Bibliometric Mapping of Trends, Applications and Challenges of Artificial Intelligence in Smart Cities

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Abstract

INTRODUCTION: The continued growth of urbanization presents new challenges. This, in turn, will lead to pressure for sustainable environment initiatives, with demands for more and better infrastructure in the diminishing space available and improved quality of life for city dwellers at a more affordable cost. Smart Cities are part of the solution to the growing challenges of urbanization. The adoption of new technologies like artificial intelligence (AI) is transforming cities, making them smarter, faster, and predicting opportunities for improvement.
OBJECTIVES: This study is conducting a detailed bibliometric survey to investigate the applications and trends of Artificial Intelligence research for different areas of smart cities and emphasizing the potential effects and challenges of AI adaptation in smart cities over the past 30.5 years.
METHODS: For this study, the Scopus database was used to collect a total of 1925 documents published between 1991-2021 (July). The bibliometric analysis includes document types, subject categorization, document growth, as well as top contributing sources, countries, authors, and funding sponsors. It also analyses keywords, abstracts, titles, and characteristics of most cited documents.
RESULTS: The analyzed findings of this research study reflect not only the significance of AI technology for various applications within numerous sectors in the smart city but also major obstacles in AI research for various sectors of smart cities.
CONCLUSION: The research demonstrates that AI has the ability to construct today's and tomorrow's smart cities, but that each region's potentials, conditions, and circumstances must be addressed in order to achieve a smooth internet city development.

1. Introduction

The urban population is anticipated to strike between 66% to 70% by 2050 globally as stated in the reports [1, 2] due to rapid urbanization. The immense growth and surge in urbanization will pose a significant challenge in numerous facets of one's lifestyle viz the quality of services in medical, educational, environmental, transportation, and security sectors [3]. To deal with the meteoric growth in urbanization expeditiously and to remain sustainable, a novel approach is indispensable.

The concept of Smart City was initiated in 1993 when Singapore officially called "The Republic of Singapore" was presented as an "intelligent city" [4]. Thus, various countries around the world, including

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Japan, the European Union, the United States, and others, have realized that the smart city project concept effectively addresses the viable looming challenges as it circumscribes the whole human ecosystem [5]. "Smart Cities", also known as "Internet Cities", refers to a city that uses digital and information technologies to solve some of the most complex urban problems while incorporating elements of smart systems in livability, sustainability, and inclusively [6]. Smart cities aimed to provide a lifestyle gleaned from unprecedented crucial technological developments such as "Artificial Intelligence (AI)" systems, "Machine Learning (ML)", "Deep Learning (DL)", the "Internet of Things (IoT) ", and "big data", to enhance available resource's usability, minimizing energy consumption and wastage, creating an environment that enhances creation and innovation.

The field of computer science that deals with perception, reasoning, interacting, learning, and intelligent retrieval is known as artificial intelligence (AI) and the term was coined at a conference held at Dartmouth College in July 1956 [7]. Fundamentally, its essence is to strive to imitate human consciousness information processes using machines or systems, predominantly by improving machine intelligence and thus designing Intelligent Agents [8]. A machine is said to be intelligent if it can gather information from the environment and draw conclusions. Artificial intelligence (AI) is widely used in numerous sectors such as security, energy and mobility management, food systems, smart cities, education, and health care, etc. [9]. The most promising application of AI is the Smart City and its most significant advancements have revolutionized smart solutions. Plenty of cities equipped with AI-driven services and processes are intending to become "Smart Cities" such as AI-based transport management systems, intelligent security cameras, autonomous flying objects for Ariel View Monitoring, smart parking, etc. To fulfil the requirements of such Internet cities the efficient and effective utilization of AI technology is imperative to adequately administer smooth and efficient operations of smart cities.

1.1. Objectives

This research focuses to examine documents published over the last 30.5 years for detailed bibliometric survey for growing trends in AI research and its applications in many sectors for smart cities. The following are the authors' significant contributions to this study:

- Survey of research trends of AI for various sectors in smart cities.

- AI applications for medical, education, surveillance, transport, e-governance, etc.

- Analysis based on contributing funding agencies and countries for AI research for smart cities.

- Analysis of research trends based on abstract, titles, and keywords analysis.

- Literature survey of top 25 most cited documents for Artificial Intelligence.

- Analysis of top journals, authors, institutes contributing research in AI for smart cities.

- Analysis of major obstacles for AI research for various sectors of smart cities.

1.2. Research Questions

This work is the result of a collaborative effort to contribute to the literature on the emerging trends and uses of artificial intelligence for smart cities over the last 30.5 years. With a thorough bibliometric analysis of articles published on AI by diverse authors, journals, countries, and funding organisations, this work adds to the current research. Abstract, titles, keywords, and 25 most cited published document have also been analyzed to enhance publication patterns. This research work is focused on the following three questions of research:

RQ1: What are the possible applications of artificial intelligence for smart cities?

RQ2: What are the trends and directions of AI research for smart cities?

RQ3: What are the major obstacles to AI adoption in smart cities?

The rest of the study is organised in such a manner that the data collection and analysis methodology is described in the next section. The applications of AI for various fields such as mobility, education, health, surveillance, water management, waste management, management of energy etc. in smart cities are included in the third section. The followed section is discussing the analyzed results for emerging trends in this field and the challenges for researchers adopting AI technology for the establishment of smart cities are described in Section 5. The last section is discusses the study's findings and limits, as well as future research prospects.

2. Methodology for Data Analysis

The data for this work has been gathered from the Scopus database as it's the biggest peer-reviewed database of conference proceedings, books and scientific journals. A total of 1925 published documents are surveyed from the last 30.5 years i.e. from 1991 to July 2021. The graphical view of complete methodology is presented in Figure 1. The research study includes published articles' types, count of publications, subject-based categorization, top-cited documents, analysis of top authors,
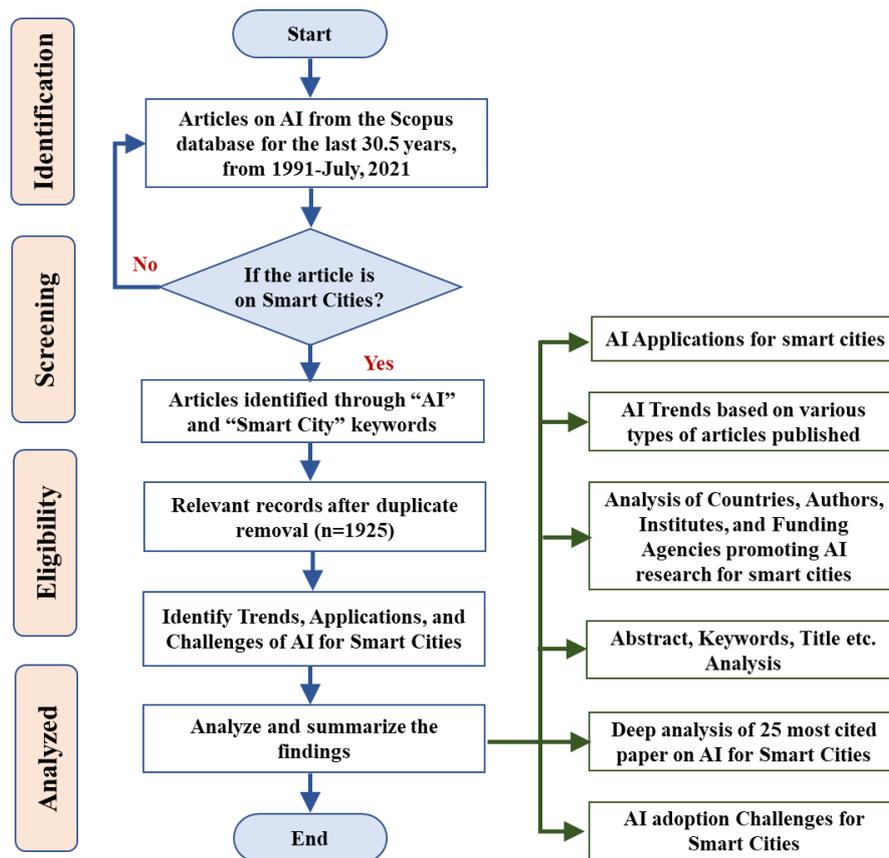
Figure 1. Methodology used for Data Analysis

sources, affiliations, title words, keywords, and abstract words. For better understanding through visualization word clouds of the top 100 frequently used words from title, keywords, and abstract have also been plotted based upon the words' frequency. "Annual Growth Rate (AGR)" and "Compounded Annual Growth Rate (CAGR)" of documents published on artificial intelligence for smart cities were also evaluated. In addition, a brief of applications and challenges for AI in different areas of smart cities are also presented.

3. Applications of AI for Smart Cities

RQ1: What are the possible applications of artificial intelligence for smart cities?

To different individuals, the word "smart city" has varied connotations. Its significance varies from location to location and nation to nation, the readiness to transform and improve, and the citizens' prospects. In comparison to established countries such as Russia, China, and the United States, a smart city in any other part of world would be unique. Every locality has its unique set of requirements, which are determined by the topographical location and routine activities of its residents. A smart city can be defined as the culmination of all of a country's smart city engineers' and developers' expectations. This fantasy has a solid organization and applications that will best fulfil the desires of its people. In smart cities, a variety of services [10], can be given, some of which are shown in Figure 2 and listed below as.

3.1. Management of Energy

In order to control electricity supply, smart cities require a smart grid infrastructure. It must contain intelligent measurement mechanism to measure the usage of resources such as electricity, water, fuel and cooking gas etc. Smart street lighting can be included to maximize resource efficiency and eliminate waste. Data collection for usage of resources must be done with care, and the process should be governed by a central authority [11]. This strategy should promote more environment friendly projects in the construction of green buildings and residences [12] [13]. A smart city could also contain a system that is in charge of properly managing renewable resources.
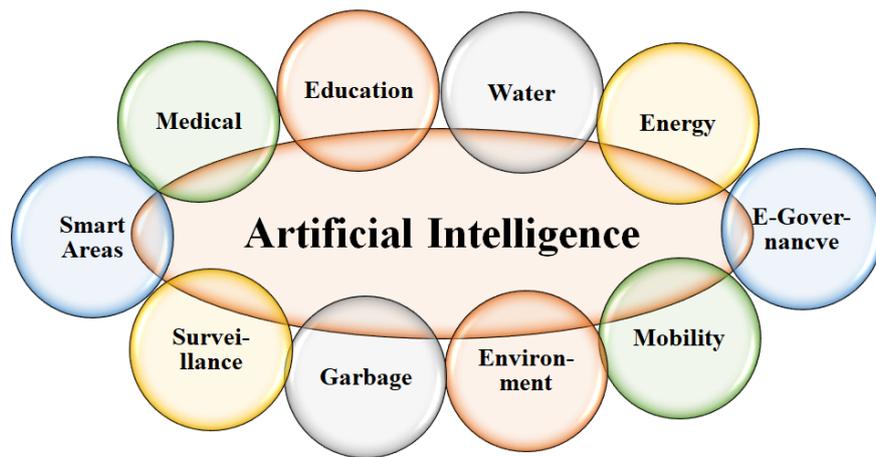
Figure 2. Applications of AI for Smart Cities

3.2. Mobility in the Metropolitan Area

A good traffic management system is now a prerequisite for cities. Vehicles in smart city should be smart not in terms fuel consumption but also in parking and mobility. Public and personal vehicle of citizens must be include in the smart city scenario [14]. Planners of smart city must consider long term plans for conserving nonrenewable resources in the city while planning roads and pathways in the city.

3.3. Citizen services and e–governance

A smart city's backbone is e-governance. Officials should handle municipal services intelligently so that citizens have least requirement to take appointment in municipal offices to pay bills or file grievances on a daily basis. Smart citizen service facilitation, integrated operations in different agencies, data analysis, and decision services are all vital components in a smart city's e-governance system [15].

3.4. Management of Water

Water is necessary for all living things to survive. It should be used with caution, as there is no life on Earth without water. Smart meters should be implemented in homes, workplaces, and industries to better monitor their usage and waste. The administration of water supplies should be done digitally. To reduce waste, an auto-detected leakage detection and prevention system should be in place [16]. Water quality should be monitored and managed accordingly.

3.5. Management of Waste

Container and waste bin data should be monitored in real time. For example, if bins are overfull, a message should be sent to the appropriate team so that an empty bin can be substituted. Waste classification, assortment, and dumping should all be scheduled using an intelligent scheduling system [17]. An intelligent waste management system can improve the air and water quality of a city.

3.6. Smart Areas

In a smart city, spaces such as the supermarket supply chain must be handled digitally to ensure that client requests are met in a timely manner. Intelligent automation is required in industrial areas [18]. Such enterprises may include urban heating and cooling systems. Micro substructure, such as sensor networks and smart appliances, can assist such sectors and give better provision for developing smart plans.

3.7. Smart Environment

Buildings that are both green and efficient are essential components of smart surroundings. Aside from creating smart constructions, it is important to ensure that nonrenewable resources are not misused. Data hubs and servers having the capability to manage the data for supporting various applications must have environment friendly behavior [19]. A smart pollution control system with the ability to monitor air toxicity must be implemented. A network of smart meteorological stations could be an important part of the smart environment, enabling the use of weather forecasting data in a range of municipal applications. Smart forest fire monitoring and preclusion, must be a part of smart surrounding so that wildlife can be preserved.

3.8. Smart Surveillance and Communication

Wireless connectivity and city-wide Wi-Fi facility can support a variety of applications. Surveillance gadgets

and knowledge center analytics should be utilized wisely in order to reduce crime [20]. An intelligent system must monitor smart home security systems and traffic systems so that police can respond quickly.

3.9. Healthcare

Healthcare services can be considerably improved through smart hospitals, improved clinical workflow, and telemedicine. Various applications built expressly for smart healthcare systems can improve patient interaction [21]. Healthcare centers might include proficient smart card readers for ensuring security of personal health related data of citizens, an advanced information system and mobile healthcare [22].

3.10. Education System

During the pandemic, smart teaching and learning environment were critical in keeping students and researchers educated. Various online learning platforms have made a large number of courses available to help people improve their skills [23]. Skill development and upgraded programs conducted online have played an important role in skill up-gradation of employees. When an educator and a student are unable to interact face to face, Smart teaching-learning systems and simulation laboratories ensure that students do not lack in practical knowledge.

4. Results and Discussions

RQ2: What are the trends and directions of AI research for smart cities?

4.1. Documents' types on AI for smart cities

Based on the Scopus database, a total of 1925 documents have been published during the last 30.5 years i.e. from the year 1991 to July 2021 on applications of artificial intelligence for smart cities as depicted in the Figure 3. Among these published articles, a maximum number of 1213 (63%) documents have been published only in conferences. The remaining 25.35% of documents have been contributed as articles. Book chapters are next in the queue with 4.41% of publications. Conference-based review and other review documents acquire 3.32% and 2.85% of total publications respectively. Last in the list are editorials, books, and short surveys with a minimum percentage of documents published as 0.57%, 0.41% and 0.05% respectively.

4.2. Domain based categorization of published documents on AI for smart cities

The documents published on artificial intelligence for smart/Internet cities during the last 30.5 years have
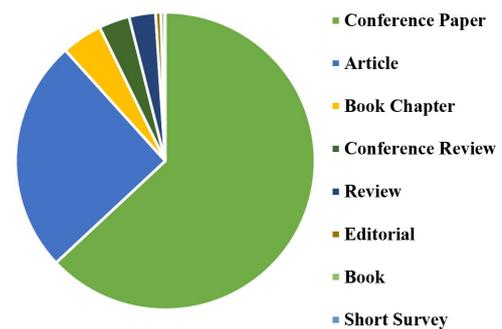
Figure 3. Documents' types on AI for smart cities

been categorized into 22 domains as listed in Table 1. Table 1 is listing the domain category names along with the corresponding number of publications. The table has not included 2 documents published under an undefined subject category. Here, one document might belong to multiple domains. The study reveals that AI has significantly influenced various domains of smart cities such as computer science, social sciences, engineering industry, mathematics, energy, environmental sciences, decision sciences, materials science, business management, the accounting industry, medical professionals, earth sciences, planetary sciences, chemical industries, art, humanities, biochemistry, genetics biology, molecular biology, economics, and Finance.

Thus, AI for smart cities has maximum applications for the engineering industries. Next on the list is the education domain with documents published for mathematics, social, energy, and other studies. The accounting and Business management industry is also greatly influenced by the applications of AI with a total of 60 publications. Lastly, medical, health, and nursing professionals domains are also benefited from the AI in smart cities.

4.3. Documents' publication swing on AI for smart cities

Figure 4 depicts the publication trends for the applications of AI for smart cities over the last 30.5 years, i.e. from 1991 to July 2021. Other evaluated factors like "Annual Growth Rate (AGR)" and "Compounded Annual Growth Rate (CAGR)" for the research publications trends of AI for smart cities over the last 30.5 years are listed in Table 2. There was only one publication during the initial year of AI i.e. 1991. Then there were no research publications for the next eight years. After that, only four research articles were published in the year 2000. For the following year, the number of publications was reduced by 50% with a negative AGR of -50. But during the next year (2002) the research publications were increased with an AGR of 250. Later, a downfall in the publications can be noticed

Table 1. Domain based categories of documents.

Domain	ND	Domain	ND
"Computer Science"	1499	"Earth and Planetary Sciences"	48
"Engineering"	788	"Chemistry"	46
"Mathematics"	352	"Biochemistry, Genetics and Molecular Biology"	45
"Social Sciences"	292	"Chemical Engineering"	22
"Decision Sciences"	227	"Arts and Humanities"	12
"Energy"	204	"Econometrics, Economics, and Finance"	9
"Physics and Astronomy"	145	"Agricultural and Biological Sciences"	8
"Environmental Science"	124	"Multidisciplinary"	4
"Materials Science"	86	"Psychology"	4
"Business Management and Accounting"	60	"Health Professions"	3
"Medicine"	52	"Nursing"	3
ND: Number of documents			

for the next eight years. Even there were no research publications for the years 2003, 2005, 2007, and 2008. But from the year 2011, the publications trends for AI in smart cities started growing gradually, as shown in the graph of Figure 4. A downfall of publications in the graph for the last year i.e. 2021 is just because of data collected till July 2021.
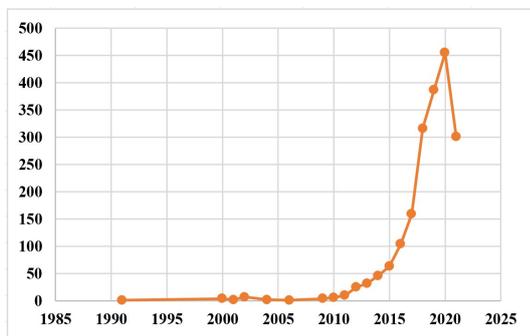
Figure 4. Publication swing on AI for smart cities

The average publications' count, AGR, and CAGR for the considered years are calculated as 63.11, 13.05, and -30.53, respectively. Thus, it is by and large clear from the trends that applications of AI in smart cities are drastically increasing day by day.

4.4. Top 20 Countries contributing documents on AI for smart cities

The analyzed result has a total of 25 countries that have contributed research publications on applications of AI for smart cities during the last 30.5 years based on the Scopus database. Among them, the top 20 filtered countries are listed in Table 3. Based on the continents, Asian countries have contributed the most in research in artificial intelligence for smart cities

with 756 published documents. In the Asia continent, China (East Asia) is on top with 377 published research articles. Next on the list is India (South Asia) with a count of 203 published documents. Other countries from the Asia continent are Saudi Arabia, Japan, Turkey, and United Arab Emirates with respective 59, 48, 36, and 33 published documents. Europe is the second continent leading research in this field with a total of 618 published articles. Countries belonging to the European continent are the United Kingdom (Northwestern Europe) having 138 published documents in this field; Italy (Southern Europe) with 120 articles, Spain with 117 published articles; Germany (Western Europe) with 72; France (Western Europe) with 55; Russian Federation with 42; Greece with 41; and Portugal with 33 number of published articles in this field. The next continent on the list is North America having a count of 260 publications from the United States (206) and Canada (54) in the field of AI in smart cities. South Korea with 76 and Morocco with 33 published articles belonged to the Africa continent resulting in a total of 109 research publications. Last on the list are Australia and Brazil (South America) having 65 and 39 research publications in this field respectively.

4.5. Top 20 Funding agencies contributing research on AI for smart cities

Funding agencies are the essential support to promote many types of research practices and to boost the researchers' spirit. There are around 161 agencies worldwide that have sponsored research in AI for smart cities during the last 30.5 years. For analysis, a list of the top 20 such agencies is filtered out and shown in Table 4 based on the number of provided research grants. From the results, it can be absorbed that China has sponsored a maximum of

Table 2. Year wise documents' classification on AI for smart cities

Year	Publications	Annual Growth Rate (AGR)	Compound Annual Growth Rate (CAGR)
1991	1	-	-
1992	0	-100.00	-100.00
1993	0	-	-100.00
1994	0	-	-100.00
1995	0	-	-100.00
1996	0	-	-100.00
1997	0	-	-100.00
1998	0	-	-100.00
1999	0	-	-100.00
2000	4	-	14.87
2001	2	-50.00	6.50
2002	7	250.00	17.60
2003	0	-100.00	-100.00
2004	2	-	5.08
2005	0	-100.00	-100.00
2006	1	-	0.00
2007	0	-100.00	-100.00
2008	0	-	-100.00
2009	4	-	7.57
2010	6	50.00	9.37
2011	10	66.67	11.59
2012	25	150.00	15.76
2013	32	28.00	16.26
2014	46	43.75	17.30
2015	63	36.96	18.02
2016	104	65.08	19.56
2017	159	52.88	20.65
2018	316	98.74	22.82
2019	387	22.47	22.81
2020	455	17.57	22.63
2021	301	-33.85	20.21

Table 3. Top 20 Countries contributing documents on AI for smart cities

COUNTRY/TERRITORY	Continent	NoP
China	East Asia	377
United States	North America	206
India	South Asia	203
United Kingdom	North-western Europe	138
Italy	Southern Europe	120
Spain	Europe	117
South Korea	Africa	76
Germany	Western Europe	72
Australia	Australia	65
Saudi Arabia	Asia	59
France	Western Europe	55
Canada	North America	54
Japan	East Asia	48
Russian Federation	Europe	42
Greece	Europe	41
Brazil	South America	39
Turkey	Asia	36
United Arab Emirates	Asia	33
Portugal	Europe	33
Morocco	Africa	33
NoP: Number of Publications		

217 research projects. The "National Natural Science Foundation of China" (108), "Ministry of Education of the People's Republic of China" (26), "Ministry of Science and Technology of the People's Republic of China" (22), "Fundamental Research Funds for the Central Universities" (19), "National Basic Research Program of China" (16), "Ministry of Finance" (14), and "National Key Research and Development Program" of China (12) are the agencies belonged to China those have sponsored research in this filed. The next ranking is of agencies belonging to the European continent with 167 sponsored grants as "European Commission" (83), "European Regional Development Fund" (38), "Horizon 2020 Framework Programme", "European Commission" (32), and "Ministerio de Economía y Competitividad" of Spain (14). From the remaining list, the institutes belonging to the North American continent are having the next highest 51 sponsored research projects in the field of AI for smart cities. The institutes contributing from the North American continent are the "National Science Foundation of United States" (31), "Natural Sciences and Engineering Research Council of Canada" (11), and "Government of Canada" (9). The Asia continent has contributed equally to North America with the same number of 51 research projects during the last 30.5 years in this field. "Ministry of Science", "ICT and Future Planning of South Korea" (15), "Deanship of Scientific Research", King Saud University (14), "Ministry of Science and ICT" of South Korea (13), and "King Saud University" of Saudi Arabia (9) belonged to the Asian continent. The "National Research Foundation" of Korea belonged to the African continent has sponsored 29 research projects. The last in the list is "Ministério da Ciência, Tecnologia e Inovação" of Brazil belonged to South America continent with 9 research grants.

4.6. Top 20 Institutes' contributing documents on AI for smart cities

The above Table 5 shows the top 20 institutions that have researched and worked with the implementation of artificial intelligence in smart cities. The descending order listing of table 5 is based on the number of

Table 4. Top 20 funding agencies contributing research on AI in smart cities

Funding Sponsor	NoP
National Natural Science Foundation of China	108
European Commission	83
European Regional Development Fund	38
Horizon 2020 Framework Programme, European Commission	32
National Science Foundation, United States, North America	31
National Research Foundation of Korea, Africa	29
Ministry of Education of the People's Republic of China	26
Ministry of Science and Technology of the People's Republic of China	22
Fundamental Research Funds for the Central Universities, China	19
National Basic Research Program of China (973 Program)	16
Ministry of Science, ICT and Future Planning, South Korea, Asia	15
Ministry of Finance, China	14
Ministerio de Economía y Competitividad, Spain, Europe	14
Deanship of Scientific Research, King Saud University, Saudi Arabia, Asia	14
Ministry of Science and ICT, South Korea, Asia	13
National Key Research and Development Program of China	12
Natural Sciences and Engineering Research Council of Canada, North America	11
MinistÃ©rio da CiÃªncia, Tecnologia e InovaÃ§Ã£o, Brazil, South America	9
King Saud University, Saudi Arabia, Asia	9
Government of Canada, North America	9

publications done by the institutes. When the table is considered continent-wise, Asia dominates, it has 12 institutes in the top 20. Out of these 12 institutes, 6 institutes are located in China, 2 each in Singapore, India, and Saudi Arabia. After Asia next continent is Europe, it has 6 institutes in the Table 5. Out of these 6, 2 are from Spain and one each from France, Hungry, Romania and Portugal. From the continent, North America has one institute on the table. Depending upon the QS world ranking of Institutions, the ranking column is included in the table. According to ranking two institutes are having ranking below 100, one from each China and Singapore having 13 and 15 rankings

respectively. King Abdulaziz The University of Saudi Arabia has 143 ranks and 17 publications in the area of AI in a smart city. This university has topped the Table 5 with the highest number of publications in this research area. In 200-300 ranking range three institutes named University of Ottawa (Canada), Wuhan University (China), King Saud University (Saudi Arabia) ranked as 279, 287, and 246 respectively have 13,10 and 10 publications for utility of AI-based applications in smart cities. In the ranking range 300- 400, Huazhong University of Science and Technology (China) having rank 396 and 11 publications. In the 400-500 ranking range two universities are present in the table named Universidad Politécnica de Madrid (Spain) and Beihang University(China) has 12 and 9 publications. Out of 20 institutes ranking of 10 institutes could not be found. The top 3 institutes in the table 5 have 17, 16, and 15 publications after that the number of publications ranges from 13 to 8.

4.7. Abstract Analysis of documents on AI for smart cities

In the form of an abstract, the writers define their study aims and limit them down. The abstract describes the work's overall flow and summary. From the abstract, other researchers can recall and follow the important techniques of a whole work. This section has examined the top 100 most often used words retrieved after preprocessing from the abstracts used by diverse scholars over the last 30.5 years from the Scopus database to identify contemporary recommendations and trends. The cloud of words depending upon the frequency of matching terms is presented in Figure 5. The analysis presents that smart systems have been evolved as a boon to numerous areas such as health care and medical, education, engineering, environment monitoring, tourism industry, etc. for life long experience for students. Also, the proliferation of such smart technologies along with mobile communication has facilitated the simulation of various innovative smart city applications and services aimed at improving urbanization, human lives and enhances knowledge. Some authors have discussed regarding smart cities development with a special focus on the advancement of future autonomous mobility models.

A smart city is a kind of technological development that depends upon the use of "information and communication technology (ICT)", the "Internet of Things (IoT)", communication and social networks, machine learning algorithms, user interfaces, and Artificial Intelligence to give usable multimedia data for the proper management of resources, components, and assets. The integration of the web based digital world and physical reality is crucial for making a city

Table 5. Top 20 Affiliations contributing documents on AI for smart cities

Institutions	Country	Rank	NoP
"King Abdulaziz University"	Saudi Arabia	143	17
"Universidad de Salamanca"	Spain	601-650	16
"Chinese Academy of Sciences"	China	-	15
"University of Ottawa"	Canada	279	13
"Tsinghua University"	China	15	12
"Hassan II University of Casablanca"	Morocco	-	12
"Universidad Politécnica de Madrid"	Spain	451	12
"Nanyang Technological University"	Singapore	13	11
"Huazhong University of Science and Technology"	China	396	11
"Amity University"	India	-	11
"CNRS Centre National de la Recherche Scientifique"	France	-	10
"King Saud University"	Saudi Arabia	287	10
"Wuhan University"	China	246	10
"Vellore Institute of Technology"	India	-	9
"Beihang University"	China	449	9
"Universidade do Minho"	Portugal	-	9
"University of Chinese Academy of Sciences"	China	-	9
"School of Computer Science and Engineering"	Singapore	-	9
"Obuda University"	Hungary	-	9
"University Politehnica of Bucharest"	Romania	-	8
NoP : Number of Publications			

smart. In other words, emerging cognitive technologies can be trained to recognize pat-terns in data generated by the connected smart city sensor devices. Based on the articles published by various researchers, the ultimate interest of a smart city's architecture is to reconcile technological innovation along with various economic, social, and environmental challenges.

Figure 5. Top 100 Abstract words analysis

The research is aimed at taking this opportunity by analyzing the innumerable applications and activities of smart cities. The creation and integration of smart city applications can be aided by smart city software platforms. The various instances are illustrated below:

- The use of computer vision plays a vital role and ensures proper traffic control. Traffic lights gather da-ta from sensors and vehicles, altering timing to respond to real-time traffic and hence minimizing road congestion.

- To provide effective parking solutions, smart parking systems also make use of computer vision technolo-gies as they can efficiently detect vacant parking spots.

- Video and image analytic is a strong tool that has the potential for analysis and the development of real-time response intelligent systems in Smart Cities, whether they are associated with safety, security, traffic management.

- The implementation of technologies like geospa-tial and geolocation has a huge impact in, refin-ing energy consumption, real estate development, crime prevention, and event management, etc. An example of a geo technology implementation is geofencing which is a virtual boundary for a physical geographic area.

- A smart grid provides a two-way interactive capacity and can be defined as an electrical network that amalgamates an electrical network and smart digital communication technology. It helps in the efficient transmission of electricity, load balancing, reduces power disturbances, etc.

- Smart education is a collaborative, interactive, and visual learning paradigm adapted to the juvenile popu-lation of digital inhabitants. It improves accessibility for students as they can access education remotely. It imparts training and assesses the outcome of learning smartly.

- The boom in the digital revolution leads to innovative emerging and integrated adoptive technologies in the computer science engineering field such as IoT and Smart City, Blockchain, Quantum Computing, Ar-tificial Intelligence (AI) and Machine Learning, etc. With such technical assessments users are interested in a long-term career in this industry and also find a huge number of opportunities.

4.8. Title Analysis of documents on AI for smart cities

Title classifies the main goals of any academic document. The properly framed title not only presents the research objectives, scope, and trials but can also spade the other researchers' interest. Thus, a title must reflect the author's vision and appeal. This section examines the top 100 most commonly used words in titles of the 1925 research publications listed in the Scopus database during the last 30.5 years for popular trends and standards. After rigorous filtering and pre-processing the 100 most usable words have been identified and the Figure 6 depicts a word cloud formed on the basis of frequency of selected words. The analysis is based upon the remaining words after removing duplicate words from the abstract analysis. According to studies, the smart city development is linked with various crucial areas such as transportation system, education, culture, etc. COVID-19 pandemic has changed the education system dramatically as it transferred the education model from offline to online or blended mode. As in Covid times, campuses and universities use to impart education on digital platforms. The adoption of education technology leads to a huge surge in the usage of various AI and augmented reality tools that help in visualization, video conferencing, online education-related gaming platforms, etc. Gaming stimulates logical, reasoning capabilities and charges one's brain with complex challenges.

Figure 6. Top 100 Title words analysis

Various studies have presented that smart cities also provide smart solutions for pedestrians, vehicles, bicycles, and other passengers on public transport. Optimizing city transport options for tourists, residents, and workers is a key component of smart cities. Farmers are using smart irrigation systems to enhance their production. Smart electric panels, grids, meters, etc. are doing wonders and creating a cost-efficient environment. A Smart City concept relies heavily on collecting huge amounts of data. But, the development of big data and artificial intelligence has led to one of the crucial concerns, i.e. privacy of data. Certain researchers have discussed that there is a crucial role of federated learning in this context and also for data collection and federated learning processes as they can provide a solution to various privacy and security concerns.

4.9. Keywords Analysis of documents on AI for smart cities

The subjects, issues, areas, subareas, approaches, and techniques addressed by researchers are defined in terms of keywords in a research document. The keywords in a research document serve as a lead for search engines and databases such as Proquest, Google Scholar, Scopus, and others to find and list that paper as a result of a search for interested scholars. As a result, authors should carefully select relevant and specialized keywords, as making a work searchable can make it more approachable. This section is based on a survey of the 100 most commonly used terms derived from a keyword analysis of publications produced on AI applications in smart cities over the last 30.5 years. This can guide researchers in deciphering the newest studies' trends and themes. Figure 7 shows a word cloud displaying the frequency of filtered 100 terms based on the keywords' analysis. The analysis is based on the unique terms left after filtering duplicate words from abstract and title analysis.

Figure 7. Top 100 Keywords analysis

The studies reflect that in the modern geographical era, 3D modeling can assist cities in becoming smarter by improving environmental performance,

transportation activities, utility interfaces, and hybrid navigation systems that include Loran, GPS Mapping, VANET, etc. The researchers have also highlighted concerns about how smart cities are always striving to make their food industry more viable, fair, resilient, and healthy. For smart cities, crowdsourcing refers the process of gathering information from a group of people over the internet via social media, smartphone apps, sensing IoT devices, etc. Data can also be retrieved from Bayesian inference methods. Thus, structures and illustrates of the smart cities offer a variety of ways to collect, monitor, and analyze urban data with the latest pervasive programming and computing technologies.

4.10. Top 20 Publication sources on AI for smart cities

The top 20 sources from all identified sources of Scopus indexed published documents in AI research for smart cities over the last 30.5 years have been listed in Table 6. The listing is done based on descending order of the count of published articles in the area of AI research for smart cities from 2006 to July 2021. The table is presenting the name of the source along with the Number of published Documents (ND) belonged, Impact Factor (IF) if applicable, the score of citations, SCImago Journal Ranking (SJR), Source's quartile, publisher of the source, and the country from where source belonged. The Springer Verlag publisher's "Lecture Notes in Computer Science" ranked first with a maximum number of 155 publications and "Advances In Intelligent Systems And Computing" has been ranked second with 124 published articles. Rest other sources are not even able to touch the mark of 100 publications in this field. Next on the list is the "ACM International Conference Proceeding Series" with a count of 65 publications. The rest of the sources are having even less than 50 publications in this field. Thus, the analysis shows that the AI research for smart cities is still behind the mark.

The analysis also shows that 70% of published research documents belonged to conferences, only 30% sources are journals including "IEEE Access", "Sensors", "Sustainability", "IEEE Internet of Things Journal", "Sustainable Cities And Society", and "Applied Sciences" having impact factor of 3.4, 3.5, 3.2, 9.9, 7.6, and 2.7 respectively. Amongst all sources "IEEE Internet Of Things Journal" is having the highest impact factor, the highest SJR ranking of 2.08, and also the highest cite score of 14.9. Followed to this journal the second rank based on IF and cite score is occupied by the "Sustainable Cities and Society" with the second-highest impact factor and cite score as 7.6 and 10.7 respectively. On citing score basis next positions are occupied by "Sensors", "IEEE Access", "Sustainability", "Procedia

Computer Science", and "Applied Sciences", "Lecture Notes in Computer Science", and "ACM International Conference Proceeding Series" with citing score of 5.8, 4.8, 3.9, 3, 3, 1.8, and 1.2 respectively. The rest of the sources are having less than one cite score. Two of the top twenty sources belonged to quartile Q1, three to quartile Q2, one to quartile Q3, and four to quartile Q4, while the rest were not allocated to any quartile. From the total publications of these top twenty sources 46.8% publications belonged to the Springer, 14.8% to IEEE, 10.5% to MDPI, 9% to ACM, 5.2% to IOP, and 4.8% to Elsevier publisher. The rest of 8.6% publications belonged to workshops and conferences only. Based on countries, Switzerland is the origin of five of these sources, Germany of four, three of the sources originated each from the US and UK, two from the Netherlands, one each from Portugal and China.

4.11. Top 20 Authors contributing documents on AI for smart cities

Artificial intelligence is entering all phases of life to make human tasks easier and quicker. It is an important aspect of turning cities into smart cities. Despite these facts, very few researchers in the last 30.5 years have focused on this area. The Table 7 shows the top 20 authors in descending order of their number of publications, who have researched in the utilities of implementing AI in various smart city sectors. The table also includes h-index, h-index including self, total documents by the author in Scopus, total citations, and citation by the document. An important consideration in the table is the "h-index", which refers to the highest number of publications with at least a similar number of citations. The next column is "H-index excluding self "it shows the h-index of the author excluding the citations which are done by the author back to their research papers. An author's total number of publications is always equal to or greater than his or her h-index.

The number of research articles in the Scopus database relating to the author is listed as total documents in Scopus. The "Total citation" column contains the total number of citations by other authors as well as citations done by the author to their research work (also known as self-citation). The column titled "citation by document" contains the citations by other authors excluding the self-citations. Mehmood, R. from Saudi Arabia has the highest number of research papers, his h- index is 25 however the author at second place Yigitcanlar, T. from Australia has an almost similar number of research papers but his h-index and count of citations is much greater than first place author in the table. Boukerche, A. from Canada has the highest citation by document among all authors i.e., 9287, also the maximum h-index belongs to this author.

Table 6. Top 20 Publication sources on AI for smart cities

Journals	ND	IF	Cite Score	SJR	Quartile	Publisher	Country
"Lecture Notes in Computer Science"	155	–	1.8	0.3	Q3	Springer Verlag	Switzerland
"Advances In Intelligent Systems And Computing"	124	–	Discontinued	–	–	Springer Verlag	Germany
"ACM International Conference Proceeding Series"	65	–	1.2	0.2	–	Association for Computing Machinery (ACM)	United States
"IEEE Access"	40	3.4	4.8	0.59	Q1	Institute of Electrical and Electronics Engineers Inc.	United States
"Sensors"	36	3.5	5.8	0.64	Q2	MDPI Multidisciplinary Digital Publishing Institute	Switzerland
"Mccsis 2018 Multi Conference On Computer Science And Information Systems"	33	–	–	0.1	–	International Association for the Development of the Information Society	Portugal
"Ceur Workshop Proceedings"	29	–	0.8	0.2	–	CEUR-WS	Germany
"Sustainability"	28	3.2	3.9	0.6	Q2	MDPI Multidisciplinary Digital Publishing Institute	
"Communications In Computer and Information Science"	27	–	0.8	0.2	Q4	Springer Verlag	Germany
"Journal of Physics Conference Series"	26	–	0.7	0.2	Q4	IOP Publishing Ltd.	United Kingdom
"Proceedings 2018 IEEE Smartworld Ubiquitous Intelligence And Computing Advanced And Trusted Computing Scalable Computing And Communications Cloud And Big Data Computing Internet Of People And Smart City Innovations"	20	–	–	–	–	IEEE Computer Society	China
"Lecture Notes Of The Institute For Computer Sciences Social Informatics And Tele- communications Engineering Lnicst"	19	–	0.7	0.1	Q4	Springer Verlag	Germany

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Table 6 – *Continued from previous page*

Journals	ND	IF	Cite Score	SJR	Quartile	Publisher	Country
"Procedia Computer Science"	18	–	3	0.3	–	Elsevier BV	Netherlands
"IEEE Internet Of Things Journal"	17	9.9	14.9	2.08	Q1	Institute of Electrical and Electronics Engineers Inc.	United States
"Sustainable Cities And Society"	17	7.6	10.7	1.65	–	Elsevier BV	Netherlands
"2017 IEEE Smartworld Ubiquitous Intelligence And Computing Advanced And Trusted Computed Scalable Computing And Communications Cloud And Big Data Computing Internet Of People And Smart City Innovation"	16	–	–	–	–	IEEE Computer Society	USA
"2019 IEEE SmartWorld, Ubiquitous Intelligence & Computing, Advanced & Trusted Computing, Scalable Computing & Communications, Cloud & Big Data Computing, Internet of People and Smart City Innovation"	14	–	–	–	–	IEEE Computer Society	*United Kingdom*
"Applied Sciences"	12	2.7	3	0.44	Q2	MDPI Multidisciplinary Digital Publishing Institute	Switzerland
"Iop Conference Series Earth And Environmental Science"	12	–	0.5	0.18	–	IOP Publishing Ltd.	United Kingdom
"Lecture Notes In Networks And Systems"	12	–	0.6	0.17	Q4	Springer International Publishing AG	Switzerland
ND = Number of documents, IF = Impact Factor, CS = Cite Score							

Table 7. Top 20 authors contributing research on AI for smart cities

Author Name	NP	University/Organization	H-index	H-index excluding self	documents in Scopus	Total citation	Citation by document
Mehmood, R.	10	"King Abdulaziz University, High Performance Computing Center, Jeddah, Saudi Arabia"	25	16	131	2284	1103
Yigit-canlar, T.	9	"Queensland University of Technology, School of the Built Environment, Brisbane, Australia"	46	32	220	5840	2959
Corchado, J.M.	7	"Universidad de Salamanca, Salamanca, Spain"	46	40	625	7557	4196
Park, J.H.	7	"Seoul National University of Science and Technology (SNUST), Seoul, South Korea"	33	31	414	5007	4313
Alba, E.	6	"Universidad de Málaga, Departamento de Lenguajes y Ciencias de la Computación, Malaga", Spain	47	44	445	9742	6670
Chamoso, P.	6	"Universidad de Salamanca, BISITE Research Group, Salamanca, Spain"	15	15	83	820	570
Kantarci, B.	6	"University of Ottawa, School of Electrical Engineering and Computer Science, Ottawa, Canada"	29	26	229	3179	2296
Aloqaily, M.	5	"Al Ain University, Al Ain, United Arab Emirates"	25	23	108	1742	1106
Analide, C.	5	"Universidade do Minho, Department of Informatics, Braga, Portugal"	7	6	73	282	230
Bouker-che, A.	5	"University of Ottawa, PARADISE Research Laboratory, Ottawa, Canada"	47	44	996	12648	9287
Chui, K.T.	5	"Hong Kong Metropolitan University, School of Science and Technology, Hong Kong, Hong Kong"	13	12	49	518	467
Serrano, W.	5	"University College London, London, United Kingdom"	5	4	33	96	73
Streitz, N.	5	"Smart Future Initiative, Frankfurt am Main, Germany"	20	19	66	1761	1440

Continued on next page

Table 7 – *Continued from previous page*

Author Name	NP	University/Organization	H-index	H-index excluding self	documents in Scopus	Total citation	Citation by document
Alamaniotis, M.	4	"The University of Texas at San Antonio, Department of Electrical and Computer Engineering, San Antonio, United States"	13	10	135	669	399
Albeshri, A.	4	"King Abdulaziz University, Jeddah, Saudi Arabia"	15	14	62	920	583
Chalon, R.	4	"École Centrale de Lyon, Ecully, France"	7	4	54	200	161
Charissis, V.	4	"Glasgow Caledonian University, Glasgow, United Kingdom"	12	9	51	406	270
Costanzo, A.	4	"Università degli Studi di Catania, Department of Electrical, Catania, Italy"	6	5	24	105	79
Cuzzocrea, A.	4	"LORIA Laboratoire Lorrain de Recherche en Informatique et ses Applications, Vandoeouvre-les-Nancy, FranceUniversità della Calabria, DEA Lab, Rende, Italy"	36	17	532	3757	1871
David, B.	4	"École Centrale de Lyon, Ecully, France"	10	9	79	460	404

Another author Alba, E. from Spain has also the highest h-index in the table i.e., 47. The maximum number of research papers by an author in the field of AI in the smart city is 10 while the minimum count is 4, other authors included in the table have 9,7,6, and 5 research publications.

4.12. 25 Most cited documents on AI for smart cities

This section has concentrated upon the top 25 most cited published documents in the domain of AI in smart for the last 30.5 years. The list is shown in Table 8 in descending order of the corresponding citation index. The paper published by Diro et al. (2018)), as mentioned in the first row of Table is the one with 257 citations as the highest citation score, stated that Security breaches are one of the major issues raised by different sectors of Cybersecurity in smart cities [24]. There is the requirement of advanced neural network algorithms and protocols, which help to detect these cyber-attacks and provide strong intrusion detection systems. Traditional machine learning algorithms are not able to detect these mutants of attacks. However, nowadays-deep learning can provide advanced algorithms, which perform better than the existing ML-based algorithm to detect cyber-attacks and provide network security in smart cities. Document published by Wellman et al. (2002) is having the second-highest citation score of 227, focused on the transformation of the whole world to digital by connecting every service [25]. The focus has been on how to transformed communities from small areas to Globalized with the help of networks. These transformations result in digital-based smart cities.

Rahman et al. (2018) having 224 citations at third position in the table, proposed a recurrent neural model which is used to predict energy consumption hourly for residential and commercial buildings [26]. It used smart technologies and sensors for predictions. The model has considered slight information on the working schedule of the buildings. The model helps in taking decisions related to production and electricity distribution management in smart cities. The model-based upon a deep neural network provides predictions with greater accuracy. Tian et al. (2015) have stated that in smart cities, intelligent Traffic routing is one of the important slices. Many times series-based model and machine learning-based models are available for smart transformation system predictions which works with good accuracy [27]. But these models are only applicable to instant traffic prediction and required historical data. The authors have proposed a long-term memory recurrent neural network that used three multiplicative units for predictions and performs better than existing intelligent traffic systems for internet cities. Alam et al. (2017) have described the

detailed survey on data fusion, challenges, and future opportunities of describing mathematical models for data fusion for applicability of IoT-based services for internet/smart cities [28]. As the Internet of Things (IoT) was be able to connect and handle approximately 50 billion objects by the year 2020. IoT has become the main source of big data. They have also addressed the IoT-specific environment and its emerging areas like the use of deep learning in data fusion, smart cities, autonomous vehicles, etc.

Allam et al. (2019) have discussed about the application and role of AI technology in the context of designing Internet cities by considering economic aspects by the applications of big data and sensors through the IoT technology [29]. They have proposed a novel framework for smart cities by integrating AI to enhance economic growth and livability. Wang et al. (2020) have discussed the impact of AI in the domain of Fusion of edge intelligence and intelligent edge, its implementation strategies, applications, and demonstrated deep learning-based customized framework for edge computing [30]. They addressed how deep learning is able to thrive its services and intelligent applications for the establishment of smart cities and factories. Komninos et al. (2011) addressed the role of spatial intelligence in collaboration of community to individual's skills as well as intelligent machines as an orchestration intelligence [31].

The use of smart devices increases problem-solving capabilities with innovative ideas and intelligent decision-making support in the domain of smart cities development. Eltoweissy (2010) have proposed an autonomous vehicular cloud model which helps authenticated users in providing services on sea areas, terrestrial and aerial pathways [32]. The authors also described the amalgamation of AVC with infrastructures and smart cities, the potential of enabling cyber services with vehicular-based networking services has also been discussed. Mohammadi et al. (2018) have proposed a deep reinforcement learning framework for handling the underutilized data for smart city services [33]. In the proposed framework data have been grouped into labeled and unlabeled data categories based upon user feedback. The authors have also described the challenges encounters while deploying the model into smart city services. Shi et al. (2020) have performed the past 5-year detailed survey for the use of various applications based upon emerging technologies in smart cities [34]. The authors described the model STIMES which is the combination of microelectronic and emerging technologies I.e., artificial intelligence, Augmented reality. The proposed work also stated the STIMS applications in human and non-human related areas.

Zheng et al. (2015) have proposed a car parking model based on IOT for smart cities to maximize the

Table 8. 25 Most cited documents on AI for smart cities

SN	Authors	Title	Year	Cited by
1	Diro A.A., Chilamkurti N.	Distributed attack detection scheme using deep learning approach for Internet of Things	2018	257
2	Wellman B.	Little boxes, glocalization, and networked individualism	2002	227
3	Rahman A. et al.	Predicting electricity consumption for commercial and residential buildings using deep recurrent neural networks	2018	224
4	Tian Y., Pan L.	Predicting short-term traffic flow by long short-term memory recurrent neural network	2015	222
5	Alam F. et al.	Data Fusion and IoT for Smart Ubiquitous Environments: A Survey	2017	152
6	Allam Z., Dhunny Z.A.	On big data, artificial intelligence and smart cities	2019	141
7	Wang X. et al.	Convergence of Edge Computing and Deep Learning: A Comprehensive Survey	2020	145
8	Komninos N.	Intelligent cities: Variable geometries of spatial intelligence	2011	120
9	Eltoweissy M. et al.	Towards autonomous vehicular clouds: A position paper (Invited paper)	2010	119
10	Mohammadi M., Al-Fuqaha A.	Enabling Cognitive Smart Cities Using Big Data and Machine Learning: Approaches and Challenges	2018	117
11	Shi J. et al.	Smart Textile-Integrated Microelectronic Systems for Wearable Applications	2020	107
12	Zheng Y. et al.	Parking availability prediction for sensor-enabled car parks in smart cities	2015	106
13	Skouby K.E., Lynggaard P.	Smart home and smart city solutions enabled by 5G, IoT, AAI and CoT services	2014	100
14	Allam Z., Jones D.S.	On the coronavirus (Covid-19) outbreak and the smart city network: Universal data sharing standards coupled with artificial intelligence (ai) to benefit urban health monitoring and management	2020	99
15	Virrantaus K. et al.	Developing GIS-supported location-based services	2001	97
16	Medvedev A. et al.	Waste management as an IoT-enabled service in smart cities	2015	95
17	Braun T. et al.	Security and privacy challenges in smart cities	2018	91
18	Idowu S. et al.	Applied machine learning: Forecasting heat load in district heating system	2016	90
19	O'Dwyer E. et al.	Smart energy systems for sustainable smart cities: Current developments, trends and future directions	2019	85
20	Patel P. et al.	On Using the Intelligent Edge for IoT Analytics	2017	82
21	Alam F. et al.	Analysis of Eight Data Mining Algorithms for Smarter Internet of Things (IoT)	2016	80
22	Al-Hader M. et al.	Smart city components architecture	2009	80
23	Sivanathan A. et al.	Classifying IoT Devices in Smart Environments Using Network Traffic Characteristics	2019	76
24	De Paz J.F. et al.	Intelligent system for lighting control in smart cities	2016	70
25	O'Grady M., O'Hare G.	How smart is your city?	2012	70

car parking facilities. The proposed work has been based upon different machine learning algorithms to analyze the proposed model for performance and also conducted the scenario-based study in the cities of Melbourne, San Francisco, Australia, and the USA [35]. Skouby et al. (2014) have proposed four layer-based models for integration of emerging technologies i.e., 5G, IoT, cloud, and artificial intelligence in smart homes or smart cities based upon big data [36]. Allam et al. (2020) have conducted a survey on the utilization of standardized protocols for health-related data sharing in smart cities networks during the Covid-19 pandemic [37]. The author also focused on the effects of lockdown on the economical state of countries, political issues, and many more, but sharing of health-related data in smart cities has been required a better understanding and for safe management and development of smart cities.

Virrantaus et al. (2001) have presented a novel service "Location-based service" in the domain of mobile networks for smart cities[38]. As telecom industry has been growing day by day which further increased the internet-enabled services. The authors also described an LBS pilot system for smart cities maps that can execute on smart mobiles, terminals, and PDAs. Medvedev et al. (2015) have discussed the waste management methods for smart cities and proposed an advanced system for decision support for smart cities' waste management tasks [39]. The proposed system makes real-time basis coordination amongst truck drivers and performed dynamic route management tasks. The system can also work well in inaccessible areas of smart cities. Braun et al. (2018) have discussed the issues and challenges related to privacy and security in Internet cities and provide solutions [40]. The challenges focus on privacy, network security, data sharing, adopting Artificial intelligence, and methods to handle failures. The authors Idowu et al. (2016) have proposed a model to forecast the aggregate thermal load of water and space in smart cities [41]. The proposed model-based upon machine learning algorithms mainly support neural network, regression, and vector machine. The model takes the input from the environment for forecasting. The results show that apart from the linear regression model other algorithms provide better results.

O'Dwyer et al. (2019) have discussed the current advancement in the field of energy management while consideration of energy demand and discussed the importance of intelligent algorithms in the area of energy management for smart cities[1]. The proposed work presented the internet thing architecture base upon fog computing. Patel et al. (2017) have discussed various stakeholders and their roles in order to design IOT based applications for various domains like smart cities, security [42]. Alam et al. (2016) have stated that the Internet of Things is the new growing technology in

the present era and a proper mechanism is required to handle such huge volume of data [43]. The authors have discussed various data mining algorithms based upon deep learning and artificial intelligence for handling a large volume of data with efficiency.

Al-Hader et al. (2009) have discussed the need of monitoring the various services like electricity, water, gas sewerage to effectively utilize the resources in smart cities [44]. The authors stated that a decision-maker system is desirable in smart cities to reduce operational costs. Sivanathan et al. (2019) have discussed the contribution of IoT for Internet cities and presented a framework for the classification of various IoT devices in the field of traffic monitoring using different machine learning approaches [45]. De Paz et al. (2016) have discussed the role of "machine learning" algorithms in energy management. The proposed architecture controls the public lighting system at the central level and provides an intelligent method to economize lighting while taken care of quality [46]. O'Grady et al. (2012) have stated that ambient intelligence in smart cities makes the present environment related to human being more approachable to full fill individual needs [47].

From the research analysis related to the role of Artificial Intelligence in Internet cities, it has been revealed that AI-based tools and techniques are beneficial for the establishment and maintenance of sustainable internet cities. The researchers designed various A.I.-based tools, which provide better facilities in different areas of smart cities. As per the highest citation value, the top 25 papers have been selected and summarized in the above section. The present study reveals that Artificial technology-based applications i.e., deep learning, IoT, network, ambient intelligence plays a vital role in the various domain of smart cities like security, privacy, energy management, essential services, IoT, Traffic routing, parking facilities, medical, etc. It has been revealed that in the top 25 documents, 32% of research work have been carried out by implementing IoT based tools; 32% of studies have been published using deep learning techniques and models, 16% of the work have been conducted using network-based techniques, 8% work have been carried out using GIS-based applications,4% have been conducted using cloud and ambient intelligence techniques individually.

5. Challenges with AI adoption for smart cities

RQ3: What are the major obstacles to AI adoption in smart cities? A sustainable smart city with smart technology for managing governance, infrastructures, transportation, commerce, security, healthcare, and energy not only leads to quality life but also opens up enormous potential for businesses, public safety, and disaster management [48]. On the other side

development of smart cities has a number of technical problems that interconnect all domains of possible applications of AI [49]. For smart cities, the systems' design must be flexible and scalable, allowing for easier incorporation and utilization of new platforms as AI deployed systems for smart cities need to deal with big data having a variety of data formats and information integrity along with required security to ensure long-term growth.

The authors in some studies have supported the fact that the majority of the technical problems faced by government IT initiatives are organizational rather than technical [50]. The authors in [51] have discussed the power management issue for an economically feasible AI deployment for Smart Microgrids. They have also suggested utilizing renewable power resources. The author in [52] has raised the infrastructure design, citizen privacy, environmental integration, sustainability, and collaboration as the major challenges for the development and deployment of AI technology solutions for smart cities. According to [53], even with the progress of AI technology for smart cities, there is a growing realization in the AI community that they must keep people at the utmost priority in order to avoid technological dystopias. They have also focused upon the major barriers for the successful deployment of AI for human-centric applications in smart cities such as robustness, security, ethical, and interpret ability concerns.

Certain published studies have mentioned privacy preservation with high-dimensional data exchange and storage procedures from the network attacks as the crucial issue amongst all challenges [40]. There are many reasons and explanations for this such as in regard to banks, safety and security may be the main cause. On the other side, the government can utilize the information and knowledge collected from such public data sets for national security purposes [54]. Apart form this the data can also be utilized to conduct large-scale mobility and behaviour studies [55]. The authors have also suggested that employing AI technology can minimize failures cascading across the smart networks. In addition to these issues, some authors have also mentioned social adaptation of developed AI applications among the community as another major challenge [56]. Nonetheless, despite of all advantages, we must exercise caution in selecting the appropriate AI technology for the correct application, as well as assuring its cost and compliance with sustainability standards, as well as taking into account concerns of community acceptability [57].

6. Conclusion, Limitation and Future Scope

To deal with issues related to urbanization, the concept of smart/internet cities has been brought as a new innovative solution. It has become imperative to adopt some new technologies which employ AI for rendering better services to the citizens. AI is rapidly ameliorating the efficiency of a variety of urban sectors, including education, health, energy management, business, data analytics, transportation monitoring, security, and e-governance. Thus, this work has reviewed the applications, trends, and challenges of creating and implementing AI technology for smart city development over the last 30.5 years i.e., from 1991 to July 2021. The analysis shows that AI has the potential to build today's and tomorrow's smart cities but in order to get a smooth internet city development each region's potentials, conditions, and circumstances need to be modified. Therefore, to convert a city to a smart city, certain difficulties need to be resolved involving private and public players, network and IT service providers, product integrators, indirect and direct stakeholders. Also, smart cities must start with a core and standards-based IT infrastructure that meets and supports a wide range of demands and can adapt to technological developments such as IoT sensors, analytics, and measurement tools geared up by artificial intelligence solutions.

The analysed study identified the benefits of AI in smart cities development but still there are some challenges that need to be addressed. Henceforth, future work should focus on three main key areas. Firstly, it must be investigated that on what extent smart cities are prepared for adopting and employing artificial intelligence technology. Another aspect that should be investigate is that how the populace will respond to AI's interference in their personal and social life i.e. sharing of data with sensors for further investigation and its effect on the society as a whole. Lastly, in what ways various AI applications can be brought into use and how to integrate it with legacy systems.

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