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Review

Transformation of Buildings and Urban Spaces to Adapt for Future Mobility: A Systematic Literature Review

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Abstract: The development of smart cities has led to transforming modern city operations by applying emerging technologies from the fourth industrial revolution such as the Internet of Things, BIM and machine learning. To prepare for the future development of cities, it is necessary to investigate the current status of city development, research topics and the direction toward future cities. In this study, a systematic literature review was conducted following the combination of literature review guides by Kitchenham and the PRISMA statement. The review identified 141 peer-reviewed academic papers from web-based archives, such as Web of Science and SCOPUS, that were categorized into five topics related to smart cities and urban areas. The technologies applied in the research were analyzed to determine the direction future cities should take based on current smart cities and emerging technologies that will shape individuals' daily lives. However, it was discovered that research papers on critical areas, such as mobility and management, were lacking compared to those on building design and urban planning. This paper concludes with an example of a future urban area that has been transformed due to adoption of future mobility technology to address the shortcomings of the reviewed literature on building and urban environments.

Keywords: smart city; mobility; daily life; PRISMA statement; future cities

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1. Introduction

The use of information and communication technology (ICT) for city planning dates back to the late 1960s, when the Community Analysis Bureau in Los Angeles used computers for statistical analysis [1]. ICT has since become a powerful tool for smart cities, which are urban areas that use technology to improve their efficiency, sustainability and livability [2]. The smart city concept was pioneered by major corporations such as IBM and Cisco, who invested in developing and deploying technology solutions for urban management in 2008 and 2009, respectively. In South Korea, the legal framework for smart cities using ICT was established in 2008 [3]. In Japan, Yokohama was chosen by the government as a demonstration project for smart city innovation, showcasing how energy consumption in urban areas can be effectively reduced by using smart technologies [4]. Around the same time, South Korea also enacted laws to support the construction of smart city infrastructure and related industries [5]. The development of smart cities was measured by the smart city index, which was launched in 2017 by IMD business school and Singapore University of Technology and Design (SUTD) [6]. The latest update of the smart city index showed a ranking of cities, as presented in Table 1 [7].

Smart cities are urban areas that use information and communication technology (ICT) to improve their efficiency, sustainability and livability. The IMD smart city index is a global ranking of smart cities based on how citizens perceive the impact of technology on their lives. The index is produced by IMD business school and Singapore University of

Technology and Design (SUTD) and was introduced in 2019. The index covered 102 cities in 2023, and uses a survey of residents to measure five key dimensions: health and safety, mobility, activities, opportunities and governance. The index aims to provide a balanced perspective on the economic and technological aspects of smart cities, as well as the humane dimensions of quality of life, environment and inclusiveness. The index also reflects the challenges and opportunities that cities face in the context of the COVID-19 pandemic and the climate crisis.

Table 1. Smart city ranking 2021 according to smart city index.

City	Smart City Rank 2021	Smart City Rank 2020
Singapore	1	1
Zurich	2	3
Oslo	3	5
Taipei city	4	8
Lausanne	5	New
Helsinki	6	2
Copenhagen	7	6
Geneva	8	7
Auckland	9	4
Bilbao	10	24
Vienna	11	25
New York	12	10
Seoul	13	47

The survey consists of two parts that observe infrastructure and technology. Infrastructure refers to the physical and social facilities that support the functioning of a city, such as sanitation, public safety, medical services, air pollution and housing. Technology refers to the use of digital and smart solutions that enhance the quality and accessibility of urban services, such as online reporting, public WIFI, CCTV cameras and air filtering systems. Within the two parts are five key factors that affect the daily lives of citizens: health and safety, mobility, activities, opportunities (work and school) and governance. These factors capture the various aspects of urban living, such as health, security, transportation, leisure, education, employment and participation.

The IMD smart city index is a valuable tool for city leaders, policymakers and stakeholders who want to understand the strengths and weaknesses of their smart cities, as well as learn from the best practices and innovations of other smart cities [8]. The index is updated annually and provides insights and recommendations for improving the quality of life and well-being of urban residents.

Smart city systems are constantly evolving with the introduction of new technologies and the application of developing technologies [9]. Everyday tasks and lifestyles are expected to change, as witnessed in the digital age [10]. Therefore, a systematic literature review using keywords such as smart city and technology is required to investigate the main areas of study and acknowledge a need for studies in less studied areas.

This paper presents a review on the trend for future technologies and city spaces focusing on a key factor from the smart city index ranking system. Section 1 includes background information regarding the history of smart cities and the direction of technological advancement in terms of mobility. Section 2 presents a systematic literature review from two web-based academic literature databases, that is, web of science and SCOPUS. Section 3 presents the findings from the literature databases that are focused on smart city research and advancing technology from the analyzed papers. Section 4 details potential changes to city spaces and daily lives upon individuals adapting to the advancing technologies. The conclusion is given in Section 5.

1.1. Smart City Definition

The definition of a smart city has been developing over time as development has revealed the direction more clearly. However, there are different definitions for a 'smart city' from different authors. A collective of smart city definitions from previous studies is shown in Table 2.

Table 2. Smart city definitions according to previous authors.

Authors	Smart City Definition
Hall (2000)	A smart city monitors and integrates the conditions of all of its critical infrastructure (e.g., roads, bridges, airports), optimizes its resources, plans its preventive maintenance activities and monitors security aspects while maximizing services to its citizens [11].
Giffinger et al. (2007)	A smart city refers to the search and identification of intelligent solutions that allow modern cities to enhance the quality of the services provided to citizens [12].
Eger (2009)	A smart community is a community that makes a conscious decision to aggressively deploy technology as a catalyst to solve its social and business needs [13].
Washburn and Usman (2010)	The use of smart computing technologies to make the critical infrastructure components and services of a city—which include city administration, education, healthcare, public safety, real estate, transportation and utilities—more intelligent, interconnected and efficient. Smart cities use computing technologies to make their critical infrastructure, components and services more intelligent, interconnected and efficient [14].
Harrison et al. (2010)	A city is smart when it connects the physical, IT, social and business infrastructures to leverage the collective intelligence of the city [15].
Chen (2010)	Smart cities take advantage of communications and sensor capabilities sewn into the cities' infrastructures to optimize electrical, transportation and other logistical operations supporting daily life, thereby improving the quality of life for everyone [16].
Thuzar (2011)	Smart cities have a high quality of life and pursue sustainable economic development through investments in human capital and communications infrastructure and manage natural resources through participatory policies [17].
Thite (2011)	Creative or smart city experiments aim to nurture a creative economy through investment in quality of life, which in turn attracts knowledge workers to live and work in smart cities [18].
Smart city Korea (2020)	In general, it is a platform for improving the quality of life for citizens, enhancing the sustainability of cities, and fostering new industries by utilizing the innovative technologies of the Fourth Industrial Revolution [19]
Van twist et al. (2023)	Inspired by the vision of technology as a catalyst for positive change, governments collaborate with residents, research institutions, and private companies to implement smart city applications. These applications leverage data and digital solutions to enhance various domains of urban life, such as governance, people, economy, mobility, environment, and living [20]
Nam and Pardo (2011)	A smart city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiency, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively and share data to enable collaboration across entities and domains [21].
Komninons (2011)	Smart cities are territories with a high capacity for learning and innovations. Smart cities are based on the creativity of their population, their institutions of knowledge creation and their digital infrastructure for communication and knowledge management [22].
Caragliu, Del Bo and Nijkamp (2011)	A city is smart when it invests in human and social capital, transport and ICT to attain sustainable economic growth and a high quality of life through a wise management of natural resources and participatory governance [23].
Lombari, Giordano, Farouh and Yousef (2012)	A smart city applies ICT on human capital/education, social and relational capital and environmental issues [24].
Lazarouiu and Roscia (2012)	A smart city is a community of average technology size, interconnected and sustainable, comfortable, attractive and secure [25].
IDA (2012)	A smart city refers to a local entity—a district, city, region or small country—that takes a holistic approach to employ IT with real-time analysis that encourages sustainable economic development [26].
K. Kourtit, Nijkamp and Arribas (2012)	Smart cities are cities that have high productivity as they have a relatively elevated share of highly educated people, knowledge-intensive jobs, output-oriented planning systems and creative and sustainable initiatives [27].
K. Kourtit and Nijkamp (2012)	Smart cities are the result of knowledge-intensive and creative strategies that enhance the socio-economic, ecological, logistic and competitive performance of cities [28].

Table 2. *Cont.*

Authors	Smart City Definition
Cretu (2012)	Smart cities execute everything related to governance and economy using new thinking paradigms that are embedded in networks of sensors, smart devices, real-time data and ICT integration in every aspect of human life [29].
Guan (2012)	A smart city is a city prepared to provide conditions for a healthy and happy community under challenging conditions that global, environmental, economic and social trends may bring [30]
Barrionuevo, Berone and Ricart (2012)	A smart city is a high-tech, advanced city that connects people, information and city elements using new technologies to create a sustainable, greener, competitive, innovative and livable city [31].
Bakici, Almirall and Wareham (2012)	Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centers that are at once integrated, habitable and sustainable [32].
De Lange and De Waal (2013)	Technologies that make cities more efficient and enjoyable [33].
Kitchlin (2013)	A smart city is increasingly composed of and monitored by ubiquitous computing. Its' economy and governance are driven by innovation and creativity enacted by smart people. One significant aspect of smart city concept is production of sophisticated data analytics for understanding, monitoring and planning the city [34].
Peirce, Freed and Townsend (2013)	Places where information technology is deliberately used to improve city operations and management, to enable innovation in public services and governance and increasingly to improve long-range planning [35].
Zygiaris (2013)	A smart city is understood as a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth [36].
Attour and Rallet (2014)	A smart city designates the aggregation of elements that make a city economically competitive, effectively managed and pleasant [37].
Marsal-Llacuna, Colomer-Llinas, Melendez-Frigola (2014)	Smart city initiatives try to improve urban performance by using data and information technologies (IT) to provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration among different economic actors and to encourage innovative business models in both the private and public sectors [38].
Karima Kourtit, Nijkamp and Steenbruggen (2017)	Advanced ICT use in cities with the aim to enhance efficiency (e.g., competitiveness) and sustainability (e.g., energy saving) [39].
March (2018)	The concept of smart city encapsulates the desires and prospects on the transformative and disruptive role technology in solving urban issues [40].
Kumar, Goel and Mallick (2018)	A city concentrating on the environmental, economic and social aspects of urban life in competent, convenient and clever way for attaining the quality of life with the amalgamation of intelligent and sustainable technologies [41].
Yun and Lee (2019)	The purpose of a smart city is to solve its inherent problems while simultaneously reducing its expenditure and improving its quality of life [42].
Woods (2020)	Smart cities can be seen as the latest, and implicitly more efficacious, incarnation of the sustainable city [43].

Source: Adapted and updated from Albino, Berardi, and Dangelico (2015) [44].

From assessing the various definitions of smart cities, it is observed that the definition of a smart city is dynamic, that is, dependent on global issues such as networking, ICT and sustainability. With the development of autonomous technologies, the modern definition is shifted to full autonomous services for citizens and combines previous definitions. In order to comprehend the modern definition of smart cities, an analysis of previous definitions is necessary. Therefore, a word cloud was generated with Python to analyze in detail the definition of a smart city.

Figure 1 shows a smart city definition word cloud generated using Python [45]. The text for the word cloud is from Table 1, where varying definitions from 2000 to 2020 are shown. The word cloud shows the most frequently used words within the collection of definitions. Frequently occurring words such as smart, smart city, smart cities, city and cities are included in the stopwords. Also included in the stopwords are general stopwords that link sentences grammatically, which leaves keywords for analysis.

The keywords that are most often used to define a smart city are infrastructure, sustainable, economic, life, services, quality, technologies, resources, intelligent, improve, social and knowledge. In other words, collectively from previous studies, the definition of a smart city should consider the main keywords extracted from the word cloud.

Figure 1. Smart city definition word cloud.

A smart city requires an intelligent-technology-based infrastructure to provide services, resources and knowledge with the aim of improving sustainability, life quality and the city's economy.

A space within a city is often identified by a common usage that is otherwise known as an urban space. Research has been conducted to explore the requirements for urban spaces in the 21st century [46]. However, the long-term demand is limited to the social aspects of a city due to the city space users. To reflect this, studies are focused on urban green spaces and sustainability. Within a city, there exist spaces that are either unused or misused [47]. These spaces can be called urban void spaces, as they exist within an urban environment but serve no purpose and, therefore, are wasted. Moreover, these spaces can be temporal as they are certainly used during a particular time of day [48]. For example, an office worker with a 9 to 5 job, with the main transportation method of a private vehicle, would utilize a parking space at home only at nighttime. This has a consequence of creating a temporal urban void space during the daytime where it is unused.

1.2. Urban Mobility

Mobility is directly linked to infrastructure and is a key concern for a smart city environment. Traffic congestion and public transport providing services to citizens fall within the infrastructure portion of the smart city index survey. Relating to technologies, Industry 4.0 has allowed citizens to utilize car-sharing apps, search for available parking spaces, hire bicycles, buy tickets online for public transport and search for information, such as congested areas and signal change times, to improve their quality of life. In the late 2010s, the idea of autonomous driving became a popular topic [49], where technologies from Industry 4.0, such computer vision and machine learning, were being implemented in vehicles to achieve the fully autonomous level proposed in research. Parallel to the recent development of technologies for energy and sustainability, electric vehicles that have the potential to replace cars with internal combustion engines were developed [50]. In the future, this development is expected to reach its full potential and therefore will shape the daily lives of humans. In response, cities and the infrastructure of transportation for future cities will also need to adapt and evolve.

2. Systematic Literature Review following Guidelines by Kitchenham and PRISMA Statement

2.1. Literature Review Methodology

In this study, a systematic literature review was conducted under the guidelines of Kitchenham [51], and the results are reported following the preferred reporting items for systematic reviews and meta-analysis (PRISMA) statement [52]. This section covers the methods and steps taken in the systematic literature review. The search began with the decision to search two online peer-reviewed journal archives, which are Web of Science and SCOPUS, to increase the search area. The search was performed by using keywords related to RQ1 and RQ2. With the papers found, the titles, keywords and abstracts were used to perform an analysis that produced a word cloud and a visual network analysis that is described in an upcoming section. The papers that were screened and filtered were further analyzed, focusing on the methodology to investigate how the research was performed using techniques from the fourth industrial revolution. Section 2 expands on the methodology used in this systematic literature review.

2.1.1. Literature Review Guide by Kitchenham

A guide that was set by Kitchenham in 2004 describes a literature review as a means of evaluating available research that is relevant to a research topic. It aims to evaluate the literature fairly by using a reliable methodology. It was originally created for software engineering research updated from the literature review methods in the medical field. This particular guide covers three phases, which are planning, conducting and reporting the review. However, it does not consider mechanisms for conducting the search or the impact of the questions.

Initially, the guide covers the need for a systematic literature review that is summarized as follows. First, the need to summarize existing technology or methods. Second, the need to identify research gaps to suggest further research. Finally, the need to provide a framework to be applied to new research activities. The guide for the systematic review was created to emphasize the importance of the review. Moreover, it is necessary for the guide to exist to assist researchers to conduct a fair review to base their research on.

It is described in the guide that a systematic review is considerably more difficult than traditional reviews. As the review is systematic, it needs to be replicable and consistent. It begins with the definition of a review protocol to specify research questions to create a boundary for the review. To be replicable, it should define search strategies to maximize the success of the search. The search should be well documented to inform readers of the completeness of the review. For the screening and filtering process, the review requires a clear outline on the inclusion and exclusion of documents and the related justification. To analyze the literature found in the review, it is required that the information obtained from each primary study includes quality criteria.

It is explained that during the planning stage of the review, the need for the review is identified along with the development of review methods. The review should be conducted by identifying the research and primary study selection, conducting a quality assessment and extracting, monitoring and synthesizing data. Each of the steps for planning and conducting the review should be explained in the reporting phase of the review. It is important to note that these steps require iteration to extract the best result from the study analysis.

In this study, planning for the systematic literature review involved two key steps: identifying the research needs and establishing research questions. The identified research needs are conventionally the shortcomings of current methods or research that may require updating to correspond with the progress of knowledge, i.e., technology. Establishing research questions is an important step in the planning process to keep the review focused and prevent unnecessary explanations for studies that are not related to the research.

2.1.2. PRISMA Statement

Preferred reporting items for systematic reviews and meta-analyses is commonly known as the PRISMA statement. Similar to the guide from Kitchenham, the PRISMA statement was derived from a systematic review for medicine. It was expanded based on a checklist from the QUOROM statement that was developed over a three-day meeting held in Canada. From previous statements that PRISMA was built from, only essential items remained that were used to build the fundamentals for the updated statement. It includes a 27-item checklist that covers from the title to the discussion of a systematic literature review.

Unlike the guide from Kitchenham, the checklist is presented in a table form that makes it easier for researchers to follow. Included in the statement is a flow chart that focuses on the process of screening and filtering of a literature review that clearly shows the process researchers have undertaken to deliver clear evidence of the review protocol.

2.2. Research Questions

According to the systematic literature review guideline proposed by Kitchenham, one is required to formulate research questions to address the issues within the boundaries of the study. To formulate the correct questions in the field of smart cities, it is important to focus on issues that happened in the past. Also, as a smart city is reactive to the technologies that are developing, technologies that will shape the future are also required to be addressed. Finally, it is crucial to include the effect developing technologies will have on a smart city and users to provide vital insights into what the next issue will be for smart cities. The questions that have been formulated are shown in Table 3.

Table 3. Research questions required for the PRISMA statement.

Code	Research Questions
RQ1	What is the research trend for city spaces adapting to smart technologies?
RQ2	What are some of the future technologies that will shape the future?
RQ3	How will life in a city change for an individual?
RQ4	What are the fundamental requirements to prepare for the future?

RQ1 addresses the research trends that are related to transformation of urban spaces that were present between 2020 and 2022. For example, developing the mobility will have an effect on the required infrastructure, and it comes under the topic of transportation. RQ2 addresses the technologies that will be available for the public and industry that are the focus of this study and will shape the urban area within city spaces and more importantly urban voids within a city. Studies related to void spaces and the method to tackle this issue are directly linked to this question. As the researched topics and the developed spaces will have an effect on the individual, RQ3 is an important question to formulate as it will focus on the impact on the daily lives of city residents. RQ4 is a question that regards the important requirement for the preparation of the new up-coming technologies, the required infrastructure and the effect it will have on users. Combining the research questions, the study is focused on technologies applied to cities, spaces and buildings, with a focus on the application and impact it will have on a city to become smarter and the requirements for the future.

2.2.1. Database Search Criteria

The literature review was conducted based on two academic journal archives: Web of Science and SCOPUS. Journals that were reviewed are focused on peer-reviewed academic papers that are crucial for this study. A peer review by professionals within the field is required to assess the reliability of the paper. The search is also focused on academic journal papers.

These web-based peer-reviewed academic paper archives were chosen as they are platforms that allow access to numerous databases from journals and conferences, mainly focusing on diverse academic disciplines. It should be noted that some journals are not accessible from the respective archives. Therefore, the two archives were searched together in order to widen the search area.

The keyword 'smart city' was used as it is the main topic of interest. Other areas of interest relate to the words 'technology' and 'space' according to the research question. To broaden the search area, the Boolean operator 'OR' was used instead of the conventional 'AND' to search for journals containing technology and space. The resulting literature from the search criteria is expected to contain application of technology or the redevelopment of an existing space of a building that is in a smart city. The search covered the period from when the smart city initiative began in 2017 and 2022.

2.2.2. Screening and Filtering

The search protocol was based on the search method in the previous section. It was used in two web-based peer-reviewed academic journal archives, i.e., Web of Science and SCOPUS, and the search was limited to between 2017 and 2022. The search words used were 'smart city', 'technology' and 'space' and were used with the Boolean operators 'AND' and 'OR'. The search yielded 976 papers from both sources, where 417 and 559 papers were found from Web of Science and SCOPUS, respectively. From the combined papers, duplicates and papers without specific authors were excluded, leaving 967 papers. Due to the wide search area, papers that were not related to space and buildings were also included. Papers relating to other aspects of a smart city such as energy, data and thermal networks were excluded. As the search word included 'space', it included papers relating to cosmic space and also molecular spaces. Identification of these papers was performed by analyzing titles, keywords and abstracts, leading to 610 papers being excluded. The 357 papers that remained were screened again only using the title to focus on building spaces, leading to 175 records being excluded. With the remaining 182 papers, the full papers were searched online, as only papers where the full article is available are deemed eligible. Conclusively, after the filtering and screening process, 141 papers were left to be analyzed.

Figure 2 shows the flow chart of the screening and filtering process of the search protocol as recommended by the PRISMA statement. It shows the identification, where papers were found from two web-based peer-reviewed academic journal archives; screening to exclude unwanted records; and finally the eligible records.

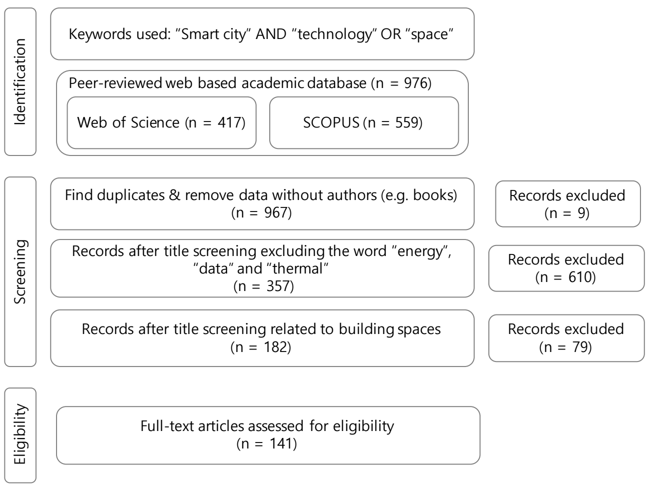


Figure 2. PRISMA-statement-based screening and filtering flow chart.

3. Results and Analysis

3.1. Literature Review Results

Titles, keywords and abstracts were extracted from the 141 papers that were eligible for analysis. First, to identify the common topics of the research, a word cloud was created using Python. The most frequently used words are shown as words in large fonts. The size of the word differs based on the frequency of the word in the titles, keywords and abstracts. Also, three visualizations were produced to further analyze the text extracted from the eligible literature. The three visualizations are a network diagram, an overlay diagram and a density map. A network diagram shows words that are linked in a network to identify connected words. An overlay diagram was produced to show where the words appear according to the year. This shows the key topics of study according to the time of publication. A density map shows a collection of words representing the area of study that are studied collectively. The visualization was produced in VOSviewer 1.6 software.

Figure 3 shows a word cloud of titles, keywords and abstracts from the 141 eligible records. Some of the major keywords that were studied are design, urban, model and system. This shows that current research that focused on smart cities, technology and space is focused on the design of urban areas. To be consistent with smart cities, we focused on research related to urban design. Also, technological systems for application in urban design are seen to represent the majority of the research area.

Figure 3. Word cloud of title, keyword and abstract from eligible records.

Figure 4 shows a network visualization of the same text that was used to create the word cloud. The keywords that are related most to other words were identified as city, information and performance. The network visualization shows that research conducted with city spaces as the main topic of study is mainly concerned with smart cities. It also shows that research was mainly focused on providing information and analyzing performance. These main keywords are colored to show words that are linked to the keywords. The word 'city' is shown to be linked with other words such as concept, urban space, architecture and community. This shows that research concerning a city is connected to concept design of an urban space, which is closely linked to architecture. The word information is colored to link with the word technology. This shows that technology is used to extract information about the city. Performance is linked to a vast amount of words such as comfort, simulation, building space, office and satisfaction as shown by red dotted square. This shows that the word 'performance' is linked closely to the efficiency and management of a space for a particular usage, such as offices.

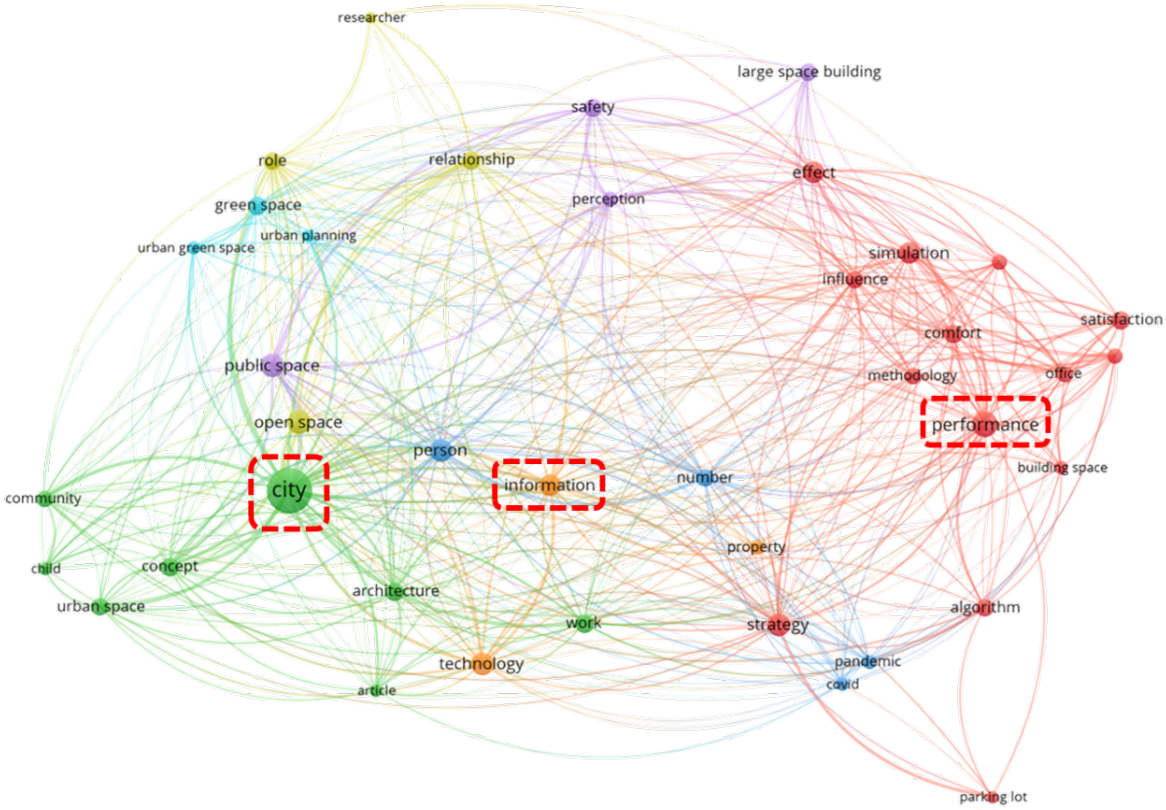


Figure 4. Word frequency network visualization of eligible records.

Figure 5 shows the overlay visualization from the 141 eligible records using VOSviewer 1.6 software. The overlay visualization shows the keywords according to date of publication. The legend shows purple to yellow colors that show the date of publication. Purple shows records published prior to 2019 and the yellow shows records that were published in 2021. The words 'pandemic' and 'COVID' are colored yellow, shown on the far-right side of the legend, representing latest articles, reflecting the response to the COVID-19 pandemic, with results beginning to appear in 2020. Other networks that are colored yellow show recent research areas of interest, which are open space and urban green space. On the other hand, words related to technology and information are colored purple to represent research conducted before 2019. The words that are frequently linked with other topics has been highlighted by a dotted red square.

Figure 6 shows a density map of the words extracted from the titles, keywords and abstracts of the 141 eligible records. It shows that urban, public and open spaces are related to cities, focusing on people and urban areas using technology, information and architecture. According to the map, performance is focused on the business areas of building management and offices, where simulations are used to increase comfort and satisfaction.

The systematic literature review revealed that for a smart city, technology and space are focused on urban areas and that space should be utilized in urban green spaces. It showed that recent research interests are focused on utilizing technology to gain information for analysis of spatial performances in terms of the comfort and satisfaction of users. Although it shows that research was mainly focused on the keywords, there was a small amount of research conducted related to concepts and design. This means that there is a lack of a direction in which recent technology has been applied. Development and utilization of technology within a city space naturally respond to changes in structural aspects, i.e., infrastructure. The systematic literature review shows that there is a lack of research concerning the re-design of existing urban areas to accommodate for developing Industry 4.0 technologies.

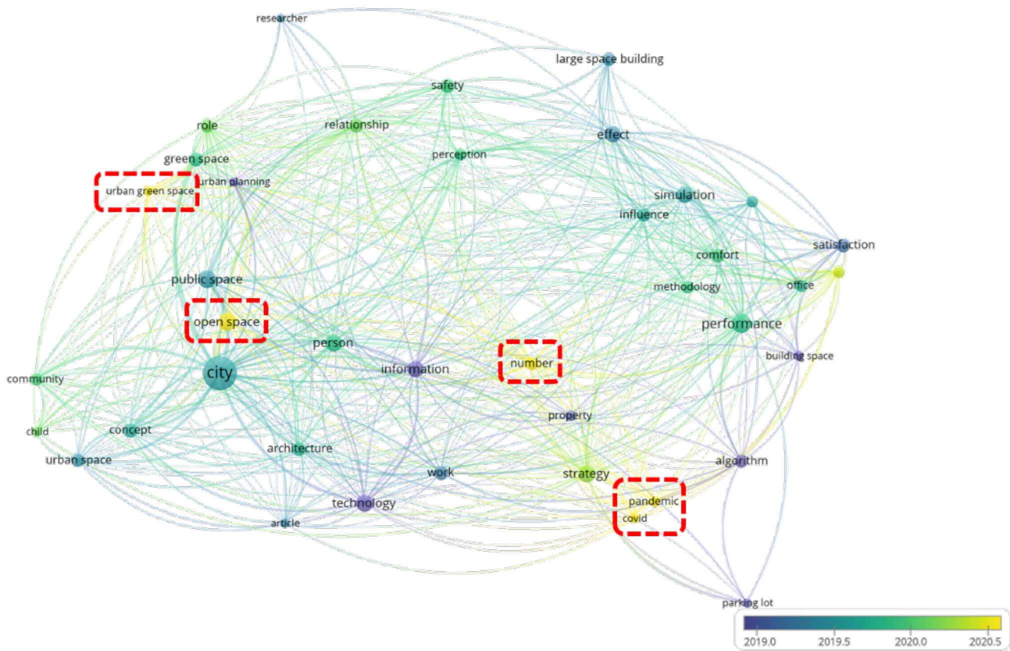


Figure 5. Time-based network visualization of eligible records.

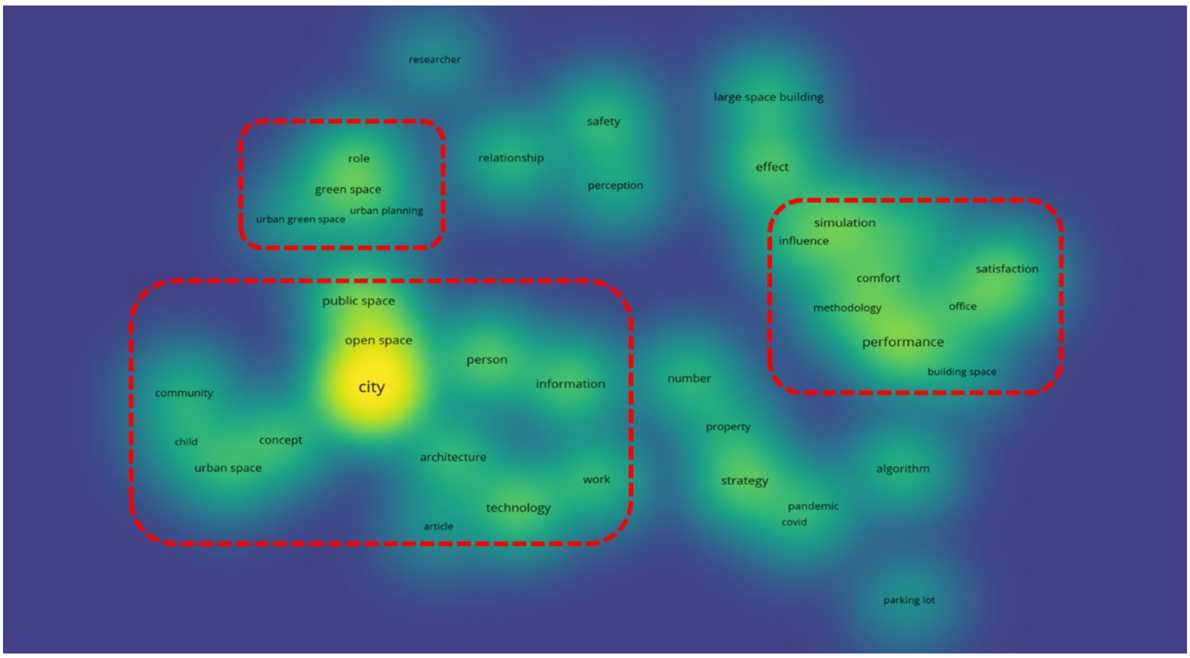


Figure 6. Density map of eligible records.

3.2. Trends in Smart City Research

The literature review was conducted on screened and filtered 141 papers that were found between the years of 2017 and 2022.

The papers found were categorized into five fundamental sections for future planning based on an engineering approach [53], which are building design, urban planning, city services, conceptual design and building management. The categorized analyzed papers are listed in Table 4. The difference between design and planning is related to the scale of the study. In other words, design considers a space within a building or building scale spaces. Planning considers a larger area of space, whether that be urban neighborhoods or on a city scale. The Concept category considers publications that are based on the future or on studies related to the direction of city development. Finally, publications related to management consider both the maintenance and management of spaces within a building.

From the smart city index, relevant topics were found, which are technology, health and safety, mobility, activities and opportunities. Technology refers to the inclusion of information and communication technology (ICT) devices that were studied for assisting with city living. Health and safety refers to studies relating to the well-being of users and residents. Mobility includes research that is closely related to transportation methods such as parking, railway and autonomous vehicles. Activities relates to the social and leisure spaces provided for city dwellers such as parks or green areas within a city. Opportunities is focused on a similar guide from the smart city index and comprises education and work opportunities with an added focus on people with disabilities. Further categories include key architectural topics such as building information modelling (BIM), sustainability, heating ventilation and air conditioning (HVAC), pandemics, spatial, heritage and urban. Papers that are focused on virtual analyses of a building or a city project fall under the sub-category of BIM, as 3D modelling is the primary source of data on which an analysis is performed. Sustainability is a major topic within architecture and also city planning. HVAC concerns an indoor environment focused on users. Papers that are focused on the response to COVID-19 are included in "pandemic". Research papers that are related to space were found and were included in the spatial category. Studies related to historic buildings were placed in the heritage category. City scale studies that are focused on dense residential areas have been sorted into the urban category.

A visualization to organize the papers was performed using GEPHI 0.10 open-source graphing software. A total of 141 journal papers were found and have been identified as soft and hard methods of research, and were initially categorized based on future planning engineering approaches. In order to determine the research direction, i.e., the research trends, papers were further categorized based on architectural trends and the smart city index. This is shown in Figure 7, where topics are highlighted within the categorized papers. Studies relating to design and planning were found to be the majority. It was also identified that studies relating to design were focused on simulations and analyses related to the use of BIM. Sustainability was the second most studied topic, linked to the planning and application of technologies, and the urban category contained the least amount of studies.

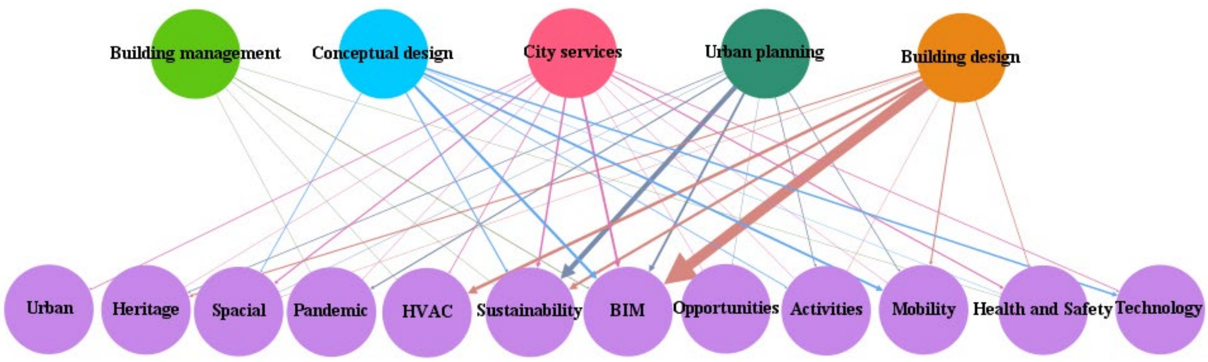


Figure 7. Network visualization of papers in respective categories.

3.3. Paper Analysis

A paper analysis was performed on the articles collected and filtered according to the PRISMA statement. The collected papers were divided into five categories, which are building design, urban planning, city services, conceptual design and building management. Articles related to building design consist of research performed based on designing and analyzing the effect of the design on buildings. Urban planning contains research that is related to the urban spaces and their effect. Research papers that are based on city services contain the latest approaches based on an analysis of the perceptions of building users. Papers that are related to conceptual design are also included, as articles were found that are related to the conceptual approach to the development of smart cities. Papers in the category of building management were also found.

3.3.1. Building Design

Papers related to design included research on green building performance, building space recognition, space heating systems, building floor space analysis, parking strategy, radiation analysis, life cycle and costs, simulation and optimization and HVAC.

Various approaches to green building performance and building performance were researched according to the findings. Building performance was analyzed using artificial neural networks to save time due to the faster calculation speeds of machine learning approaches [54]. Simulation tools were developed that yield improvements in energy-related factors such as energy consumption, overheating and payback [55]. Vertical greenery systems were installed in an indoor environment and the effect was analyzed, focusing on reducing micro dust within an indoor environment [56]. Spatial development that integrates smart cities and ecological environments was studied based on the current development of cities [57]. Research concerning building spaces has also been extensively performed. A novel approach for estimating floor spaces was presented in [58], a space recognition algorithm for building spaces was used for performance simulations [59], a spatial analysis linked with radiation effects was performed in [60], a decision-making support method was presented using design-space exploration in [61] and information extraction was performed in [62]. Included in the research based on design are the application of BIM and related analyses such as parking space allocation [63], climate daylight simulation [64], building adaptation design using physics-based simulation tools, building design sensitivity analyses [65], graphical visualization assists analyses and flow around buildings and indoor environments including turbulence [66–83].

3.3.2. Urban Planning

The planning section includes research papers related to buildings' and cities' planning projects. It includes topics that concern the utilization of and parameters for space within a building or city. Out of the screened 141 papers, 33 papers were found to be related to planning.

Studies relating to the adoption of new and upcoming technologies were found that are in line with significant topics such as sustainability. Inclusion of BIM for the purposes of planning ahead for potential conflict detection has been studied, where an additional dimension, i.e., time, was added to the simulation [74]. The significant advantage of BIM being digital is beneficial for performing numerical calculations for planning a purpose for a space given a specific condition [75,76]. Planning for natural disasters is also possible via static and dynamic simulations based on real data such as geographical information system (GIS) data [77].

The majority of the planning-related papers relate to sustainability, as the papers study the adaptation of natural elements to a particular space. Utilization of green spaces and water bodies within a residential area was analyzed, with the effect of reducing carbon emissions and shade, and a potential index for the amount of green space was proposed [78–81]. Additional studies relating to the adoption of natural elements were present, where the temperature effect from green spaces [82], applications in various formats [83], a comparison between objective and perceived built environments [84] and an analysis of spatial disparities in urban areas [85] were presented.

Other studies relating to planning include responses to the COVID-19 pandemic, preserving heritage spaces, inclusion of mobility technologies and space application within city space. Lessons learned from the pandemic have been studied for business and educational environments via a case study, where the aim was to reduce the risk of infection [86,87]. Emergency evacuation for retail spaces has been re-evaluated by performing case studies [88]. To preserve heritage, other case studies were performed to investigate limitations for creating offices spaces from historical buildings [89]. Moreover, adoption of Industry 4.0 in cultural heritage environments has led to a multi-disciplined concept that is the 'Internet of Cultural Things' [90]. Cities will need to adapt to the application of developed technology to mobility; research papers were found that consider feasible ways to adapt to changing city spaces and conduct performance analyses [91,92].

3.3.3. City Services

User-based research papers are studies focused on the experience and comfort of users in a specific space. Research on user experiences was focused on technology, sustainability, health and safety and others.

In terms of technology, research on the application of BIM was found that used virtual geometric data to perform numerical calculations such as pedestrian spatial experience according to specific time and place [93], pedestrian evacuation simulations [94], occupancy modelling using a multi-objective optimization algorithm and the queuing approach [95,96] and analyzing the use of space within buildings [97]. Other technology-related papers were found, where a geographical information system (GIS) was used to study built environments, which led to the use of space syntax metrics to observe pedestrian volume [98] and information and communication technologies were applied in a smart city to search for determining factors that allow networking in public spaces [99].

Studies related to sustainability analyzed building performances focused on user preferences [100], observed the impact green spaces have on residents' activity [101], analyzed visitor patterns within urban spaces [102] and analyzed the effect of green building certification on tenant decisions in a building space [103].

Another topic that concerns occupants within a building space and residents in urban areas is health and safety. Studies on urban areas include perception of the safety of an urban area according to gender [104], understanding the built environment for the disabled [105] and an attempt to tackle socio-economic issues, such as substance abuse, by using urban spaces for a specific activity [106]. For building space areas, the occupant status within commercial and academic buildings [107] and the impact of COVID-19 restrictions [108] have been studied.

Other study sub-topics that were centered around building occupants and urban residents included spatial impact, HVAC, heritage and mobility. Building spatial factors and their corresponding effects on occupants have been studied, particularly in indoor environments and specified spaces [109,110]. HVAC studies, from the two found articles, were focused on space heating demand estimation for buildings [111] and spatial classroom designs for naturally ventilated buildings to ventilate human bioeffluents [112]. Other studies include an impact analysis of heritage buildings in terms of socio and spatial impacts [113], a study on adaptation of autonomy systems for future smart cities for the automation of the hierarchy of needs [114] and a study on user satisfaction related to indoor spaces for terminal buildings [115]. Studies focused on the future and sharing a vision for the future were also found, which included application of interactive technologies to public spaces to influence human behavior [116], an analysis of new concepts such as running multiple businesses in the same space [117] and gathering opinions from specific target groups about smart city concepts [118].

3.3.4. Conceptual Design

Studies that applied developing concepts and technologies were focused on smart city applications and evaluated their effects. The majority of the studies applied developing technologies, such as digital twins, augmented reality and other media-related technologies, with the purpose of improving management and the construction environment and digitizing smart cities [119–123]. Research relating to adaptation of hardware, according to fourth industrial revolution, has been performed, including service-providing sensors, signaling, navigation systems for specific environments and system development for connected intelligence spaces [124–127]. Case studies were performed that considered technological adaptations for public spaces within smart cities to benefit residents' health, social interactions and safety [128,129].

In terms of sustainability, green spaces have been studied by multiple authors, where the re-design of urban open or unused spaces was considered based on future prospects and the addition of developing guidelines [130,131]. Applications of energy-related technologies in unused and non-usable spaces have been researched to incorporate green energy solutions in educational buildings [132]. A review study was performed specifically on sustainable smart cities and the integration of green spaces in smart cities for the benefits of residents [133].

Other studies on conceptual ideas include a study that compares how space is utilized in terms of architecture, information for design and human and insect construction [134]. Also, the significance of visibility in urban areas that could become urban landmarks has been highlighted regarding the adaptation of smart urban spaces [135].

Conceptual studies that include mobility were found to be the majority. Various methods for adapting to new mobility methods have been studied, where a step towards commercialization of unmanned aerial vehicles (UAVs) is demonstrated. For example, scheduling a fleet of UAVs within smart cities has been studied using numerical methods [136] and a conceptual space–air–ground integrated network for controlling UAVs [137] has been researched. Other studies on mobility considered ground-based mobility and the corresponding urban areas. Studies on parking spaces, where machine learning was applied for predicting parking spaces within smart cities [138], and application of smart technologies within parking spaces to provide real-time occupancy information and recommendation areas to drivers [139] were found. Future mobility concepts and the corresponding transformation of urban environments have been studied, where suggestions for analyses were presented [140].

3.3.5. Building Management

The management portion of the found papers relates to studies and research performed on managing buildings spaces. Adaptation to BIM and the potential use of the information found from BIM were studied, where an education office building management system was developed for operation and management [141]. BIM was also adopted to model the performance of open urban areas to evaluate resilience and smartness plans [142]. A model was developed to analyze social distancing in a built environment [143]. Other technological adaptations include a fusion of sensors for monitoring public spaces within smart cities [144] and an effect risk management system for large, crowded building spaces [145]. A framework was developed based on half-open spaces for urban ventilation and air pollutant purposes [146] and a framework for stakeholder engagement was proposed according to 12 ecosystem case studies [147]. For a sustainable future, the management of buildings was studied to support the 2030 agenda [148]. Conceptual studies were presented, and the potential changes to technologies for managing public spaces have been studied [149], where the consequences of shifting toward smart urban spaces have been determined.

3.4. Literature Review Summary

Table 4 shows the publications placed in their respective categories, which are building design, urban planning, city services, conceptual design and building management. Out of 141 publications, 48, 33, 29, 23 and 8 publications were sorted, respectively, into these categories. Further analysis was performed in order to understand the research trends. The topics of the categories were attained from two sources that are the smart city index and major architectural topics.

Table 4. Categorized authors and the general topics of research.

Category	Authors	Topics
Building design (48)	[54–68,71–73,78,94,102,115,150–171]	Green building performance; building space recognition; space heating systems; building floor space analysis; parking strategy; radiation analysis; life cycle and costs; simulation and optimization; HVAC
Urban planning (33)	[74,76,78,79,85–92,172–188]	Space planning; space utilization; spatial flow allocation; green space analysis; disaster evacuation; space development; urbanization; sustainability; housing price impact; spatial performance analysis; COVID-19; smart city
City services (29)	[94–100,102–116,118,119,121,160,163]	Heating demand analysis; spatial experience; satisfaction analysis; co-working spaces; autonomous development; safety perception; pedestrian volume analysis; building occupancy; space-use analysis; ventilation analysis; disability support; human behavior
Conceptual design (23)	[119–122,124–131,133–140].	Biomimicry; autonomous vehicle; smart green spaces; BIM; unused open spaces; smart city concept; smart city; transportation adaptation
Building management (8)	[141–148].	Ventilation and air pollution management; social distancing analysis; operation and maintenance; stakeholder engagement; safety in crowded buildings; sensors; 2030 agenda

The paper analysis shows that topics regarding the design of the building lean towards the application of BIM, numerical simulations and virtual analyses. It was found that research is focused on the application possibilities. Thus far, the majority of the studies adopted computational fluid dynamics (CFD) for environmental analyses. Moreover, finite element analysis (FEA) was used for energy-based simulations, including for the adaptation to Industry 4.0 and sustainable technologies such as solar power and solar utilization for amenities.

In general, research papers relating to planning for urban areas and building spaces showed hotspots related to the application of developing technologies and concepts with the aim of sustainability and heritage preservation and adaptation, the response to pandemics and the application of new technologies.

Studies that concerned occupants within buildings and residents in urban areas used technologies, such as BIM and GIS, to analyze the movement of people using numerical calculations and agent-based simulations. Also included was the impact of their application, user preferences and the expected results of applying developing technologies and simulations for a specific purpose such as HVAC and sustainability. Studies and research in academia have consistently demonstrated the significance of considering user perceptions in building environmental design and planning for smart cities to ensure informed decision making for a sustainable future.

Papers containing conceptual studies were presented to prepare for the adaptation to technology and smart cities. Technologies based on BIM included augmented and virtual reality based on digital twin models. Moreover, they also included fourth industrial revolution technologies to provide additional information to users of buildings and urban areas. For sustainable smart cities, green spaces were also studied based on guidelines for urban spaces. Also, green energy solutions, such as solar power, that reused void spaces within buildings were researched. Studies concerning the future of mobility and the transformation of buildings and urban areas have also been performed. Moreover, adaptation to automation and UAVs was researched to provide insights and processing and analysis methods for various aspects of mobility and public transportation. Other conceptual studies included biomimicry and analysis of significant factors of urban landmarks.

Studies within the management portion of the review adopted developing technologies such as BIM. They also included the development of frameworks and research toward compliance with upcoming agendas for managing and operating buildings and urban environments.

4. Discussion

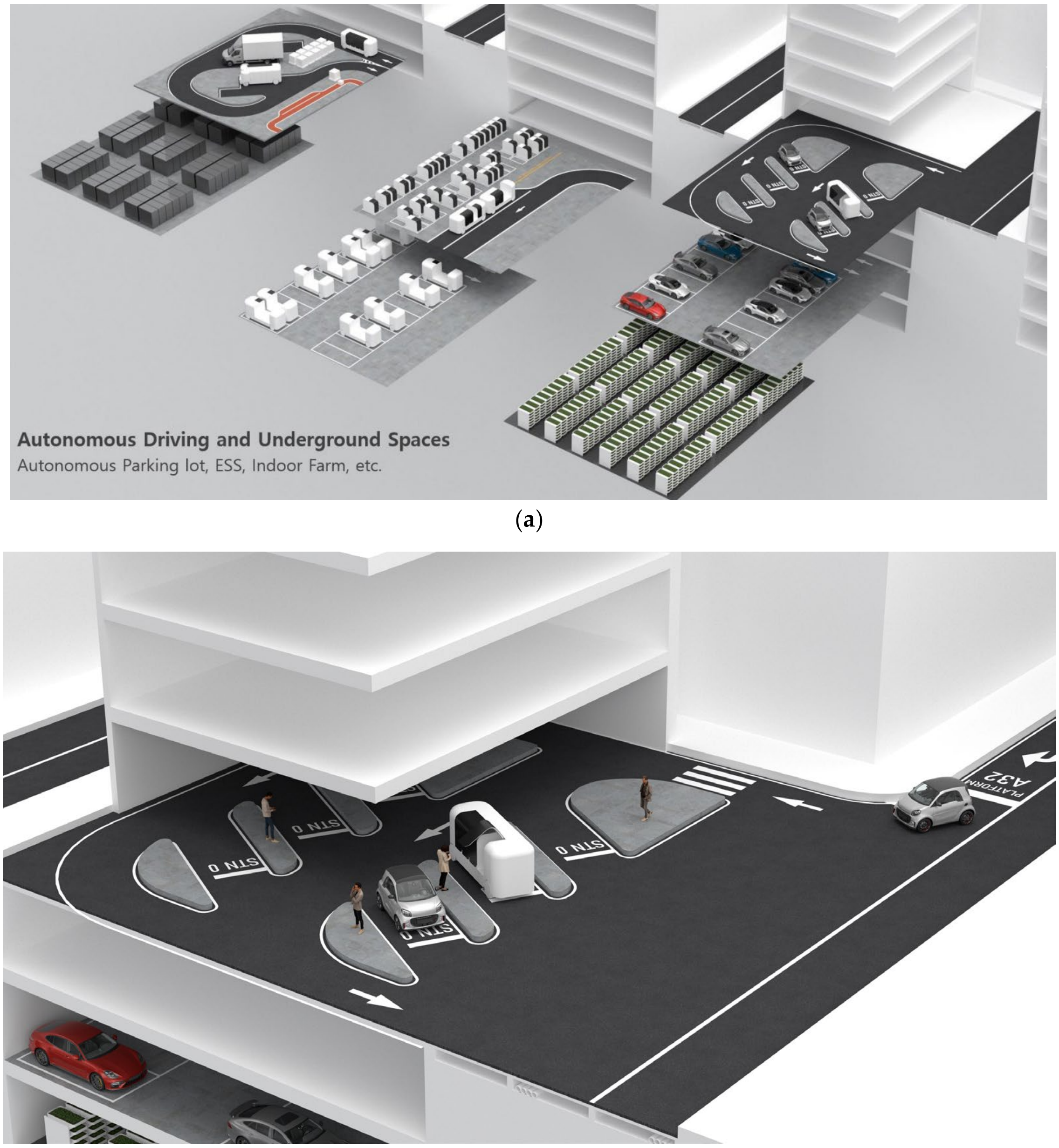
It was found that studies relating to smart cities and urbanism can be sorted into five categories, which are building design, urban planning, services, conceptual and management. Within these categories, a further analysis was conducted to determine the method and direction of the research. To answer RQ1, it was found that the majority of the studies were related to developing technologies, including BIM, virtual experiences and sustainability. On the other hand, studies regarding mobility and conceptual studies were relatively few. This shows a need for research on less studied topics in smart cities and even future cities that reflects the development of mobility technology.

For RQ2, one of the technologies that will be utilized in the future is the application of machine learning and artificial intelligence to assist in solving some of the issues of smart city planning and to provide services. At the time this paper was written, full utilization of these technologies was still in development for various applications such as autonomous driving, computer vision and robot developments. In this study, development of mobility is further highlighted, as it will have a direct impact on building architecture, urban planning and the quality of life of an individual.

Changes to the mobility paradigm are coming, with companies pushing the boundaries of autonomous driving. According to recent international technology advancements, purpose-built vehicles (PBVs) and unmanned aerial mobility (UAM) are thought to be some of the mobility technologies that will emerge in the future. This is particularly crucial as mobility has a symbiotic relationship with other areas of engineering such as infrastructure, traffic, architecture, urbanism and city planning. To answer RQ3, changes in the lifestyle of an individual are expected alongside the adaptation of physical environments for mobility technology. Figure 8 shows a conceptual design tailored for PBVs and future technologies.

In an underground parking space of a building, less space is expected to be required to provide parking spaces for building users. With fully autonomous driving, the need for the safety of humans and basic parking space dimensions will change as the need for drivers is eliminated. The extra space can be utilized to implement new technologies with the aim of sustainability, energy and mobility. In Figure 8, extra spaces are utilized to hold energy storage systems and indoor farms for sustainable building management. The capacity of the service determines the area of service, as it can even be extended beyond the building scale. Figure 9 shows another conceptual station at the entrance of the buildings related to the adaptation to PBVs. It shows drop-off zones, where passengers enter and exit autonomous vehicles. Providing such service areas has been shown to increase the flow rate of building users and shorten the distance travelled on foot.

RQ4 refers to the requirements for urban and building scale in preparation for the upcoming changes driven by the development of technologies. Continuing within the topic of mobility, building and urban infrastructures should account for adaptations for individual users. Figure 9 shows an example of a conceptual design based on public transportation with the potential of adopting PBVs and the effect it may have on an urban area. To support the PBVs, the hub includes service areas for maintaining the condition of a PBV unit. Showcasing various versions of the PBV in collaboration with businesses is considered in spaces with the most pedestrian traffic. Spaces for these stations are possible due to the less required space for parking, as this mobility system utilizes fully autonomous driving.

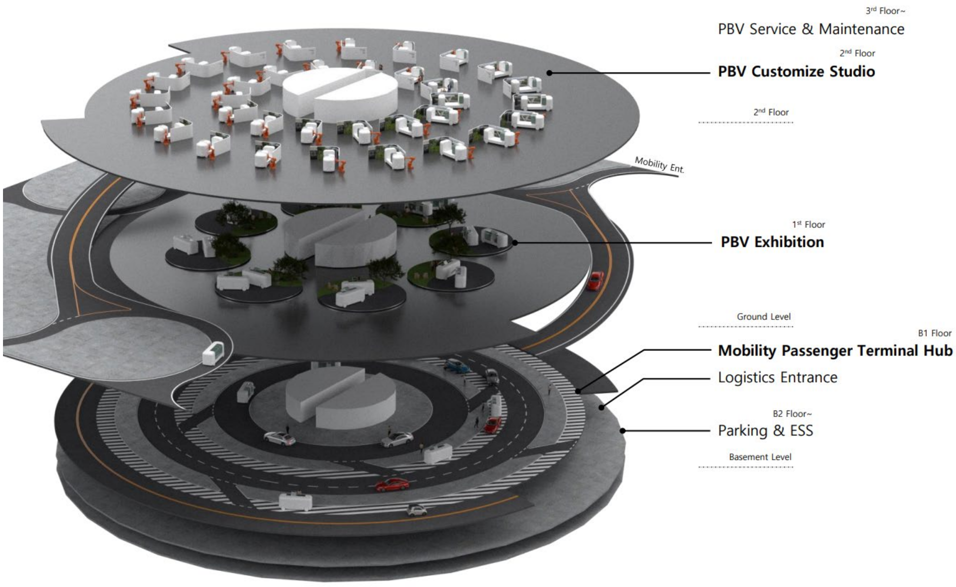


(**a**)

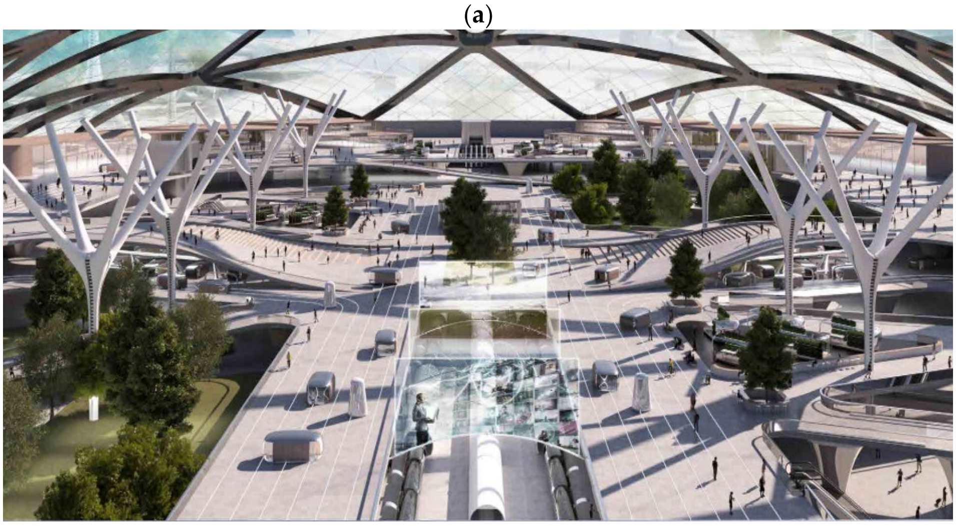
(**b**)

Figure 8. Conceptual building design adapting to PBVs. (**a**) Conceptual adaptation of underground parking space using developing technologies, (**b**) conceptual design of pick-up/drop-off area for PBVs and automated vehicles.

A conceptual vision for the change in urban area is also shown in Figure 9. Sustainability and the environment quality are considered in spaces with green areas. The space is also shielded to provide a controllable environment. Pedestrians and PBVs utilize the same elevated space for travelling purposes.



(**a**)



(**b**)

Figure 9. Conceptual design for building and urban infrastructure. (**a**) PBV hub showing use of space with respective purposes, (**b**) urban area based on PBV application.

5. Conclusions

In order to obtain ideas for the development of smart and even future cities, a systematic literature review is conducted following a combination of literature review methods provided by Kitchenham and the PRISMA statement. Research questions are created based on background studies regarding smart cities and emerging technologies. From two online academic journal databases, that is, web of science and SCOPUS, keywords relating to smart cities are searched. A total of 141 academic papers are found after the filtering and screening process. The papers were categorized into topics of study that included building design, urban planning, services, conceptual and management. Within these categories, the applied method and technology were further analyzed to investigate the trends in applied technologies. The research questions were answered based on the information gathered via the literature review, where example conceptual building and urban changes are included in the discussion.

The systematic literature review showed a trend in which researchers and academics are applying BIM in all categories, where it is utilized for computational numerical analyses and computer vision purposes. On the other hand, implementation of technologies that will influence an individuals' daily life and the adaptation of building and urban environments were found to be lacking, which shows the need for further research on these topics.

Modern mobility can be thought of as a system that combines developed technologies with the aim of realizing fully autonomous vehicles. One of the products that has been showcased at CES2020 is the idea of a PBV unit that provides space while in motion that is only possible with full automation. As modes of transportation are evolving, the infrastructure of buildings and urban environments should account for the changes needed to adapt the methods of mobility to improve residents' quality of life. Conceptual changes to buildings, purpose-built stations and urban environments are included within the discussion of this paper. The development of concepts has been realized by including BIM, which is capable of analyzing energy, traffic and pedestrian management. As a result, the contributions of this study are as follows: descriptions of current smart city statuses, emerging technologies as of the time this paper was written, research trends for smart cities and future urban areas, the effects technology will have on an individual and the requirements for the future in building and urban scale.

Further study is still required to validate the conceptual BIM and its effects in terms of multiple fields of engineering. The vision for future designs of urban areas should include both engineering aspects and services for residents and building users. This paper is limited to a conceptual design due to the inclusion of fully autonomous vehicle products. Therefore, it is necessary to envision beyond mobility to include other fields of academia beyond architecture, city planning and mobility. However, this study provides an insight into the development direction of future buildings, urban areas and future cities, which also includes prospective technologies that will bring about a change to the daily life of an individual.

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