

TOPICAL REVIEW

Predicting Trends and Research Patterns of Smart Cities: A Semi-Automatic Review Using Latent Dirichlet Allocation (LDA)

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ABSTRACT Smart cities are a current worldwide topic requiring much scientific investigation. This research instigates the necessity of an organized review to a heedful insight of the research trends and patterns prevailing in this domain. The string is formulated to extract the corpus from Scopus largest database of publications. The corpus of 8320 articles published from 2010 to 2022 is processed using Latent Dirichlet Allocation. Two, five, and ten topics have been extracted to provide the recent trends for IoT in smart cities. There has been an increased recognition that more attention needs to be paid to the area of smart cities so a complete overview of the topic of smart cities research, including the most prominent nations (institutions, sources, and authors) and noteworthy research directions has been presented in this paper. The scientific collaboration across countries (regions), organizations, and authors has also been widely discussed. A detailed and comprehensive overview and visualization of the trends and research patterns used to integrate the Internet of Things in Smart Cities. This data based experimental study signifies a roadmap of the research trends in Smart Cities by implementing topic modeling technique that has never been used in this domain. Based upon the topic modeling using LDA, authors have formulated three research questions and answered those question based on the in-depth research. At the end this study concludes the areas suggested are at the growing phase and need more insight for their growth.

INDEX TERMS Smart cities, Internet of Things (IoT), latent Dirichlet allocation (LDA), scopus.

I. INTRODUCTION

With each passing year, the population is rising all over the world. As per the reports, out of the entire population hike, around one-third of the population increase is in cities. The current trend in technology and its effect on lifestyle has impressed the people to live a more intelligent and pleasant living. The government of various countries is working on identifying the technologies to develop smart cities. These technologies include Artificial Intelligence (AI), Internet of Things (IoT), Information and Communication

Technology (ICT), and many more [1]. IoT out of these works on offering smart ways of improving the city scenario indulging smart applications like smart homes, smart streets, smart business organizations, smart vehicle management on road, smart security, and so on [2]. Therefore, the interconnection of infrastructures in these different domains for business, homes, and social concerns is referred to as a smart city represented in Figure 1. Smart city applications involve a particular set of actions starting from essential data collection to forwarding the data, to store the data, and final data processing and analytics. After completing this action, final decision-making can be done using deep learning or AI-based techniques [3].

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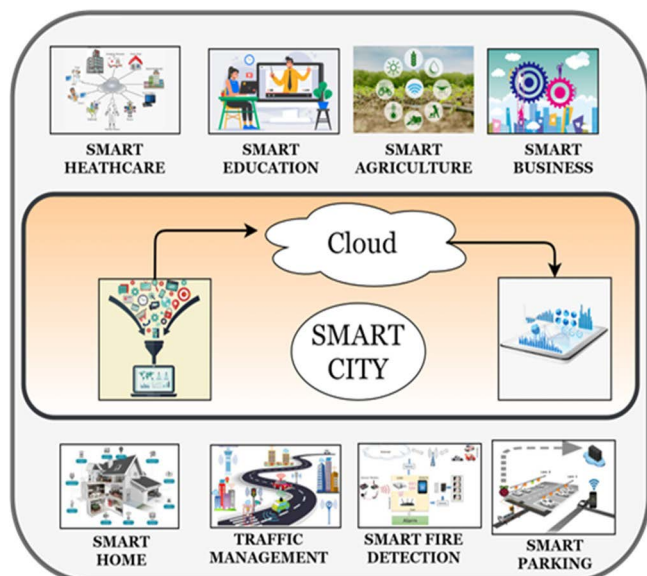


FIGURE 1. Smart city representation.

Smart city networks can be formed from either deploying segregated Wi-Fi networks all over the city, 4G, LTE, 5G, or Wi-Max can also be preferred for operation [4]. Finally, data collected can be stored in the cloud for data analysis [5].

People with implanted heart monitors, farm animals with biochip transponders, and automobiles with tyre pressure monitoring sensors built into the vehicle, Sensors, actuators, gadgets, appliances, and machines are all examples of IoT devices, which can be configured to do specific tasks and broadcast data over the internet or other networks.

Application related to agriculture fetch the crops, temperature, and humidity [6]. Applications related to traffic management bring the number of vehicles, accidents, road conditions, temperature, and many more. Once the data is accumulated at the application layer, the next business layer manages the complete process for designing a plan of action to frame policies for the network [7].

This investigation of the many IoT services utilized to achieve the realization of smart city foundations is motivated in large part by the rapid development and deployment of Internet of Things technology. Researchers in the literature are working on smart environment monitoring, smart waste management system, smart home automation, and smart vehicle management system [8]. These applications can be amalgamated together to form a smart city project. Diverse individuals and technologies are involved in making the city a smart one. People interested can be engineers, data scientists, data analytics, managers, etc. Therefore, this research paper highlights the different aspects and key terms associated with the smart city's highly in trend concept.

Smart cities are discussed in detail in Section I, which includes examples of various smart technologies, such as smart health care systems, intelligent transportation systems (including self-driving cars), intelligent business management systems, and intelligent fire detection systems.

Section II discusses smart cities in greater detail. Section II examines the literature produced by many scholars who have investigated the application of Internet of Things technology in Smart Cities. When the researcher conducts inquiries on Smart city technology, Smart healthcare systems, and future research trends in Section III of this work, which is a key technique of topic modelling, the topic modelling is deluded by the researcher's inquiries on Smart city technology, Smart healthcare systems, and future research dynamics. Section V describes the methodology used to arrive at the study's conclusions. The results and responses to the framed research questions are explored and addressed in Section VII of the report. The final portion serves as a recapitulation of all that has come before it.

II. RELATED LITERATURE

After an initial overview of related work, we examine specific prior work on the on bibliometric analysis of smart cities was started in 2017. A review of major studies in this area confirmed that the first research using bibliometric was first done in 2017. A bibliometric study of the literature written on the topic of smart cities between the years 1992 and 2012, spanning the field's first two decades of study. The analysis reveals a lack of unity and coordination in smart-city research, as well as the existence of two distinct growth trends in the field [9]. In a survey of 4409 research manuscripts on smart cities from the Web of Science's core collection published between 1998 and 2019, the majority of the earliest work focuses on the study of bibliometric analysis of smart cities [10]. A recent study presents a bibliometric analysis of 1354 documents to gather as much information as possible about Smart Cities. In addition, the findings of the bibliometric study allowed for another analysis to be conducted in order to investigate the co-occurrences of keywords, thereby identifying the variables, key dimensions, and primary areas [11]. In another bibliometric analysis, the researchers have presented a comparative perspective of smart governance and smart cities. Bibliometric analysis is based on the Scopus database, which contains 775 recent publications, and a range of bibliometric approaches. The results show Smart Public Governance research's evolution. Despite smart cities being the primary focus of SPG research, smart government has become increasingly important in recent years, as seen by articles in Government Information Quarterly [12]. Taking this research into consideration, the researchers have started the literature review and applied more advanced technique along with some of the features of bibliometric technique. Researchers have applied topic modelling using LDA for fetching current research trends in this field. Additionally, latent Dirichlet allocation (LDA), one of the most classical topic modeling methods in bibliometrics, facilitates the screening of large datasets. LDA has been applied in various fields like Blockchain [13], Cyber security [14], Machine Learning [15] and many more, as per the analysis drawn from prior literature and reviews LDS studies are not found on smart cities. Thus, the prior literature analysis, reviews, and

TABLE 1. Existing and current research differentiation.

Existing Research		Current research
Title Research Study	Research Concept	
“The first two decades of smart-city research: A bibliometric analysis”	A bibliometric study of the literature written on the topic of smart cities between the years 1992 and 2012	In the current research, the LDA Technique has been applied on Scopus Data set from 2010 to 2022.
“Bibliometric analysis on smart cities research”	The Data set is taken from Web of Science and technique applied on data set is bibliometric analysis	The difference lies in the dataset and the technique used for the analysis.
“Smart City: a bibliometric analysis of conceptual dimensions and areas”	The current dataset comprising 1354 documents after refining the data set and subject area is based upon business and accounting	The final corpus comprising of 8320 documents whereas the subject area defined by the researchers is technology.
“Bibliometric Analysis of Smart Public Governance Research: Smart City and Smart Government in Comparative Perspective”	A comparative perspective of smart governance and smart cities is presented by the researchers	A technical perspective of Smart Cities is presented by the researchers with current research trends.
“Blockchain for intelligent transport system”	LDA Technique has been applied on Blockchain Dataset	Technique is same but dataset is different.
“Clustering and topic modelling: A new approach for analysis of national cyber security strategies”	The researchers have collected and examined 60 national cybersecurity strategies that have been developed during 2003-2016 using clustering techniques	The researchers have collected and examined 8320 research papers that have been published during 2010-2022 using LDA technique.
“Performance analysis of machine learning algorithms in intrusion detection system: a review”	A manual systematic review has been carried out by the researchers on ML algorithms for IDS	Semi-Automatic review has been carried out by the researchers using text mining technique.

surveys have approached this domain with this conceptualization. Table 1 show the difference between current research with the recent studies carried out by various researchers.

In the most recent survey, authors have applied the same technology on blockchain technology integration to different platforms [16]. The researchers have applied LDA technique to predict the research trends in the field of blockchain technology. They have predicted 17 research trends which are in to practices and needs more focus. Upon studying the literature, it is concluded that LDA techniques are not applied to smart cities data to predict the research trends. This became the motivation for the researchers to choose this topic for current study.

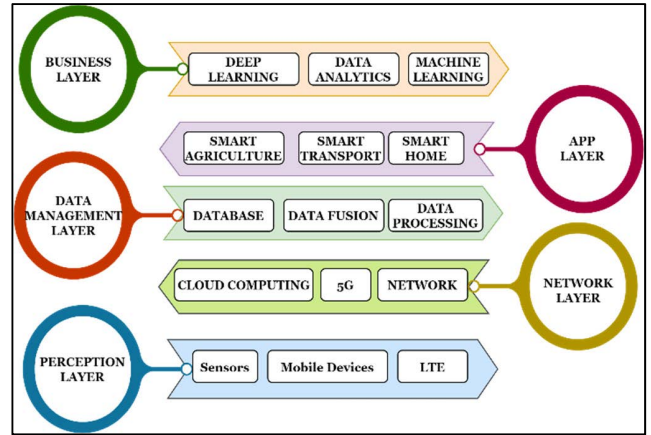


FIGURE 2. Layers orientation in IoT.

III. OVERVIEW OF SMART CITIES

The foundation of an application employing the internet in the late '90s had led the way for the introduction of the “Internet of Things (IoT)” in 1999 [17]. IoT provides smartness to various applications including smart homes, smart industry, smart parking, and many more. Combining them, IoT was later used for deploying smart city scenarios. Although it seems to be a vibrant solution for smart cities, it has numerous challenges and checkpoints. One of the critical challenges is the heterogeneity of connected devices and how to exchange data among them securely [18]. Another challenge is many interconnected nodes in IoT demands for optimized load balancing to improve the overall lifetime of the network [19].

The general workflow during operations of IoT for smart cities comprises data collection, data processing, and finally, data analytics used for decision making [20]. First, data collection is performed using variants of sensors as per application needs. Then, data collected is communicated to storage systems or servers using network connectivity like Wi-Fi. Servers and storage systems store data in raw format. Refining the data and providing valid and fruitful information to external devices is processed in the second stage for decision-making. Various methods are adopted in literature to find a smart city solution in correlation with IoT. Table 2 describes the different approaches bead on IoT Technologies used for smart cities and their advantages and shortcomings, helping the novice make better decisions over choosing a method for research work.

A well-defined architecture of IoT is required to cater to the needs of smart cities. The architecture consists of five layers of operation, with each layer providing a specific set of services, as shown in Figure 2. Layer 1, the perception layer, is the bottom layer used to collect the data using multiple sensors, smart equipment in working. Smart working devices help detect and collect the data as per the occurrence of events [21]. Anything with an Internet Protocol (IP) address and the ability to send and receive data over a network qualifies as a “thing” on the Internet of Things (IoT). The major challenge faced by the layer is the heterogeneity in data

TABLE 2. Approaches used for Shaping Smart City along with IoT.

Ref.	Methodology Used	Advantage	Shortcomings
[18]	Drone based	Data collection becomes easy by equipping drones with IoT devices	Image capturing and processing becomes an additional overhead
[24]	Fog Computing	Different data caching methods using AI and Machine Learning (ML) make the smart city project more efficient	Scalability, Power Constraints, Scarce Resources
[25]	Computer Vision	Security Provisioning in IoT by detecting the presence of people through image analysis	The image capturing analysis is not a reliable option if focus or real object is not captured
[26]	Semantic Web with ML	It supports scalability to include real-time and heterogeneous data	Stability is required for semantic web-based languages
[27]	Big Data	The cloud-driven method makes data collection easy when a considerable amount of data is collected from sensors or other devices	Quality of service requirements wants extensive data integration with intelligent networks
[28]	Data Models	Reusable data models are created for smart cities to use data again over various applications	Static data is collected and used repeatedly that lacks dynamicity in real-time applications

collected from various sources, making the task complex for the management and processing of the data. Layer 2 is the network layer that helps the collector devices at the perception layer pass their information to the application desiring it [22]. The network technologies used to depend on the area covered by the collector devices. For smaller sizes, Bluetooth, Wi-Fi, Zigbee can be used. Wi-Max or 4G, 5G technology is required for devices covering huge areas. This layer supports the real-time operation and decision handling in an event. Layer 3 is the data management layer; this layer fetches the data collected from the perception layer and carries the information in the refined form to the above application layer [23]. This layer works on data collection, management, filtering, security, and analytics. The sole responsibility of smart city operation depends on the data management layer, and appropriate steps taken in this layer lead to the proper decision-making. Layer 4, the application layer, grabs the data from Layer 4 depending upon the type of application in the smart city. The technologies which are behind the smart city are as follows:

A. INTERNET AND COMMUNICATION TECHNOLOGIES

For creating two-way communication channel.

B. INTERNET OF THINGS

A smart city's devices must all be connected to one another in order for them to communicate and make choices on their own, enabling the administration of a megacity's resources. This is where the Internet of Things steps in, offering the perfect model of a network of communicative devices that provides clever answers to common issues.

C. SENSOR TECHNOLOGY

Sensors are required in every intelligent control system. The environment influences how a process is improved, and for a control system to be aware of its surroundings, it is frequently outfitted with a variety of sensors from which it gathers the necessary data.

D. GEOSPATIAL TECHNOLOGY

To enable software-based solutions focused on smart infrastructure, geospatial technology offers the essential foundation

for collecting data and processing observations in these collections.

E. ARTIFICIAL INTELLIGENCE

Artificial Intelligence Technology enables machine-to-machine communication by analyzing data and drawing conclusions from it.

F. BLOCKCHAIN TECHNOLOGY

The blockchain application is new to the concept of a smart city. Data transfer using blockchain technology is secure. By incorporating it into smart cities, connection across all municipal services might be improved along with security and transparency.

G. SMART INFRASTRUCTURE

A smart city should have a smart infrastructure since this enables improved data analysis, preventative maintenance, and future planning for the city.

The approaches mentioned in Table 2 can make smart city projects more attractive and valuable. Adding value to a smart city can cause several applications to run significantly and supportively. Considering the literature, many researchers identified the applications that make cities smart. Table 3 highlights the IoT applications and their potential for working towards a smart city. Additional components and technologies are required for shaping smart cities. Moreover, multiple applications will ultimately help make the city smarter when combined. The literature survey mentioned in the Table 2 also concludes that IoT alone cannot provide desired services for smart cities as the technology comes with both advantages as well as shortcomings. When integrated with other technologies, the Internet of Things can contribute significantly more to the development of smart cities. As a result of the insufficiency of legacy IT systems to handle the data that is acquired by sensors, new technologies such as big data models, semantic web applications, fog computing, and drone-based technologies have been developed. Applications for smart cities, such as smart houses, can give rise to a new type of smart home if they are linked with other technologies, such as computer vision. This new type of smart home would be

TABLE 3. Applications used for shaping smart city.

Ref.	Application	Requirements
[29]	Smart Home	It is the heart of smart city operation as smartness comes from smaller but maximum modules. Motion sensors, ambient sensors, power monitors are required for smart homes
[30]	Smart Healthcare	ICT is required for smart health. Sensors for tracking health, Remote diagnosis, and telemedicine services are essential aspects
[31]	Smart Transport	GPS used inside vehicles, roadside units for monitoring traffic and road conditions are requirements for smart transport. Sensors in parking areas can also be used for smart parking
[32]	Smart Industry	Industry can be optimized by cumulating smart devices that capture the live status of products and mentoring workers. AI has created a boom in the industry to provide automation and intelligent decision
[33]	Smart Infrastructure	Infrastructure state like the condition of roads, buildings, grounds, and bridges requires different sensors. Sensors help in monitoring and continuous maintenance and city conditions
[34]	Smart Waste Disposal	Generating alarms after incorrect disposal of waste, checking the full bar reached the limit of dustbins leads to smart waste disposal

particularly helpful for persons of advanced age or those with impairments. Technological literacy is essential for a city to become a smart city—one that is well-connected, sustainable, and resilient—and to have information that is both available and findable. The main goal of smart cities is to provide their residents with access to intelligent services that can help them save time and make their lives easier. It is also necessary to connect people to governance for them to provide feedback to the government on how they want their city to be. This goal cannot be met without the use of technology.

IV. TOPIC MODELING

Data mining is a new area developed to extract information from unstructured data, and topic modeling is a powerful method in text mining developed in Natural Language Processing (NLP) to investigate the connection between the data and the documents being gathered [34]. This technique is used by a variety of researchers in their respective fields, such as medical research [35], semantic analysis [36], engineering [37], and so on, to bring the connection between the materials and the themes to a close. When it comes to topic modeling, techniques like Latent Dirichlet Allocation (LDA), Non-Negative Matrix Factorization (NMF), Latent Semantic Analysis (LSA), and Parallel Latent Dirichlet Allocation (PLDA) are frequently used by researchers. LDA is the most used among these techniques. It is pretty like the dimensionality reduction method used for numerical data. In topic modeling, a Bag of Words (BoW) is generated from a dictionary of words, and the process of extracting the essential features from this BoW is known as topic modeling. In NLP, the words included inside the corpus are regarded as a characteristic that has considerable significance.

Each word is treated as a feature by NLP, used to train the model. Instead of analyzing the whole data set, we can use this approach to identify the relevant information quickly. The LDA method is used to establish a connection between the documents in the gathered dataset, and the findings are displayed both statistically and visually because of this. To develop LDA, Variational Expectation Maximization (VEM) algorithm [35] is used to estimate the similarities from the corpus. This method lacked semantics in the phrase,

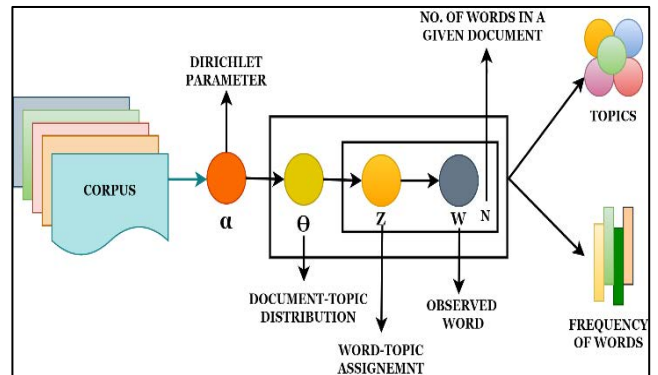


FIGURE 3. Latent Dirichlet Analysis (LDA) model.

thus usually, just the first few words from the BoW are used. According to the concept of probabilistic distribution, each document in the corpus represents the probabilistic distribution of topics, and each extracted topic represents the probabilistic distribution of words. Each document in the corpus uses LDA to represent the probabilistic distribution of topics. In the end, a clear picture of the link between the topics was achieved. LDA is applied to retrieve important information or analysis from unstructured data. For example, research on social media makes users understandable regarding reaction and conversation among the people connected in social media to conclude the patterns [35]. It is implemented in various fields, some recent research is Internet review analysis [36], Agriculture [37], Software Engineering [38], Environment [39], Deep learning [40], Medical [41], and many more. In this study, LDA is deployed to abstraction trends and emerging topics of IoT in smart cities represented in Figure 3. This study extracts research trends and patterns of IoT in smart cities by implementing the LDA technique to the dataset of 8320 articles. Dataset is a collection of published data from 2010 to 2022. This study has included the systematic gathering and display of data with the aid of the research question as a central component. Based on the titles and abstracts of published papers, two main research topics, five research areas, and ten current trends have been identified from the gathered corpus. This systematic review is influenced by various studies and considers the guidelines given

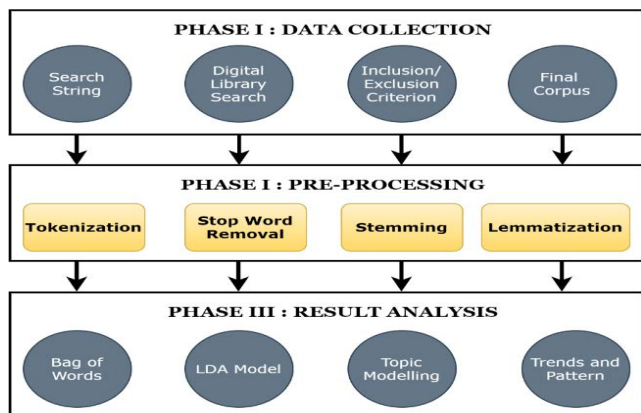


FIGURE 4. Proposed methodology in literature.

by Kitchenham and Charters [42]. The following research questions will be addressed in this research, which will result in the following research findings:

- 1) What are the extensively explored research areas in smart city technology?
- 2) How has IoT integrated with other smart technologies to make the healthcare system more efficient?
- 3) Which research areas demand greater attention from researchers?

V. METHODOLOGY

The researchers have included all the experiments and activities relating to the IoT in smart cities to analyze the research trends adequately represent the study strategy for research trends in the domain. The methodology followed to conduct this investigation is shown in Figure 4. In addition, researchers have also described the stepwise procedure of any activities conducted so far to anticipating.

A. DATA COLLECTION

The numerous online digital libraries, journals, and conference proceedings, all accessible to users via Google Scholar, were the primary sources of data gathering and developing the research corpus used in this study. The search terms for digital libraries have been chosen following the study questions. The research works of [43] have influenced the formulation of the research questions for this study. The search phrases identified were “IoT”, “Internet of Things”, “smart cities”, and “smart city”. In this study designed search string used to extract the information was (“IoT” or “internet of things”) and (“smart cities” or “smart city”). In this study, the authors analyzed the Scopus database, the most extensive database in research. Scopus database consists of a research article from various journals, conferences, books, etc. Some popular databases like Elsevier, springer, emerald, Inderscience, saga, Wiley, Taylor & Francis, and many more, are the biggest publishers, and their articles are included in the Scopus database. In total, there are 9429 articles collected initially from the Scopus database. In inclusion criteria, we consider the research papers published in English only.

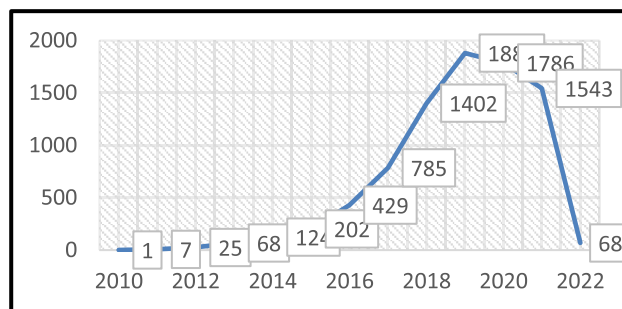


FIGURE 5. Year publication analysis.

B. DATA PROCESSING

It is the second phase that involves processing the dataset or information that has been gathered. When preprocessing information, the goal is to remove any unnecessary information included within the material. The process removes undesirable words and characters from a gathered corpus, or a corpus collected to enhance the dataset’s quality. It results in a more accurate and acceptable profile for subsequent processing.

The following are some of the fundamental processes involved in data preprocessing. The corpus has been compiled in a single excel file for author convenience. It has already been done during the inclusion-exclusion procedure; therefore, there is no need to repeat it. Following the screening and selection process, the duplicates have been removed, and the final corpus, which has been created, has been stored in an excel file for future reference. Table 3 depicts the organizational structure of the excel file. The studies considered for inclusion must revolve around the IoT in smart cities. Studies that do not have the required author name, year and abstract are deleted from the corpus. The studies published in a trade journal, editorial and short article are excluded. Total 8320 studies have been considered for the current research after applying the criteria, and year-wise analysis is shown in Figure 5. The task of document collection accompanies the process.

C. DATA PROCESSING STEPS

In the first step, tokenization is performed in which each word, letter, and punctuation mark is considered as a token, and during this phase, the emphasis is on eliminating all the punctuation marks, single characters, and other special characters such as the punctuation marks; “,”; “.”; “/”, “brackets”, and “!” In addition, any equation or formula utilized in the abstract was deleted from the document. Additionally, the numerical values were removed to get a fully functional textual token [44]. In the second step, the stop words like “the”, “if” “but”, “a”, or “an”, and so on draw no information and take a long time in processing, so it is suggested to remove from the corpus. The author used the Natural Language Toolkit (NLTK) library, which contains stop words for more than sixteen languages [45].

During the third phase of research, the process of stemming is carried out, which breaks down the word into different

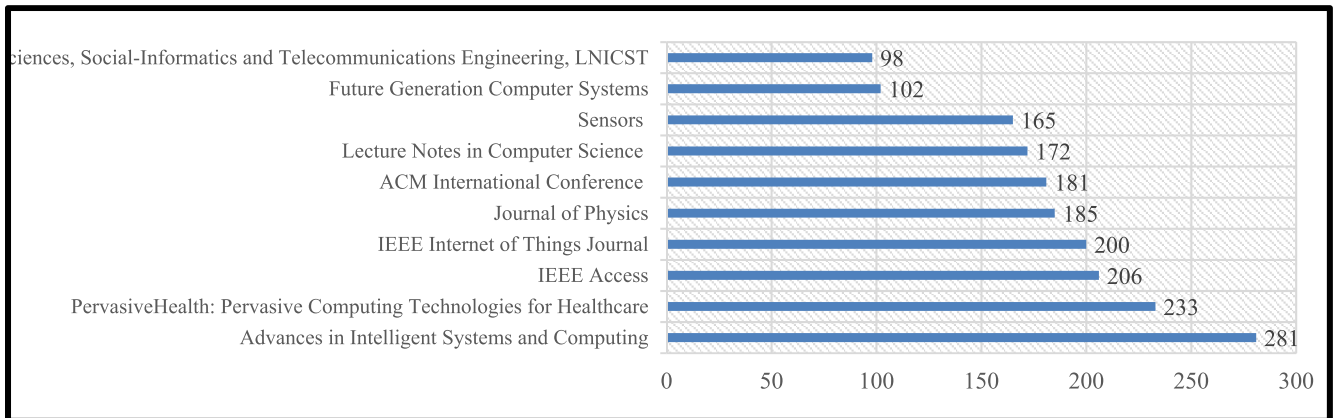


FIGURE 6. Dominating journals analysis.

pieces. They are using stemmed words, which aim to separate and extract the root or core word typically tied to English suffixes and prefixes, aids natural language understanding and processing. It eliminates all the non-significant meanings of the word and only keeps the essential part. As an example, take the root word “use”, which is formed by combining the terms “useless”, “useful”, and “uses” in the stem. Use the Snowball stemmer approach to stem words from their original forms to create a helpful corpus. The cleaned corpus is then populated with the essential keywords [46]. Finally, lemmatization is performed, which is necessary for the words that are stemmed in the previous step. This process is used to make the base words understandable, also known as lemmas [47]. The preprocessing procedures as an example is in Table 4.

D. LATENT DIRICHLET ALLOCATION (LDA)

LDA is frequently utilized in NLP. The data is sent into the LDA model after preprocessing. Before data transfer, bigrams and trigrams are removed from the corpus. Human resource management is an example of a trigram, which differs from bigrams in that it is composed of three words that are often seen together. Genism, a Python library that eliminates ambiguous phrases, helps build the LDA model. It’s possible to generate and recognize this bigram, trigram, quadgram, or even an n-gram with the help of Genism’s Phrases model [48]. This stage is included in the preprocessing process, and after it is done, the data is delivered to the LDA model for further exploration.

When applying LDA for topic modeling, issues such as the number of topics to model and the hyperparameters are essential considerations. In the absence of document distribution, the size of the Dirichlet may be determined by looking at the symbol to the right. Other words may or may not be used in conjunction with themes. However, it is believed that this parameter contains a significant number of fictitious words that are uniformly distributed over all texts. The symbol represents a Dirichlet prior over topic-word distributions, which is prior. The value for this experiment is $1/T$, where T is the intended number of topics [41]. It has been kept at 0.01 for all topic solutions to maintain consistency. The number of

iterations evaluated for finding 2, 5, and 10 topic solutions, as recommended by the researchers in the article [32], is 500 for each topic. This means that the starting values of these factors may predict the distribution of high-quality topic outcomes in a given situation. It is used to refine the BoW obtained after removing the most and least frequently occurring words from the corpus. During the research, the BoW database was cleaned up by deleting terms that appeared more than 5,000 times in the database. Figure 7 displays the top twenty most frequent terms identified in articles published at various research venues. “model” has the lowest frequency of 4246 among these 20 keywords, while “smart” is the most prevalent term in these articles. “iot,” “datum,” “internet,” “system,” and “city” are the other keywords that come under the category of “most significant keywords,” while “paper,” “service,” “time,” and “provide” fall under the category of “least significant keywords” in this list of the top 20 keywords.

This study uses Mallet, a JAVA-based NLP tool, to improve hyperparameter performance. We can utilize BoW to train a model Mallet will later use to extract key topics. There is no formal or scientific way to find the optimal number of solutions as suggested by the researchers in the research [49]. On the other hand, Cao and Arun give observational data that help the researchers to choose the optimal number of solutions [50]. The research heuristics and results [49] influenced the subject solution. The ideal number of individuals in the BOW is determined using K-mean clustering.

E. TOPIC LABELING

The LDA model is used to extract the themes, and then each subject is manually labeled using the keywords associated with it. The total number of articles in the corpus is 8320, and Table 6 lists the count of studies, critical terms of topic, top three high-loading publications, and their contribution to the subject.

VI. RESULT ANALYSIS

It was possible to get the loadings for three different topic solutions using the LDA model, as shown in Table 5.

TABLE 4. Samples of loading dataset.

Title	Year	Source title	Abstract
“Wireless Self-Powered High-Performance Integrated Nanostructured-Gas-Sensor Network for Future Smart Homes”	2021	ACS Nano	“There has been substantial research in the area of eventprocessing images within event-based systems.”
“Highly Stable Low-Cost Electrochemical Gas Sensor with an Alcohol-Tolerant N,S-Codoped Non-Precious Metal Catalyst Air Cathode”	2021	ACS Sensors	“There has been tremendous increase in solid waste generation garbage bins using dynamic and shortest route.”
“Physical layer authentication for extending battery life”	2021	Ad Hoc Networks	“There have been significant advances in the field of Internet of Things (IoT)than three base classifiers (K-NN, DBSCAN, and DT) using a standard security dataset (NSL-KDD)”
“Green internet of things using UAVs in B5G networks: A review of applications and strategies”	2021	Ad Hoc Networks	“There is a buzz around the world about building smart cities and smart homes.....challenges that will be encountered in the path of achieving the goal”
“Area and energy efficient shift and accumulator unit for object detection in IoT applications”	2022	Alexandria Engineering Journal	“This paper describes a work-in-progress programming experimentdigital online sources of data”

TABLE 5. Data processing steps.

	Steps and definitions
Sample Document	Smart City IoT has specific difficulties. Smart Cities are in trend which is helping the society for better living. People are getting various opportunities through smart city project.
After Tokenization	“Smart”, “City”, “IoT”, “has”, “certain”, “difficulties”, “Smart”, “Cities”, “are”, “in”, “trend”, “which”, “is”, “helping”, “the”, “society”, “for”, “better”, “living” “People”, “are”, “getting”, “various”, “opportunity”, “through”, “smart”, “city”, “project”
After Stop Word Removal	“Smart”, “City”, “IoT”, “certain”, “difficulties”, “Smart”, “Cities”, “trend”, “helping”, “society”, “better”, “living” “People”, “getting”, “various”, “opportunity”, “through”, “smart”, “city”, “project”
Stemming	“Smart”, “City”, “IoT”, “certa”, “difficul”, “Smart”, “Cit”, “trend”, “help”, “socie”, “better”, “liv” “People”, “gett”, “various”, “opportunit”, “through”, “smart”, “city”, “project”
Lemmatization	“Smart”, “City”, “IoT”, “certain”, “difficult”, “Smart”, “City”, “trend”, “help”, “society”, “better”, “live” “People”, “get”, “various”, “opportunity”, “through”, “smart”, “city”, “project”
Sample Document	Smart city IoT has specific difficulties. Smart cities are in trend which is helping the society for better living. People are getting various opportunities through smart city project.

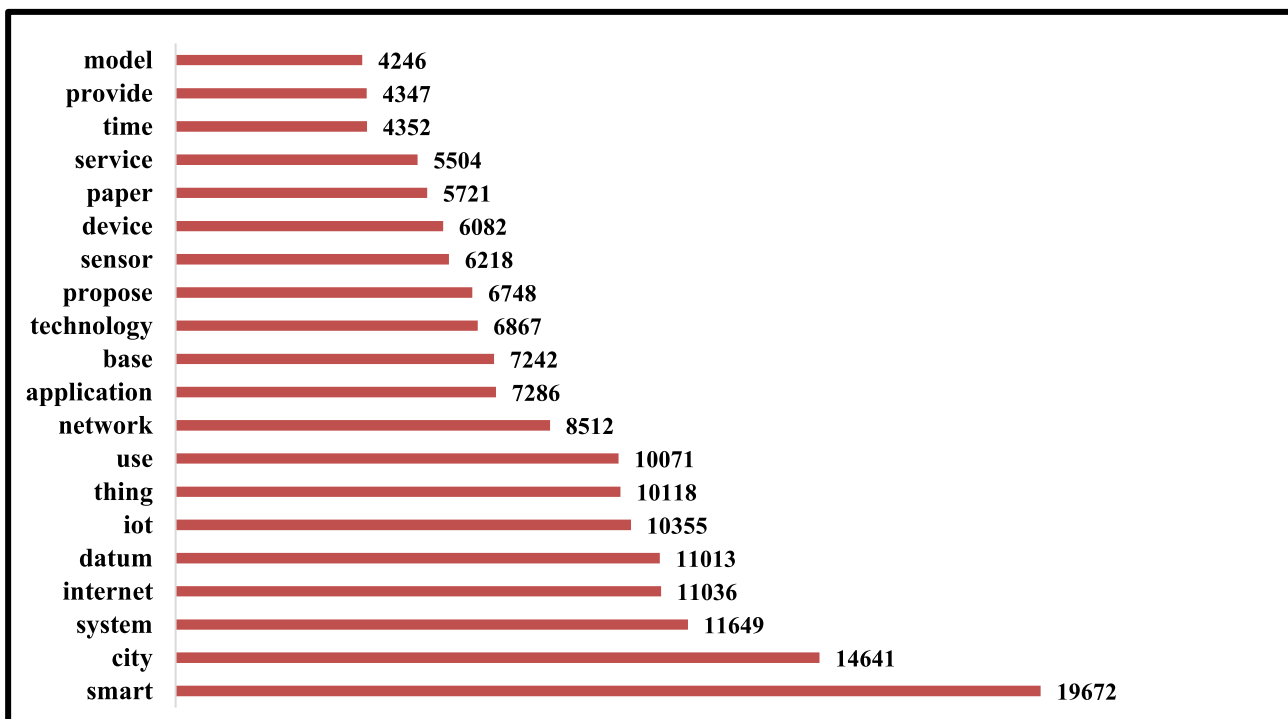


FIGURE 7. Top 20 words from corpus with frequency.

Research is selected for 2, 5, and 10 using K-means clustering and is inspired by prior work. Ideally, a coherence value

of 0.3 to 0.6 is a decent score for finding semantic similarities between the topic’s main words [101]. This study’s

TABLE 6. High loading research articles for topic solutions.

Topic ID	Count of Studies	Key Terms	Topic Label	High Loading Paper	Contribution (%)
2.1	4552	security, information, provide, challenge, management, development, model, present, environment, cloud, architecture, user, research, urban, big, solution, platform, design, infrastructure, communication	Information Security Challenges in Cloud-Based Architectures of Smart Communication	[51]	99.95
				[52]	99.89
				[53]	99.82
2.2	3768	energy, time, traffic, result, vehicle, model, power, low, real, communication, performance, wireless, node, method, parking, problem, show, cost, detection, high	Smart City Communication Architecture: Problem Detection and Solutions	[54]	99.91
				[55]	99.87
				[56]	99.82
5.1	853	security, privacy, attack, blockchain, secure, user, authentication, provide, access, communication, issue, home, information, trust, scheme, challenge, control, cloud, key, threat	Blockchain-Based Information Security, Privacy and Access Control Applications in Smart Cities	[57]	99.90
				[58]	99.85
				[59]	99.79
5.2	1386	traffic, vehicle, parking, time, management, monitor, waste, water, monitoring, provide, control, air, real, area, pollution, solution, road, information, cost, develop	Developing Cost-Effective Sensor Based Solutions for Vehicular Traffic Control and Management	[60]	99.88
				[61]	99.76
				[62]	99.74
5.3	936	model, method, time, detection, learn, result, machine, learning, real, accuracy, deep, image, show, performance, technique, high, algorithm, data, processing, video	Real Time Data and Video Processing Techniques Using Low Cost IoT Devices and Machine Learning Algorithms	[63]	99.92
				[64]	99.86
				[65]	99.81
5.4	1967	energy, power, communication, node, resource, edge, wireless, compute, low, cloud, performance, result, time, consumption, provide, computing, cost, mobile, solution, distribute	Distributed Cloud Based Computing Resource Consumption Techniques for Energy Efficient Communication In Smart Cities.	[66]	99.86
				[67]	99.84
				[68]	99.81
5.5	3178	information, development, provide, urban, research, big, management, challenge, present, model, platform, environment, design, architecture, study, infrastructure, concept, solution, make, approach	Development Of Smart Solutions: Present Research Concept and Challenges.	[69]	99.89
				[70]	99.80
				[71]	99.77
10.1	1201	cloud, compute, edge, architecture, resource, computing, time, distribute, provide, processing, fog, real, environment, platform, data, present, infrastructure, model, solution, management	Integration Of Cloud Computing Solutions into Smart City Architectures and Resource Management	[72]	99.92
				[73]	99.89
				[74]	99.88
10.2	578	low, power, wireless, communication, area, range, high, result, signal, performance, cost, radio, design, wide, show, transmission, localization, node, long, indoor	Low Power Cost Effective Transmission and Communication Designs in Smart Cities	[75]	99.85
				[76]	99.76
				[77]	99.74
10.3	462	energy, water, power, consumption, management, control, building, monitor, grid, cost, design, time, light, meter, monitoring, demand, reduce, temperature, electricity, efficiency	Designing of Smart Technology to Monitor, Control and Reduce the Electric Energy Consumption in Existing Buildings	[78]	99.80
				[79]	99.75
				[80]	99.70
10.4	696	model, detection, learn, method, machine, time, result, learning, deep, accuracy, image, feature, algorithm, neural, prediction, real, technique, show, video, classification	Feature Classification Using Image Detection, Deep Learning and Neural Network	[81]	99.91
				[82]	99.88
				[83]	99.85
10.5	771	security, privacy, attack, blockchain, secure, authentication, user, access, provide, trust, issue, scheme, communication, key, information, challenge, control, threat, environment, protocol	Security Key Management Information Access Control Schemes Using Blockchain	[84]	99.90
				[85]	99.85
				[86]	99.80
10.6	1346	development, information, model, research, big, study, management, challenge, process, design, provide, industry, concept, urban, present, develop, approach, make, analysis, platform	Design and Analysis of Information Management Models Using Industry IoT for Smart Cities	[87]	99.87
				[53]	99.82
				[88]	99.79
10.7	909	urban, citizen, quality, information, infrastructure, provide, public, solution, air, present, environment, development, pollution, life, platform, sustainable, user, area, challenge, sense	Development Of Sustainable Solutions in Present Smart City Architectures	[89]	99.93
				[90]	99.89
				[91]	99.88
10.8	688	energy, node, route, problem, result, communication, wireless, performance, resource, simulation, time, algorithm, optimization, delay, show, efficient, number, approach, consumption, model	Energy-Efficient Routing Algorithms for Better Wireless Communication Performance in Smart Cities	[92]	99.92
				[93]	99.92
				[94]	99.9
10.9	989	home, human, health, provide, user, environment, communication, object, connect, information, make, challenge, world, people, life, research, physical, present, area, machine	Smart Home and Healthcare Connected Solutions for Elderly and Physically Challenged People Using Machine Learning	[95]	99.92
				[96]	99.91
				[97]	99.91
10.10	680	vehicle, traffic, parking, waste, time, management, road, transportation, intelligent, car, problem, real, congestion, collection, garbage, solution, information, provide, develop, increase	Intelligent Waste Management Solution Development	[98]	99.91
				[99]	99.9
				[100]	99.9

coherence values are excellent, with 0.49 for a two-topic solution, 0.51 for a five-topic solution, and 0.41 for a ten-topic solution. Thus, the best option is a five-topic solution with a high coherence value.

First, let's talk about the process of labeling. The labeling of the topics has been done manually by analyzing the keywords extracted by the LDA model. Then, the author and field experts sit together to finalize the labeling of the topics to the best of their knowledge represented in Table 6.

A. RESEARCH AREAS

The two-topic solution presents an abstract view of the literature dataset and divides it into "Information Security Challenges in Cloud-Based Architectures of Smart Communication" (T2.1) and "Smart City Communication Architecture: Problem Detection and Solutions" (T2.2). These two significant labels depict the core research areas that the researchers have extensively explored. In addition, five research areas have been identified from the broader area of research, i.e., T2.1 and T2.2. The identified research areas are presented in topics (T5.1 - Blockchain-based Information Security, Privacy and Access Control Applications in Smart Cities), (T5.2 - Developing Cost-Effective Sensor-based Solutions for Vehicular Traffic Control and Management), (T5.3 - Real-time Data and Video Processing Techniques using Low-Cost IoT devices and Machine Learning Algorithms), (T5.4 - Distributed Cloud-based Computing Resource Consumption Techniques for Energy Efficient Communication in Smart Cities.), and (T5.5 - Development of Smart Solutions: Present Research Concept and Challenges).

B. RESEARCH TRENDS

In this study, we aim to provide the recent trends or provide the areas to be explored more by the future researcher. LDA provides the extension of 5 topic solutions to 10 topics. Identified current trends are labeled as (T10.1 - Integration of Cloud Computing Solutions into Smart City Architectures and Resource Management), (T10.2 - Low Power Cost Effective Transmission and Communication Designs in Smart Cities), (T10.3 - Designing of Smart Technology to Monitor, Control and Reduce the Electric Energy Consumption in Existing Buildings), (T10.4 - Feature Classification using Image Detection, Deep Learning, and Neural Network), (T10.5 - Security Key Management Information Access Control Schemes Using Blockchain), (T10.6 - Design and Analysis of Information Management Models Using Industry IoT for Smart Cities), (T10.7 - Development of Sustainable Solutions in Present Smart City Architectures), (T10.8 - Energy-Efficient Routing Algorithms for Better Wireless Communication Performance in Smart Cities), (T10.9 - Smart Home and Healthcare Connected Solutions for Elderly and Physically Challenged People using Machine Learning) and (T10.10 - Intelligent Waste Management Solution Development).

Incorporating environmental and wearable medical sensors, actuators, and contemporary communication and information technology into smart homes enables low-cost, continuous remote monitoring of geriatric health and well-being. With the introduction of smart technology, the elderly may be able to forego expensive and limited institutional care in favor of the comfort of their own homes [102]. Specially designed smart homes is the new concept these days for taking care of elderly people. When developing a "smart" home for "seniors," there are additional considerations to consider. The ability to set up and operate devices and systems becomes limited because of declining abilities, and it is likely that a family member will be required to provide remote help for the individual. This is due to the fact that the mobility, dexterity, and memory impairment of the people living in the house can vary greatly from one another [103]. The use of AI enables devices like Alexa, Google Assistant, Smart Displays and Google Nest Audio in smart home can help the elderly people giving voice commands which make it more convenient for them. Other technologies like 3D Question Answering models [104], and VizWiz Grand Challenge [105] can also be integrated in the Smarthome to help elderly people in more specified way. In a recent study, researchers have developed Internet of Things and Deep Learning enabled elderly fall detection model for smart homcare [106]. The concept enables smartphones and deep learning algorithms to detect falls in connected homes. IoT devices pre-process input video by resizing, augmenting, and min-max normalizing. The figure 8 clearly indicates the year wise performance of the topics and the whole cluster of current research trends. In the figure 8, it is also mentioned that there are 989 documents in which researchers are working on. Smart Home and Healthcare Connected Solutions for Elderly and Physically Challenged People Using Machine Learning are the areas where researchers are putting their focus mainly. The topic is contributing around 4% in the cluster of topics formulated by the researchers, this figure further shows the number of publications for each subject solution throughout the year. 2.1 and 2.2 are the generalized broad topics whereas 5.1, 5.2, 5.3, 5.4 and 5.5 are the categories under broad topics. 10.1 to 10.10 are the specified fields where researchers are putting their focus these days.

VII. RESEARCH QUESTIONS AND DISCUSSIONS

This study summarizes research trends on IoT in smart cities from 8320 publications identified by the researchers. The filtered corpus includes bibliographic databases from 2010 to 2022. We tried to compile all research articles published in Scopus between 2010 and 2022. LDA was utilized to find latent research patterns and trends in a corpus for a subject solution. This portion of the analysis of the results has addressed each specified research topic. Consequently, the literature dataset has been utilized to answer all three research questions, identifying new research options.

Research Question 1: What are the extensively explored research areas in smart city technology?

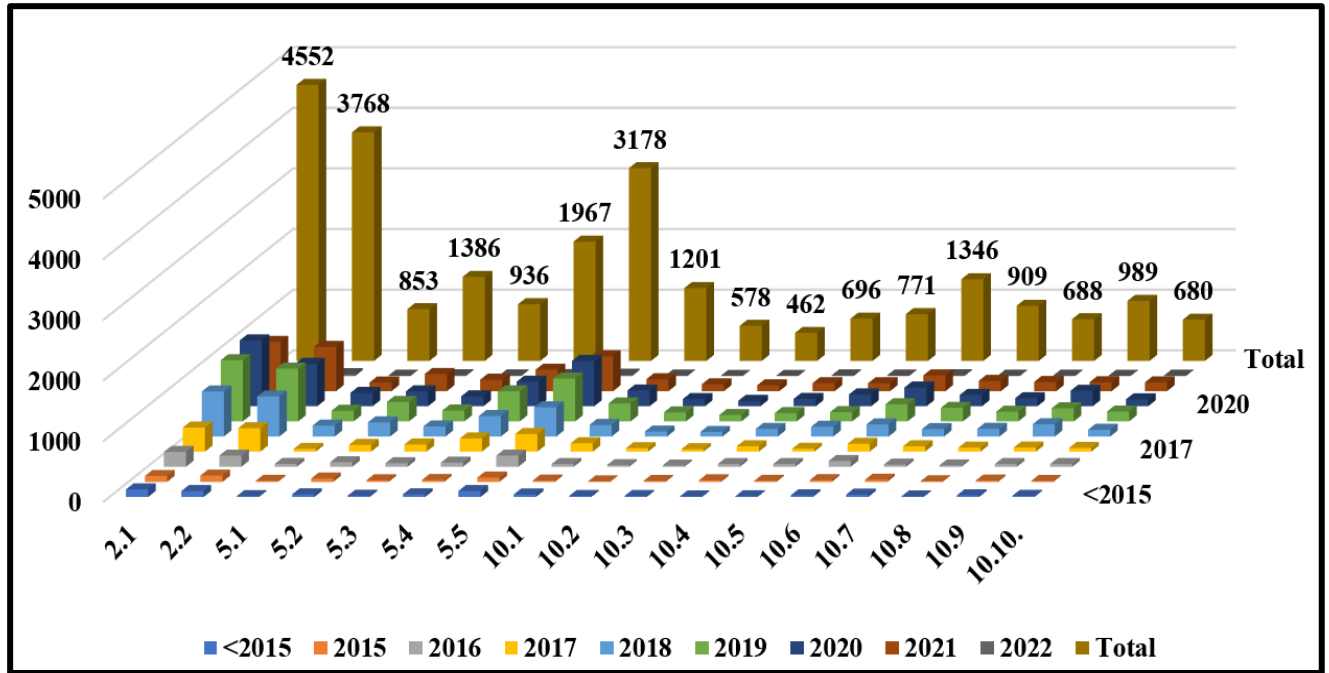


FIGURE 8. Research topics and their year wise contribution.

As time progresses, an increasing number of scientists are concentrating their efforts on making cities smarter. When it comes to smart cities, there are many devices, which is why a framework for the IoT has been established to manage them all [107]. Researchers in smart cities have concentrated their efforts on three key areas: security, connectivity, and decentralization [108]. If this tendency continues, the researcher will continue to do a lot of studies. As smart and self-driving vehicles become more common, researchers are increasingly interested in the Internet of Vehicles (IoV), rising in popularity as a component of smart cities. A wide variety of sensors and robust computing and communication capabilities are becoming more widespread in cars on the road. This sector is seeing an increase in interest in developing low-cost sensor-based traffic control and management systems. Many scientists have worked on smart solutions for modern cities for decades [109]. By combining these innovative approaches, a city was transformed into a smart city. To improve air quality, data-driven traffic management, sensor-based waste management, digitalization of city heating, wastewater treatment and energy production, and resource recovery all in one, outdoor lighting and the smart city living lab are just a few examples of the many smart solutions available. Users' access control of resources in smart cities is managed and controlled. Furthermore, the large amount of data produced in smart cities and its storage in the cloud has created a new field of study for ensuring the security and privacy of the data gathered.

As a result, blockchain-based authentication approaches are recommended to offer cyber users application security [110]. Because smart city devices have limited resources,

another area for development is power and energy-efficient routing system. This reduced use of resources will extend the life of the gadgets that are now in use. Routing Protocol for Low Power and Lossy Network (RPL) is a way of routing that may be used [111]. Research in the domain of Quality of Service (QoS) is projected to play an essential role in developing smart cities QoS. Quicker data gathering, better storage, frequent data access, rapid decision-making, and spontaneous action are part of QoS's plan to improve the smart city scenario's efficiency. Another area of interest might be extensive data management in smart cities employing various technologies [112]. Management and analysis of a large volume of data for efficient operation can be a wide area of research. To develop a functional smart city, several critical technologies come together. Smart cities are an advanced answer for today's cities, but the notion of a smart city might be used to new living environments, such as floating cities, in the future. As sea levels rise and land becomes scarcer, the idea of a floating metropolis has evolved as a creative means of providing new habitations for humankind.

Research Question 2: How has IoT integrated with other smart technologies to make the healthcare system more efficient?

When it comes to developing smart cities, the IoT framework is a development framework in which objects or things are given a Unique identification Number (UID) and the ability to transfer data over an interconnected network without the need for human interaction (i.e., between humans and computers). Since wireless technology, Microelectromechanical Systems (MEMS), and the Internet came together, the IoT has taken on a new life. RFID or sensors may also gather

data in the IoT [113]. Additionally, drones monitor pollution, accidents, and fires in a smart city [114]. Technology like AI and robots play a significant role in improving the visibility of smart city infrastructure.

When sensors or drones gather data, such data is kept in the cloud as a supporting platform. Cloud-based services and big data from the IoT may be used for various purposes. Cloud computing is used to execute the actual processing of enormous data. Cloud computing users are unaware of the exact location of their accessing data. The data obtained may be utilized to make deep learning or reinforcement learning decisions. Other location-based services such as location estimation are often used with this technology [115]. All the technologies that have been mentioned will contribute to the optimal framing and operation of a smart city. The new value may be derived from existing infrastructure via smart city applications. New income sources and operational efficiency help the government save money due to these changes [116]. To increase the quality of life and promote economic development, smart cities use their network of linked IoT devices and other technology. The IoT is used in conjunction with a range of software, user interfaces, and communication networks in smart cities to provide the public with linked solutions [117]. To achieve smart city success, the following four stages must be followed:

- 1) Data Collection: A citywide network of intelligent sensors collects information in real-time.
- 2) Data Analysis: Smart sensors gather data, then analyze it to derive new insights.
- 3) Data Communication: The findings of the analytical phase are transmitted to decision-makers via robust communication networks.
- 4) Decisions and Counter Actions: Cities utilize data to build solutions, optimize operations and asset management, and enhance the quality of life for their inhabitants, all while reducing costs and increasing efficiency [118].

Other technologies associated with smart cities are AI, Cryptography, and Blockchain Technologies. Smart City technologies need a massive amount of data processing. In some cases, it is called 'Big Data'; this data is generally of high volume, great high-velocity variety. It is important to note that big data and AI are closely intertwined.

Research Question 3: Which research areas demand greater attention from researchers?

The smart city goal emphasizes improving quality of life via networked sensors, gadgets, and people. Efficiencies in security, waste management, and transportation may be gained by utilizing data, but the data must be freely accessible and used by all stakeholders, both private and public [119]. The cloud service will help eliminate intergovernmental storage, which prevents departments from communicating and understanding each other's data priorities, a significant barrier to smart city implementation. Most of the IoT-based architectures use Cloud platforms for easy access to data. This integration area needs to be explored more on efficient

connectivity, accurate data analysis, security, reliability, and maintenance [120]. One more area of smart cities where researchers need to focus is Low Power Cost-Effective Transmission and Communication Designs. Efficiency in energy usage is a significant component of smart cities. Adopting the IoT paradigm, which allows cities to effectively govern their energy consumption, can provide considerable benefits [121]. For wireless networks, researchers are interested in energy efficiency since it will help them cope with the steady development in energy-demanding applications in situations where there are limited energy resources. There is also a need for more definitive studies in smart technology design to monitor, control, and reduce electric energy use in existing buildings. Modern building energy-saving technologies such as information transmission, computer networks, automation control, and so on may help people save energy. Buildings with energy management systems are a sequence of technique measures. Integrating ML technologies into smart cities will make the architecture more oriented towards the automation process. Pattern recognition is the area that can be included in this domain. Neural networks are used to recognize patterns. The term comes from the fact that the human brain-inspired them. They are divided into three sections: input, covert, and visible. A three-tiered approach is required to draw conclusions or make predictions based on input data. Each layer of the network is made up of artificial neurons. Technology that is both highly scalable and networked is required for multi-distributed operations in smart cities. Edge AI and deep learning are two examples of recent developments in computer vision that combine AI vision with the IoT. These new technologies make it possible for real-world computer vision systems to handle the vast amount of complex visual data while also allowing for quick processing, robustness via decentralization, and scalability. Because of the large amount of IoT data generated, smart cities are posing new issues for conventional data management, including researchers interested in IoT-based data access control systems that use Attribute-Based Encryption (ABE) and blockchain technology other related technologies [122].

The need for resources and efficient service delivery will grow with urbanization. There is a possibility that this may be accomplished with the help of the IoT. The design of an IoT system based on similar smart systems currently uses surveys. It is promising that researchers are turning to this area in the context of smart cities [123]. According to an ancient proverb, "An older person at home is like a living gold treasure," and it is the responsibility of those who reside there to care for the elderly. People used to be unable to do this because of geographic restrictions, but now they can with the help of smart systems. Governments in a few countries have undertaken the construction of old-age residences. It is critical to develop healthcare solutions that are economical, discreet, and simple to use to address the growing demand for elderly healthcare services [124]. Using smart homes, which include environmental and wearable medical sensors, actuators, and contemporary communication and information

technologies, the continuous and remote monitoring of the elderly's health and well-being may be made feasible at a low cost. Because of the smart homes, older people may be able to stay at home rather than inexpensive and confined healthcare facilities in the future.

VIII. CONCLUSION

Components such as privacy and security, service discovery, edge computing, dynamic resource provisioning, and IoT setup and administration must be mature to realize a smart city. It is researched thoroughly explored the research trends in smart cities such as Information Security, Smart Communication Architecture, Blockchain-Based Information Security, Privacy and Access Control Applications, Designing Smart Technology to Monitor, Control, and Reduce Energy Consumption, and many more. The study demonstrates that smart city research is a convergent topic. This LDA-based study shows that smart cities are a rapidly increasing scientific issue, with most of the information created being technical. Researchers have focused on three major areas: Security, Connectivity, and Decentralization in smart cities. The study has also shown that other technologies connected with smart cities include AI, Cryptography, and Blockchain. In some circumstances, this data is referred to as 'Big Data' which refers to the volume, velocity, and diversity of the information that must be processed by smart city technology. Big data and AI are intimately linked, and it is crucial to keep this in mind. Based on the analysis of various literature of smart cities, urbanization will raise demand for resources and services in the future; this may be achievable with the IoT. It is feasible to build an IoT system using existing smart systems.

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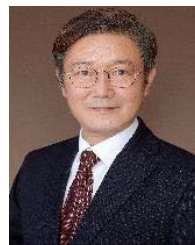
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