aspects compared to other topics.

Table 4
Google Trends results of smart city and six related words.

City concepts	Google Trends index			Growth rate (%) [2004–2023]
	2004	2014	2023	
Smart city	25.08	41.08	79.00	214.95
Knowledge city	43.08	47.17	92.67	115.09
Sustainable city	62.42	45.42	82.00	31.38
Intelligent city	42.92	18.83	26.22	−38.90
Creative city	68.67	34.42	24.22	−64.72
Ubiquitous city	28.42	7.17	6.89	−75.76
Digital city	81.00	11.67	11.44	−85.87

Table 5
Topics and related words.

No	Paper topics (20)	Patent topics (13)	Plan topics (5)
1	governance	cloud server	sustainable
2	fog computing	video monitoring	service
3	security & privacy	road	technology
4	mobility	traffic management	livable
5	resource	vehicle	solution
6	energy	street lamp	
7	waste	information	
8	object detection	water	
9	digital platform	IoT terminal	
10	region	target detection	
11	blockchain	electronic circuit	
12	healthcare	resource	
13	parking	energy	
14	sensor		
15	IoT		
16	traffic		
17	sustainability		
18	edge computing		
19	attack detection		
20	green space		

Table 6
Paper topics and six characteristics of smart cities.

Six characteristics	Paper topics
Smart economy (competitiveness)	–
Smart people (social and human capital)	–
Smart governance (participation)	Governance
Smart mobility (transport and ICT)	Fog computing, security & privacy, mobility, object detection, digital platform, blockchain, parking, sensor, IoT, traffic, edge computing, attack detection
Smart environment (natural resources)	Resource, energy, waste, sustainability
Smart living (quality of life)	Region, healthcare, green space

Table 7
Classification model performance results.

Metric	Formula	Value (%)
Accuracy	$(TP + TN)/(TP + TN + FP + FN)$	82.18
F1 Score	$2(Precision)(Recall)/(Precision + Recall)$	81.82
Precision	$TP/(TP + FP)$	82.24
Recall	$TP/(TP + FN)$	82.18

4.5.1. Uncharted territory in smart cities

The overall analysis revealed a gap in the development of sustainability and governance topics, even though they have a significant impact on building and maintaining smart cities. Moreover, when considering the six indicators of a smart city (i.e., smart economy, smart people, smart governance, smart mobility, smart environment, and smart living) [75], differences in preference for each stakeholder were observed. For example, economy was not extracted, as major research topics and healthcare (smart living) received relatively little attention in all three sectors. These topics mentioned so far represent the uncharted territory of research and practice that [12] refer to, and each collaborator should strive to close this gap in the future. Active support and development efforts seem necessary, especially in areas with large gaps. Governance, environment, economy, and health are further explored in the context of smart cities.

Smart governance Smart governance can be defined as the ability of governments to make good decisions using a combination of ICT-based tools and collaborative governance [78]. Mora et al. reviewed the governance of smart city transition from an innovation management perspective and found that the governance mechanism evolves based on three dimensions: institutional context for urban innovation, urban innovation ecosystem, and urban digital innovation [32]. Scott and Thomas characterized collaborative governance as a set of strategic tools for achieving policy goals [79]. Using an instrumental lens, Ruijer et al. also argued that tools (e.g., checklists, guidelines, and templates) can be helpful in addressing smart governance challenges and conceptualized smart governance as a toolbox [33].

The smart governance literature emphasizes the importance of multi-stakeholder collaboration for the successful implementation

Paper_Topic		Patent_Topic													Plan_Topic				
Rank	Name	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	5
1	sustainability				3		18				5				6	14	8	11	4
2	IoT	6	2	1	3	2	121	140		651	97	13	106						
3	traffic	1	9	19	43	3	527	7	5	3	86			1					
4	waste	1	2	8	14		285	8		4	229	1							
5	edge computing	12	2	14	9		157	3	1	1	81	1	4						
6	energy			7	2		267	2	8		32	1	1	12		1			
7	blockchain		1		1		7	3		5	6							1	
8	digital platform			2	19		75	1	2	1	34		2			2	1	3	
9	sensor			9	1		539	5	7	1	43	4	1	1					
10	object detection		1	1			17				15								
11	governance																		
12	security & privacy						1												
13	mobility																		
14	parking																		
15	resource																		
16	green space																		
17	attack detection																		
18	healthcare																		
19	region																		
20	fog computing																		

Fig. 6. Smart city topic relation matrix.

of smart city strategies and practices [80]. However, smart governance is highly complex, as it involves a wide range of collaborator groups [37]. The academic literature has focused on smart governance processes and stakeholders, but the ways of gaining support from management and the political sphere [33] has not been sufficiently explored. Furthermore, governance is the area that the public perceives as the least smart in smart cities. Therefore, improvements in transparency and accountability are required, and related research is needed [39].

Smart environment Due to the unprecedented levels of urbanization and associated human activities, the role of sustainability in urban planning and development remains focal [17]. Various technologies developed during smart city construction can not only improve energy use efficiency but also enhance the pollution prevention capabilities of enterprises and provide new growth engines for the green development of the economy [81]. Guo et al. explained that the construction of smart cities improves the energy efficiency of cities, contributing to energy conservation and reducing per capita CO_2 emissions [82]. The construction of smart cities has a positive impact on the upgrading of the industrial structure, the development of pollution reduction technologies, and the increase in green areas, which ultimately reduces environmental pollution [83]. Liu et al. empirically observed that the construction of smart cities has a significant impact on promoting green economic development [84]. However, although the link between smart city construction and environmental pollution has been hypothesized in some studies, analytical studies supported by empirical evidence are lacking [84, 85].

Smart economy One of the main challenges of smart city development is financial resources, and economic stability is necessary for the long-term growth of smart cities [86]. The smart economy concept is a synergy of computer science, social science, engineering, and business that has the potential to contribute to business development, entrepreneurship, economic growth, and environmental protection [87]. Countries are increasingly using smart cities as a framework for sustainable smart economies [88]. Economic-based smart city evolutionary pathways are becoming increasingly important, but the corresponding academic research is scarce [89] and limited to a few countries and sectors [87]. Specifically, when to prioritize economic benefits during the development stage of the smart city ecosystem should be considered [86].

Smart health Improvements in human health have increasingly been recognized as a co-benefit of urban planning [90]. Urban infrastructure is an important determinant of population health and health equity [91]. While smart city strategies and digital technologies have the potential to improve urban life, for example by improving public health, obstacles, such as data concerns and large population participation exist [92]. Therefore, real-world smart city examples that explicitly address human health and related governance are rare [92]. In other words, smart cities can contribute to improving the health and well-being of citizens, but relevant empirical research is lacking [93]. Specifically, little is known about the potential of smart city interventions to improve the health and well-being of racial, ethnic, cultural, linguistic, and religious minority groups [91].

A wide range of research in the four areas mentioned above is available, but much of it is conceptual or hypothesis-driven. Moreover, research has concentrated on a few countries and sectors. Specifically, empirical analysis is lacking, so it is necessary to compensate for this by analyzing tangible results and communicating them to the public.

Table 8
Countries divided into paper and plan topics.

Continent	Goals		Means		
	Livable	Sustainable	Service	Technology	Solution
Asia		Malaysia, South Korea	Israel, Singapore, South Korea, UAE	China, Malaysia, Taiwan,	South Korea
North America	Canada, USA (2)	Canada, USA	Canada, USA (2)	USA	
Oceania	Australia (2), New Zealand,	Australia	Australia (6)	Australia (4)	Australia
Europe	Austria, Czech Republic, Denmark, Germany Iceland, Netherlands, Switzerland, UK(2)		Finland, France, Germany, Italy, Norway	Norway	Denmark, Switzerland,

4.5.2. Classification of smart city plans

Table 8 lists the plan classification results by plan_topic. The criteria for classifying smart cities can be broadly categorized into goals-based, means-based, or a combination of the two [94]. Of the five extracted plan topics, sustainable and livable can be grouped as goals-oriented, and service, technology, and solution as means-oriented. Smart city initiatives and programs can have different models and templates in response to local characteristics and opportunities [28,40,94]. Therefore, even in the same country, the focus of the plans differs because each government develops a plan that fits the nature of the city. Mora and Deakin analyzed smart cities in Europe that were considered successful and found that Vienna (Austria) and Amsterdam (Netherlands) were concerned with low-carbon, energy-efficient urban environments, that is, sustainability (goals-oriented), whereas Helsinki (Finland) focused on improving the convenience and accessibility of practical services (means-oriented) [25].

Goals-oriented. Livability is an important factor to consider when applying technology in the urban context, as cities cannot exist without inhabitants [95]. Livability includes the basic conditions that enable citizens to lead a dignified life, including physical and mental well-being [96].

Interestingly, many European countries focus on being livable, whereas Asian countries focus on service and technology. According to Ref. [97], southeast Asia uses smart cities to revitalize the economy and establish national identity through technological innovation, whereas European countries adopt them to improve the quality of life and pursue sustainable cities. To some extent, this trend is reflected in the results of this study. Tang et al. argued that while smart city strategies have become localized and diverse, national governments and regional groups, such as the European Union, set their own governmental guidelines, which can lead to archetypes [94]. European smart cities are focusing on developing platforms that allow residents to engage in innovative discussions [40]. Amsterdam is a representative smart city adopting the European trend [25], it values community-based proposals for improving livability, and has clear strategic goals for sustainability (e.g., cut emissions by 40 % by 2025) [98]. Furthermore, Amsterdam has not focused on technology in its smart city approach but rather on improving the quality of life of residents through living labs [97]. This is supported by the qualitative analysis from previous studies that revealed that Amsterdam and Vienna have taken similar approaches in the European context in the design and implementation of their smart city development strategies [25].

However, as listed in Table 8, the previous classification of smart city plans by country or continent has its limitations because even in the same country, plans may have different objectives depending on regional characteristics and local government goals. The results of this study reveal how countries approach smart cities from different perspectives.

Means-oriented Tang et al. classified cities such as Singapore and Dubai (UAE) into a group of cities with high population density and the advantage of high technology, and their model aimed to provide improved services using ICT [94]. Other cities with similar characteristics include Tel Aviv (Israel) and Seoul (South Korea). Singapore has promoted a bottom-up initiative to create solutions by fostering relationships between public agencies, industry partners, and residents [40], and the country has been categorized in the 'service' category. Noori et al. analyzed the development patterns of four smart cities (Amsterdam, Barcelona, Masdar, and Dubai) using an input-output model and observed that Dubai is focusing on the service aspect with significant efforts in the area of smart healthcare [26]. Tel Aviv is also a technology-driven city that provides its residents with personalized information and services and seeks to digitize their lifestyles [40]. San Francisco (USA), home to many Internet-based companies, is also a global setter in urban technology initiatives, implementing a variety of technology-enabled application services [97]. A comparison between prior studies and this study reveals that the latter replicates previous qualitative classifications in a relatively simple way.

4.5.3. Relationship between population density and plans

Population density data were collected from OECD statistics, UN, and government websites as of 2022 (2021 if 2022 data were not publicly available). First, for OECD countries, only cities categorized into small regions (TL3) were considered to evaluate the city territory level (country, large, and small regions). Second, data were collected from the UN data portal and official government

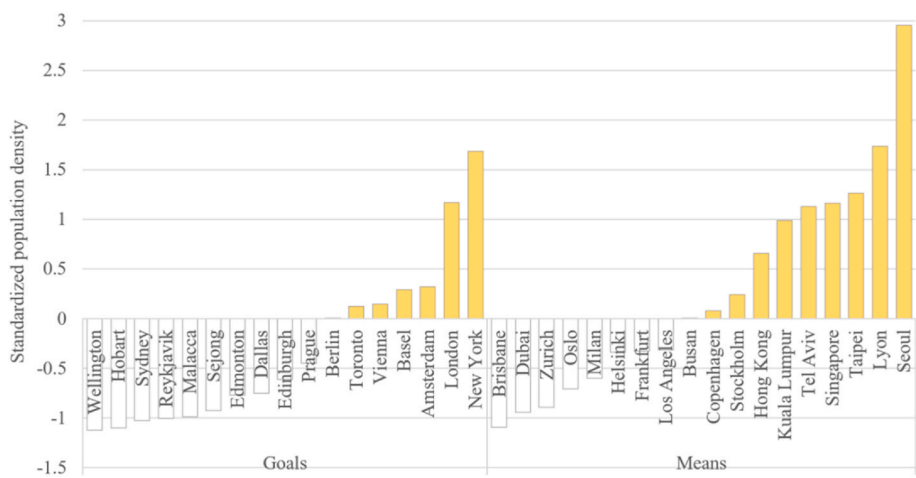

Fig. 7. Population density of cities and plan classification.

websites to ensure at least one city from each of the 26 countries in the initial samples. The final number of cities in the collected population density data was 35.

Fig. 7 shows that smart city plans are divided into goals-oriented and means-oriented categories. When the density was low, city plans were evenly distributed in both groups, but when the density was much higher than average, more means-oriented plans were observed. This is attributable to the demand for practical problem-solving using services and technologies being relatively high when the population density increases. In the case of Seoul, which has the highest population density among the analyzed cities, many urban problems began to arise along with rapid economic growth, and smart cities emerged as practical solutions to improve basic services [99]. Moreover, higher population density may increase the likelihood that citizens will engage in action on service needs.

London and New York, with their goal-oriented nature despite their high population density, have strengths in human capital and technology (ranked first and second in the Global Power City Index (GPI) [100,101]. The GPI ranks cities based on their overall strength in attracting people, capital, and businesses from around the world, which means that London and New York both have an economic competitive advantage over other cities [102]. Notably, London and New York are both managed with a marketist and capitalist approach [102]. However, despite their many strengths, they are limited by weak social cohesion [101]. London and New York are characterized by a diverse population of different races, ages, and income levels [103], and urban planning is influenced by these attributes [104]. The focus on livability in the two smart city plans may reflect citizens' desire to increase social inclusion, reduce concerns about risk and security, and ultimately improve their quality of life. For example, New York's smart city policies are based on a broader perspective, including education, housing, democracy, and human rights [105], with projects focused on improving human quality of life [102]. Fig. 8 shows a quadrant graph that combines the characteristics of smart city planning with population density. These results can assist government officials in preparing a smart city plan to compare their current situation with the benchmark cities, thus guiding them in their investment options.

4.6. *Current status and future directions of smart cities*

We examined the current status of smart cities based on the hype cycle and identified the future development direction. We measured expectations in each field based on the number of papers, patent applications, and search volume. Typically, quantitative data should be combined with qualitative assessments (positive or negative). However, many previous studies have demonstrated through sentiment analyses of smart city-related texts that interest is mostly positive [73]. In this study, therefore, we conducted the analysis using quantitative data.

Fig. 9 shows the number of patents, papers, and Google search volume by year. As of 2015, the interest of academia, industry, and the public had increased drastically, indicating the beginning of the growth trend of smart cities. The hype cycle indicated that period 1 in the figure corresponds to the technology trigger. With the rapid progress of urbanization and the growing awareness on climate change and urban infrastructure issues, smart cities have begun to be considered as future cities [77]. In addition, the development of big data and artificial intelligence technologies has the potential to support smart cities. This high potential has increased investment in smart city projects by governments and companies. However, since 2022, the growth rate of public interest and research has slowed slightly, and the number of related patent applications has declined. This may primarily be attributed to the actual performance not meeting people's expectations. The obstacles include complex regulatory and policy issues, project delays due to difficulties in adopting technologies, government and city budget constraints, and the global financial crisis. As Shi and Herniman note, even if no

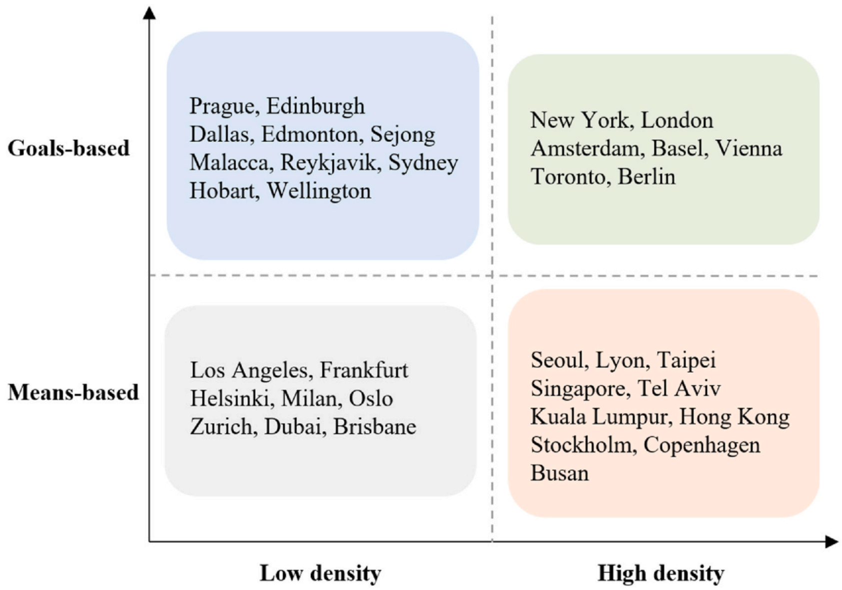

Fig. 8. Benchmark plan quadrant.

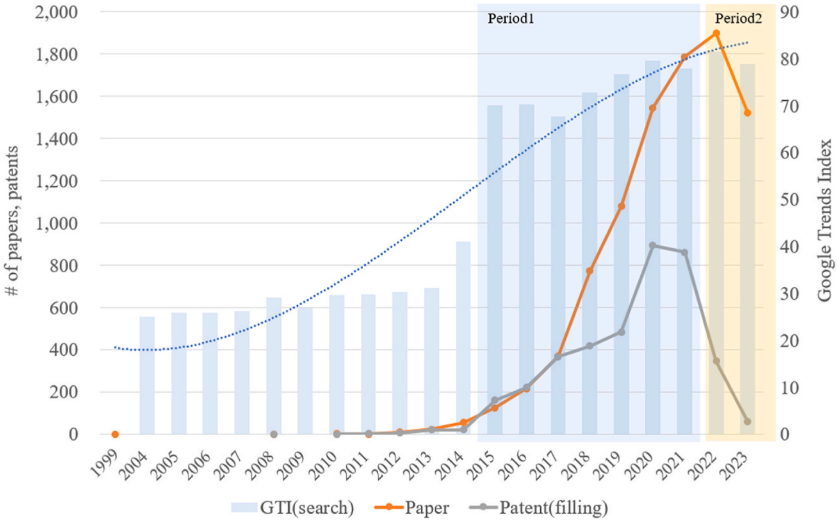

Fig. 9. Number of papers and patents and Google Trends index.

substantive outcomes in the early stages exist, this absence can lead to a rapid increase in expectations based on increased emotional expectations [53]. However, the influence of emotional expectations decreases, and the importance of logical expectations increases over time. Therefore, if smart cities do not achieve tangible results, people's expectations will decrease.

4.6.1. *Breakthroughs for the development of smart cities*

A breakthrough is needed for the development of smart cities to move from a technology trigger to a plateau of productivity rather than a trough of disillusionment (Fig. 9). This study proposes resolving the imbalance in the development distribution of academia, industry, and government as a solution. According to the topic relation matrix, the top topics in academia are mainly related to technology. Although various technologies are being developed in the industry, the focus is on IoT, traffic, and sensor topics, and patents for sustainability and governance technologies have been relatively scarce. The main plan topics were sustainability and digital platform. However, because the plans searchable on the Internet are mainly general, many of them are seemingly more branding-than implementation-oriented to attract the attention of citizens and stakeholders. In particular, since sustainability can be used as a general term for environmental responsibility, its actual incorporation into the plan needs to be confirmed by the presence of specific descriptions such as environmental goals, biodiversity, and water poverty [106].

An open and inclusive process is needed in terms of consensus building in partnership formation, as collaborators may have different goals and interests [107]. Consequently, the key issue is related to delivering the value that all collaborators expect [86]. We propose that the social aspect of smart cities should be emphasized to improve the interest and participation of residents.

The smart city approach has been criticized for its lack of focus on social aspects [108]. Social sustainability has received less attention than environmental sustainability, although it is closely related to smart cities [97]. Smart city residents and communities are interested in social diversity, which is linked to social sustainability [86]. The smartization of cities does not always require expensive, high-tech solutions; it can be implemented through readily available and relatively unsophisticated applications [109]. Therefore, the starting point for smart cities should be a social problem, not the narrow goal of technology diffusion [110], and the agenda should be demand-driven, that is, focused on the needs of residents [111]. While the number of societal sectors included in a smart city project cannot be considered a prerequisite for success [24], the presence of local actors with regional knowledge is key in a collaborative ecosystem [112].

Many urban problems, such as poverty and inequality, are social rather than technical [113]. However, equity and social concerns have yet to be systematically explored in the context of smart cities [91]. The design and implementation of effective smart city solutions require an understanding of social issues, such as the digital divide and policies that focus on digital inclusion and civic engagement [114]. Moreover, research on smart cities that target communities with low levels of digital literacy is needed [91].

Residents' perceptions of smart city developments have been studied relatively recently and can be either negative or positive, depending on the context, the localization of the development, and the flow of information provided to residents [39]. However, an academic understanding of the various forms of citizen discontent in smart cities is lacking [22]. Therefore, we propose the following two research topics. First, as a gap between collaborators may exist when judging the smartness of a city [39], and research is needed on the discussion and consensus process of smartness among actors to ensure that the vision and needs of residents, who are the end users of smart city technologies, are implemented. Second, we suggest studying smart city evaluation methodology by comparing the priorities of smart city design and operation with the priorities considered by residents. Residents have different priorities and want different levels of smartness, and this needs to be considered. The ultimate measure of whether a city is smart is how well its changes align with community needs and resident priorities [39].

5. Conclusion

Smart city research has gradually expanded from initial theoretical and conceptual discussions to a more technology-oriented field [15]. However, proactive steps are currently needed to utilize technology and services while preserving the environment to ensure sustainable smart cities. Research, policy, technology, and interest are needed to ensure that social, environmental, and sustainability considerations are embedded within smart cities. To address the gap in understanding and interest between academia, industry, government, and citizens on the development of smart cities, this study explored the directions and the topics that should be promoted. To date, many researchers have conducted conceptual studies or empirical analyses separately. Smart cities are not static but dynamic, as they are changed by various collaborators. Therefore, it is essential to comprehensively review the materials produced by various actors. Therefore, we collected and analyzed data from the four collaborators by applying the QH concept to provide a broad perspective of smart cities. Using various data sources to examine the relationship between popular and weak topics in each area can provide new insights into the current state of smart cities and prepare them for future development.

This study deepens the literature on the future development of smart cities. We identified important and underdeveloped topics in each area of smart cities. Additionally, we described the current state of smart cities based on the hype cycle concept and suggested areas that need further attention based on thematic insights from the topic relationship matrix. Methodologically, we proposed a topic analysis approach using LDA and BERT to identify challenges and solutions by simultaneously analyzing topics from different fields. Our method enables holistic analysis by identifying the topics of different collaborators according to a baseline topic, regardless of the field. This study has practical implications for researchers, policymakers, and industry stakeholders by helping them to understand which topics are underrepresented in their fields and identify which issues need to be actively addressed for the future development of smart cities.

In this study, we extracted topics for each collaborator and identified various interests and concerns within the sector. The increasing emphasis on intrasector partnerships calls for further research on collaboration that considers a detailed analysis of each actor. Research on the change of interest of each stakeholder over time will also facilitate the development of a collaborative model for smart cities.

Some citizens are skeptical of the desirability of new technologies and technological utopian visions of smart cities [22]. A growing body of literature is critical of the many existing efforts to engage the public in smart city planning (e.g., establishing roles for the public) [39]. Notably, citizen groups that are not particularly knowledgeable about smart cities may be underrepresented in the discussion [115]. Therefore, when considering smart city design and governance approaches, it is important to consider whose vision is being implemented [116].

The data collection stage represents a limitation of this study. When collecting plans, we excerpted some parts of the summary and introduction of the plan to consider the length limitation of BERT input text and equity with other data to create a text of similar length. Therefore, the collected texts contained more general content than the details of the plans, and the topic extraction results consisted of common words (e.g., citizen, service, and value). In future research, a detailed analysis of the topic relation matrix can be conducted on the entire text of plans to identify its strengths and weaknesses. In the field of smart cities, local characteristics are important, so the regional features of smart cities can be studied in the future by jointly analyzing search queries, papers, and planning patterns by region. Google Trends data can be extracted by region, and the corresponding analysis results can exhibit regional interest in search queries [117]. In terms of model performance, experiments with various PLMs, such as Scibert, which is pretrained on scientific corpus, could also be examined instead of BERT.

Funding

This work is financially supported by Korea Ministry of Land, Infrastructure and Transport (MOLIT) as Innovative Talent Education Program for Smart City.

Data availability statement

The authors do not have permission to share data. The data that support the findings of this study are available from [Web of Science, Google Trends, Google Patents]. Data are not publicly available due to [copyright issues], but are available with permission of [Web of Science, Google Trends, Google Patents].

CRediT authorship contribution statement

Jihye Lim: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Junseok Hwang:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

Declaration of AI and AI-assisted technologies in the writing process

Not applicable.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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