CHAPTER
11

Bibliometric Analysis of AI Research in Sustainable Smart Cities

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11.1 Introduction

The concept of "Smart Cities" has become increasingly popular during the past decade [1]. One common definition of "smart cities" is urban areas that have successfully incorporated digital infrastructure upgrades. Its application, data management, transmission, and sensing layers were outlined by the authors [2]. Additional works broadened the concept's scope to encompass alternative theoretical frameworks. Smart Cities put their money into things like economic infrastructure, quality of life, human capital, excellent governance, and resource management [3]. Researchers [4] put Smart Cities in context by defining them with ICTs and the smartness footprint, which is a measure of the level of education and creativity in a city.

Enhanced quality of life is a common goal of smart city initiatives [5]. Its potential uses include enhancing transportation, urban infrastructure, quality of life, governance, and the allocation of resources, as well as the settlement of social problems [6]. The European Commission (2022) states that one of the main aims of smart cities

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is to reduce emissions. Achieving SDG-11, "Sustainable Cities and Communities," is one area where the idea can be useful. To achieve SDG-11's goals of social culture, urban metabolism, and good governance, smart cities provide a helping hand [7]. To achieve the SDG-11 objectives, authors [8] emphasised that smart technologies must be integrated into the following areas: smart people, smart transportation, smart environment, smart living, smart governance, and smart economy. The authors [9] of the SDGs have found that data collaborations in smart cities can help open doors to achieving these goals. In terms of keeping tabs on Smart City's progress, they offer credibility. Insightful information is also provided to decision makers by the data through statistics on traffic, waste management, climate, emissions, and disasters [10]. However, cybersecurity measures will be necessary to guarantee the long-term viability of such technology [11]. A city's sustainable tourism can also be enhanced by smart technologies. Better tourist attractions and more energy-efficient methods are the results of their efforts to optimise corporate processes, which in turn benefit the tourism industry [11]. The local quality of life will be enhanced as a result of the increased attraction, which will lead to the creation of jobs and the development of infrastructure.

"Smart Cities" are being implemented in cities all around the globe. The integration of wireless networks, smart houses, public services, green design, medical care, tourism, smart urban management, and smart urban management are the pillars upon which smart cities are built [12]. Worldwide, implementation action plans are visible. In 2001, Tampere launched e-Tampere, a development project that would last for five years [13]. Realizing a digital economy and creating job possibilities were two other ways the project boosted the city's economy. Meanwhile, Amsterdam's smartness footprint proliferated as the city encouraged businesses and innovations. Startups were encouraged to flourish by the city, which offered tax deductions to their employees. While Seoul backed tech companies and e-government services, Singapore launched its Smart Nation plan [14]. Notable linkages between Smart Cities and SDG-11 were pointed out by the authors [15]. The uses of ANN in Smart Cities have been covered in earlier literature reviews. However, there is a lack of knowledge about how they contribute to SDG-11's success.

This research intends to address that gap by reviewing current state-of-the-art artificial neural network (ANN) studies concerning smart cities and SDG-11. To evaluate the research papers, descriptive and content analysis are employed. The results of this study demonstrate important uses and point to avenues for further study.

11.2 Research Background

Some of the primary topics covered in this review are ANN and SDG-11. This part gives a synopsis by going over the main ideas and developments of the two topics. Subsequently, the review papers that came before this one demonstrate the prior conversations and emphasise the unique aspects of this review.

11.2.1 ANN

A pattern recognition technology that captures complicated correlations between the input and an output dataset is the Artificial Neural Network (ANN) [16]. It uses a mathematical model of neurons and their connections to simulate the operation of

a biological neural system. A typical ANN construction is illustrated graphically in Fig. 11.1. An artificial neural network's neuron uses activation functions to transform input data into output. The synaptic weights are the connecting connections that allow the neuronal data flow to propagate. Neurones that process the data inputted into the system are located in a layer called the input layer. As for the output layer, it's just a collection of neurons that generate data. The hidden layers sit between the input and output layers. Information that is relevant to both the input and the output layers is processed by the hidden layers. Next, the network is trained to achieve an acceptable performance by adjusting the synaptic weights between layers. Deep ANNs are ANNs with a large number of hidden layers [17]. They contain a far larger number of hidden layers, and deep ANNs are better able to extract features.

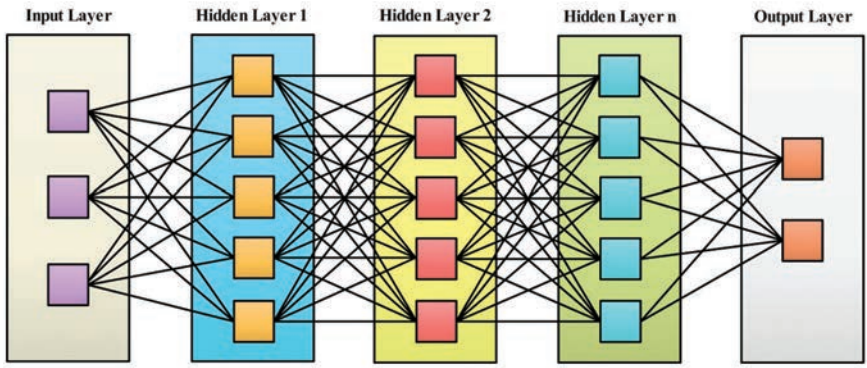

Figure 11.1: A visual depiction of a prevalent ANN architecture.

There is a wide variety of network structures used by ANNs. Specialized uses inform the design of each structure. The most popular structure is the Feedforward Neural Network (FFNN). Data flows in one way through the structure, from the input layer to the output layer [18]. Similar to FFNN, the added convolutional layer is the Convolutional Neural Network (CNN). Features with significant applications in image analysis can be extracted from datasets using convolutional layers [19]. Past results are a part of the input layers of a Recurrent Neural Network (RNN). Because of this new capability, RNN can now factor in temporal predictions while making predictions [20]. To solve the issue of vanishing gradients, RNN was extended to include Long Short-Term Memory (LSTM).

The three gates that make up an LSTM—the input gate, output gate and forget gate—take a longer time frame into account. To make an accurate prediction, LSTM finds the appropriate time interval and saves the corresponding previous data [21]. Like LSTM, Gated Recurrent Unit (GRU) models do not include cell state. Information is communicated between LSTM cells through cell state. Reset and update gates are part of GRU. According to authors [22], GRU decides what data is important to keep and what data can be deleted. Adaptive Neuro-Fuzzy Inference System (ANFIS) is a combination of a neuro-fuzzy inference system and an ANN. The goal of the integration is to make higher-level system estimation more accurate.

11.2.2 Sustainable Development Goal 11 (SDG-11) "Sustainable Cities and Communities"

To achieve sustainable development, there is a set of goals called as the Sustainable Development Goals (SDGs) (United Nations, 2015). The objectives stemmed from Brundtland's original idea of sustainable development (1987). The first objectives were proposed in 1991 by the concept through Agenda 21. The Millennium Development Goals (MDGs) brought this up-to-date in the year 2000 (United Nations, 2000). Considering environmental factors, social, and economic factors, the sustainable development goals were formulated in 2015. The target date for the completion of all seventeen SDGs was 2030.

Ensuring that human settlements are welcome, secure, resilient, and long-lasting is the aim of Sustainable Development Goal 11, "Sustainable Cities and Communities." The SDGs comprise a total of ten objectives and are subdivided into seven broad themes. This review's thematic analysis made use of the concerns listed in Table 11.1. According to the United Nations Habitat (2018) synthesis study, there are obstacles on the way to achieving SDG-11. Slum neighborhoods are experiencing a rise in population across many geographies. As the cost of housing continues to rise, the issue of affordable housing becomes more pressing. Road networks are inaccessible to one billion people, cutting them off from other forms of infrastructure. Land utilization is outpacing population increase at the same time. A decline in the standard of living for locals may ensue from this growth in tandem with sloppy city planning. The number of people killed or injured by natural catastrophes is on the rise, with floods causing the most economic damage. High-income countries are producing more garbage, with Asia expected to produce the most solid waste by 2030.

Table 11.1: Descriptions of SDG-11 themes

Theme	Explanation
Natural Disasters	Minimize the fatalities, losses of life, and economic impact resulting from catastrophic events
Transport Systems	Guarantee access to sustainable, economical, and safe transportation systems
Housing	Guarantee access to affordable, safe, and suitable housing
Environmental Impact	Reduce the ecological impact of cities
Cultural and Natural Heritage	The cultural and environmental heritage sites of the world should be preserved and protected
Urbanization	Promote sustainable and inclusive urbanisation
Green and Public Spaces	Provide accessible, inclusive and secure green and public areas to all individuals

In particular, gathering data is important for achieving SDG-11. Through the indicators, collected data shows how far along the path to SDG-11 we are. When gathering data, smart technology can be useful. Decision-makers can be aided by SDG-11 data. As an example, researchers [23] discovered that information about pricing strategies can help with garbage collection. Using big data to evaluate land use, which in turn shows how urbanised different cities are. Problems with data gathering are currently impacting several SDG-11 themes.

11.2.3 Past Review Papers

Prior research has surveyed the overarching and more specific topics of Smart Cities. Problems with cyber security, crowd counting, traffic monitoring and transportation systems, multiagent systems, the Internet of Things (IoT), and structural monitoring were among the topics covered by the deaggregated themes. In their overview of deep learning's potential uses in Smart Cities, the authors [24] offered some useful context. Their research showed that CNN was quite popular and that deep learning methods were becoming more popular.

Structured monitoring was the focus of previous literature reviews. The AI models for structural health monitoring were assessed by the authors [25]. As far as data collecting goes, they found unmanned aerial vehicles to be the most promising. 3D image reconstruction techniques of outside items. The results show the strong geometric-based approaches. Their research uncovered both free and paid programmes that can rebuild 3D images. IoT has been covered in previous reviews. The development of IoT for drones. Among the things they uncovered in their analysis was the importance of safe data transfer between cloud services and drones. A comprehensive evaluation on object detection of multimedia IoT was conducted by the authors [26]. After reviewing the literature, they concluded that existing models are slow and that it is essential to detect items that cannot be seen. Previous literature reviews also include multiagent systems. The Internet of Things scalability issue and recommendations for more research on distributed algorithms. Unmanned aerial vehicle (UAV) path planning was systematically reviewed by the authors [27]. As part of their assessment, they suggested a framework for overseeing Smart City essentials.

Among the most common topics covered in earlier reviews are transportation networks. Methods using machine learning to understand how electric vehicles charge. Public charging statistics and methods for predicting driving patterns are both inadequate, they discovered. Finally, methods are discussed for the structural analysis of traffic videos. Using traffic video structure analysis smart transport, they indicated its importance [28]. Finally, discussions of crowd management and cybersecurity have been covered in earlier reviews. Deep learning for Smart City cybersecurity was the main focus of the authors [29]. They found that deep-learning models had better accuracy. They highlighted the fact that feature extraction and data reduction to lower dimensions might be accomplished with the help of deep learning models. The majority of the review articles focused on Smart Cities and SDG-11's disaggregated thematic issues. Using bibliometric analysis, this evaluation was unable to locate any literature dealing with SDG-11 in its broadest sense. Therefore, this work's originality lies in its use of ANN to the overarching goal of SDG-11, which is to build smart cities.

11.3 Bibliometric Methodology

Previous reviews, descriptive analysis, and content analysis make up this review. Preexisting review paper structures serve as the basis for the review process [30]. Reviews on the topic that are comparable to this one can be found in previous publications. The descriptive analysis presents an evaluation of the subject using metrics. This part contains things like the trend in publications and citations, cluster analysis, the works that have been cited the most, the nations that have published the most, and the journals that have published the most. At the same time, research

trends described in pertinent publications are incorporated into the content analysis. The bibliometric methodology is shown in Fig. 11.2.

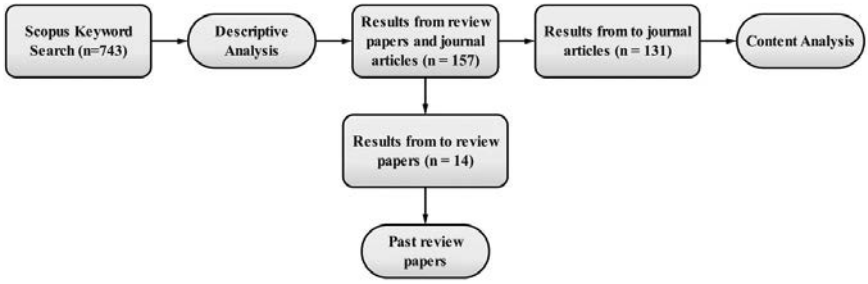

Figure 11.2: A bibliometric approach to the retrieval of documents concerning ANN for Smart Cities in the pursuit of SDG-11.

Research articles found in the Scopus database were evaluated in this review. Scopus is the only database that we can access, even though WoS is the most popular ones. Scopus has coverage in just as many academic disciplines as WoS. To top it all off, Scopus uses an external board to screen publications, guaranteeing high-quality content. Scopus document retrieval allows for an examination of comprehensive coverage with credible references.

Bibliographic linkages or citations between documents are not reflected in Scopus, which is a restriction of the database. This review only includes works that were published in the first half of 2022 or before. Publications published before the formation of the SDGs in 2015 were included in this assessment to capture previous efforts that might also target SDG-11. In this investigation, the terms "neural network," "smart," "city," "urban," and "metropol*" were used in a targeted search. The integrated SDG-11 query from Scopus is also provided. Research on artificial neural networks is encompassed by the term "neural network." Searches involving the combination of the terms "smart" and "city," "urban," or "metropol*" will provide research on SCCs. **Urban** and **metropol*** are provided as possible alternatives to **city**. The research about the themes of SDG-11 is incorporated into the SDG-11 inquiry. Even if a study didn't use the keyword "SDG-11," the authors fine-tuned the query to include all relevant results. The materials that were retrieved are used for descriptive analysis in this evaluation.

Review papers and journal articles were obtained after the first Scopus search. We extracted journal articles published by Elsevier for this content analysis. It was determined that the highest number of journals were those published by Elsevier. The evaluation of previous review studies made use of the review articles. The content analysis makes use of the journal articles. The categories utilised in the text analysis to categorise the ANN functions discovered in the academic papers are detailed in Table 11.2.

11.4 Descriptive Analysis

Table 11.3 shows that the trends in publication and citation have been increasing exponentially over the past five years. The SDGs, which were established in 2015,

Table 11.2: Description and function of ANN

Function	Description
Control	System management in real-time
Meta-Model	Serve as a substitute model in place of a given formula or simulation.
Forecasting	Develop continuous variables as the output by identifying the relationship between data sets (using a temporal variable).
Classification	Identify the correlation between data sets and generate discrete variables as the result.
Modeling	Generate continuous variables by establishing a correlation between datasets.

Table 11.3: The retrieved documents publication and citation trends

Year	Publication	Citation
2018	64	152
2019	161	365
2020	322	1085
2021	577	2883
2022	744	6503

were said to be responsible for the exponential surge (United Nations, 2015). Notable published works were subsequently published as a result of this (i.e., the most referenced works were published in 2018). The topic's academic interest began with the significant works and then snowballed.

Using the keywords illustrated in Fig. 11.4, we conducted a cluster analysis of the documents retrieved by the index. Six distinct groups were shown by the cluster map created by the programme VosViewer. Urbanization, the transportation system, and environmental impact are the SDG-11 issues that the cluster focuses on. Images, semantics, anomaly detection, security systems, and feature extraction were all part of Cluster 1. Transportation of electricity, dwellings, garbage disposal, and water management were all part of Cluster 2's urban infrastructure keywords. Keywords related to urban planning, such as study of satellite images were found in Cluster 3. Cybersecurity, sensor nodes, smart homes, and other Internet of Things infrastructure made up Cluster 4. Cluster 5 included transportation-related keywords including congestion, regulation, and prediction. The sixth cluster was highly interdependent on the others. Decision-making, optimization and Energy efficiency were all part of the cluster.

As indicated in Table 11.4, the publications with the highest citation counts were published between 2016 and 2020. In alignment with the themes discerned through the text analysis, the authors addressed the components of SDG-11 about environmental impact, transportation system, and urbanization. Urbanization was the subject of half of the most-cited books that dealt with SDG-11.

Table 11.4: Highest cited research works

Title	SDG-11 theme	Journal	Citation	Reference
Distributed attack detection scheme using deep learning approach for Internet of Things	Transport System	Future Generation Computer Systems	665	Diro and Chilamkurti (2018)
Predicting electricity consumption for commercial and residential buildings using deep recurrent neural networks	Environmental Impact	Applied Energy	512	Rahman et al. (2018)
A deep CNN-LSTM model for particulate matter (PM2.5) forecasting in smart cities	Environmental Impact	Sensors (Switzerland)	453	Huang and Kuo (2018)
An ensemble intrusion detection technique based on proposed statistical flow features for protecting network traffic of internet of things	Urbanization	IEEE Internet of Things Journal	298	Moustafa et al. (2019)
A novel CNN based security guaranteed image watermarking generation scenario for smart city applications	Urbanization	Information Sciences	258	Li et al. (2019a)
Deep cognitive perspective: Resource allocation for noma-based heterogeneous IoT with imperfect SIC	Urbanization	IEEE Internet of Things Journal	205	Liu et al. (2019)
A comparative study of PSO-ANN, GA-ANN, ICA-ANN, and ABC-ANN in estimating the heating load of buildings' energy efficiency for smart city planning	Environmental Impact	Applied Sciences (Switzerland)	218	Le et al. (2019)
Machine Learning Adoption in Blockchain-Based Smart Applications: The Challenges, and a Way Forward	Urbanization	IEEE Access	226	Tanwar et al. (2020)

The most referenced studies on environmental impact used ANN to predict energy consumption and emissions. Emissions of PM2.5 from Smart Cities: a CNN-LSTM architecture for prediction. Hybrid architecture outperformed other ML techniques, including Random Forest (RF), Support Vector Machines (SVM), and Decision Tree (DT), according to their research. A deep RNN for predicting power usage in the

medium to long term. For commercial building electricity usage predictions, the deep RNN architecture was superior to FFNN. Various artificial neural network (ANN) models for heat load forecasting in buildings are compared. The most effective model outperformed the others when it was paired with an ANN algorithm and a genetic algorithm.

Urbanization was the subject of the majority of the most quoted articles about SDG-11. Building better infrastructure is a key component of urbanisation, and vice versa. The sustainability of urbanisation can be impacted by the progress made in infrastructural development. The majority of the most-cited publications in this evaluation dealt with digital and healthcare infrastructure applications of ANN. They used ANN in healthcare systems, image processing, cyber-attack detection, and the Internet of Things (IoT) infrastructure. When it came to watermarking photographs and identifying who was responsible for them, the model performed better. The authors achieved a 93.5% success rate in ECG detection using a wavelet CNN. We spoke about the possibilities of ANN for blockchain technology. Smart cities, manufacturing, and customer service were among the areas where their work was most useful. The authors [26] assigned resources to Internet of Things (IoT) systems utilising nonorthogonal multiple access technology by employing deep RNN. The model made the technology more efficient in its use of the spectrum.

The nations that have published the most research are listed in Fig. 11.3. With 274 research papers, China produced more publications than any other country. The country's Smart City projects were credited with a substantial amount of publications. The implementation of Smart City development was undertaken by the Ministry of Housing and Urban-Rural Development of the nation, among other cities that were under consideration. India had 94 research works, placing them second. India has taken steps towards becoming a Smart City, much like China. The Smart Cities Mission was launched in 2015 by the nation. Ensuring environmental sustainability, providing an acceptable quality of life, and establishing key infrastructures are all part of the mission's focus on smart technologies. With an average of 118 citations per publication, the US ranked highest in citation efficiency.

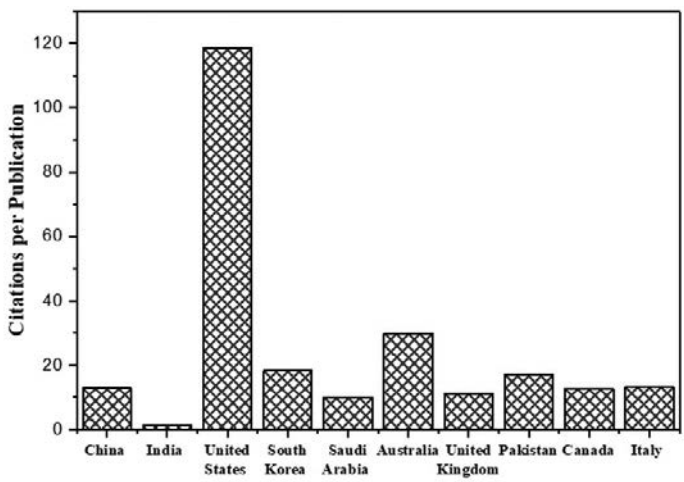

Figure 11.3: Evaluation of publication with different countries.

Among the most widely read journals, Fig. 11.4 displays the total number of publications. Image and video analysis, sensors, and the Internet of Things (IoT) provide the bulk of the journal articles' content. Transportation networks and environmental responsibility were the subjects of other discussions. The subject matter addressed aligned with the overarching themes discerned by the content analysis, namely environmental effect, transportation, and urbanisation.

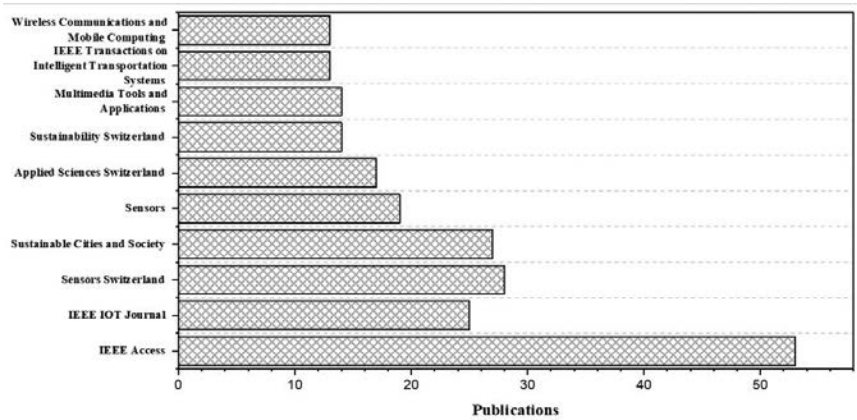

Figure 11.4: Comparison of journals with the number of articles published.

11.5 Analysis of Content

The distribution of themes from the SDG-11 content analysis is shown in Table 11.5. No research was identified about Natural and Cultural Heritage, as well as Green and Public Spaces. 43.88% of the topics discussed were related to urbanization. The remarkable distribution of Smart Cities contributes to the enhancement of the Internet of Things and ICT infrastructures. The analysis of journal papers revealed that 28.06% of them focused on the environmental impact. This discovery emphasises the focus on the possibility of Smart Cities to reduce emissions to the environment. The majority of the journal papers (25.16 %) were about transport systems. Its substantial proportion is attributable to the effect that Smart City technologies have had on the transportation sector. Two and a half percent of the scholarly articles dealt with natural disasters. The three most common artificial neural network (ANN) tasks identified were modelling classification, and forecasting (Table 11.6). Table 11.7 shows that there is a preference for a certain ANN function for each SDG theme. Various applications make use of modelling, whereas picture and video processing dealing with urbanisation

Table 11.5: Distribution of SDG-11 themes derived from the content analysis

Factors	Percentage (%)
Natural Disasters	2.16
Transportation	25.18
Environmental impact	28.06
Urbanization	43.89

Table 11.6: Distribution of ANN functions derived from content analysis

Factors	Percentage (%)
Control	3.01
Meta-Model	3.01
Forecasting	20.30
Modelling	33.08
Classification	40.60

Table 11.7: Functions of ANN within SDG-11 themes

SDG 11 Themes	Modeling	Meta-model	Forecasting	Control	Classification
Environmental Impact	34	20	19	5	3
Housing	1	-	-	-	-
Natural Disaster's	4	-	-	-	3
Transport Systems	34	23	22	-	11
Urbanization	60	43	41	39	37

frequently make use of classification. Research on the effects on the environment and transportation systems that focused on energy consumption, traffic patterns, and emissions all turned up predictive models.

Table 11.8 shows the network architectures that were discovered by the content analysis. Environmental Impact makes use of the common network structure, FFNN, for forecasting purposes. Concurrently, studies on urbanisation and transportation systems have investigated other network topologies, such as convolutional neural networks (CNNs) for detection and classification purposes. The study studies that delved into the intricate challenges surrounding the two SDG-11 themes used hybrid architectures. Themes also included deep network topologies, usually using deep CNN and deep FFNN as seen in Table 11.9. Urbanization-related research contains the greatest number of instances in which deep network topologies were implemented.

11.5.1 Environmental Impact

Predictions of heat load and energy demand were made using ANN in journal articles. ML models for predicting the amount of heat that buildings produce. The validity of FFNN for two-day building heat load forecasting was established by their results. To predict how much power homes and businesses would use, the authors employed RNN. Their prediction was for a period longer than a week. Their research showed that compared to FFNN, RNN achieves better accuracy. ANN is utilised as a meta-model for HVAC in space. Computing time was cut in half using the meta-model. Articles in the journal created hybrid models that performed better than competing ML models. The energy systems' short- and long-term energy demand can be predicted using a bidirectional LSTM and a dilated CNN. When pitted against SVR and Adaptive Boosting, the hybrid model came out on top (AdaBoost). For household energy consumption forecasting over the medium to long term, an attention-based

Table 11.8: Structures of ANN networks among SDG-11 themes

SDG-11 Themes	CNN	FFNN	RNN	GRU	LSTM	ANFIS	Hybrid	Other
Environmental Impact	16	36	-	10	9	4	2	-
Housing	-	1	-	-	-	-	-	-
Natural Disaster's	1	-	-	-	-	-	-	-
Transport Systems	24	33	14	-	13	-	8	3
Urbanization	27	42	10	-	8	-	5	3

Table 11.9: Structures of deep ANN networks among SDG-11 themes

SDG-11 Themes	Deep CNN	Deep FNN	Deep RNN	Hybrid Deep	Other Deep
Environmental Impact	-	5	-	-	-
Housing	-	-	-	-	-
Natural Disaster's	-	2	-	1	-
Transport Systems	5	-	-	-	1
Urbanization	8	20	2	-	1

LSTM was trained. Models like SVR, RF, and AdaBoost were surpassed by the model. While ANN was shown to be useful in these investigations, other journal publications indicated that other ML models were preferred.

Additional uses in the energy sector included power generation and distribution. The use of ANN in stabilising power systems, upgrading solar power plants, and predicting heating value was covered in journal publications. Compared to a lead-lag controller, the ANFIS controller was more effective in dampening oscillations. An ANN consensus mechanism for blockchain-based energy trade was developed by researchers. Other ML models' preferences in energy generation were also disclosed in journal articles. The Committee Machine Intelligent System outperforms the others when it comes to predicting the heating value of MSW. There were journal articles that used ANN to improve air quality. Researchers used a combination of the Anti-Autoencoder and LSTM to predict the spatial distribution of air pollution among nearby cities. When compared to competing structures, the integrated structure did better (e.g., CNN-LSTM). Used deep LSTM to model how air pollution affects people. An accuracy ranging from 90% to 96% was achieved by their model.

To simulate sewage treatment plants' chemical oxygen requirement, researchers contrasted ML models. They discovered that GRU performed better. The use of a hybrid LSTM framework to predict the amount of water needed by cities. Several ML models, including RNN, FFNN, and SVM, were surpassed by the hybrid model.

11.5.2 Transport Systems

Applying ANN to traffic forecasting, vehicle classification, and route planning is a current trend in traffic management research. A model that combines cellular automata with artificial neural networks to simulate traffic flow. When it came time to install smart traffic signals, their model took those limitations into account. When compared to methods like the Historical Average, the LSTM achieved respectable accuracy in predicting trip time abnormalities (HA). The traffic flows of Smart Cities were forecasted using an integrated CNN and LSTM model. After comparing the hybrid model to HA and AIR (Autoregressive Integrated Moving Average), they found that it performed better (ARIMA). They stated that their model simplified route planning by reducing its computational complexity. Their model's intended use was in autonomous monitoring systems. The best solutions for a connected car environment meta-model developed by using CNN. Predicting taxi flows in space and time using CNN and LSTM integrated. Their results demonstrated the model's superiority over competing models like FFNN, Extreme Gradient Boosting (XGBoost), ARIMA, and HA.

Researchers in the fields of road evaluation and vehicle studies also frequently employed CNN. To classify road deterioration, researchers used convolutional neural networks (CNNs). This led to the development of a multi-labeling technique of vehicle features, which helped identify road degradation quickly and cheaply. For autonomous vehicle 3D object identification, authors employed CNN. Modeling vehicle-emitted carbon emissions: a comparison of BPNN and AdaBoost, two ML methods. FFNN achieved better prediction results than AdaBoost.

11.5.3 Urbanization

Publications about infrastructures have described and used ANN for lighting system control and infrastructure characterization and management. The goal of using ANN to

regulate streetlights is to lower their energy consumption. The controller's utilisation of ANN and fuzzy logic principles resulted in a 34% reduction in energy consumption when compared to traditional systems. Compared to SVR and linear regression, the ANN model achieved a 98.7 percent accuracy level. In their study, researchers used metropolitan factors to forecast the heights of buildings. They hoped that this multi-dimensional study would be useful for city planning. In comparison to RF, the ANN model outperformed it.

Recent studies on sensors have focused on ways to enhance mobile device image processing and other related areas. An innovative convolutional neural network (CNN) for creating digital image watermarks. Through image segmentation, CNN was able to summarise videos. This method can be used to summarise footage from Smart City surveillance systems. To determine whether a mobile device is inside or outside, researchers used ANN. When tested in a real-world setting, the model's accuracy reached 90%. Articles in academic journals have introduced ANN as a tool for societal evaluation. Modeling sentiment analysis from text messages makes use of a variety of ANN structures. According to their findings, CNN is the most effective structure. When compared to ML models including AdaBoost, Random Forest, and k-NN, deep FFNN produced superior diagnostic outcomes. Internet of Things (IoT) device activity was categorized by researchers using RNN. A precision of 94.43% was achieved by the model when it came to activity classification. For this social network model, an ANN graph architecture was used. Data mining analysis can make use of the created model. Use artificial neural networks to identify people while in motion. They found that DT is more effective than ANN for detection.

Health and urban development were two more areas where the Urbanization theme found use. To make diagnoses utilising medical records, researchers employed ANN. When pitted against k-NN, SVM, and DT, the model achieved superior accuracy. Healthcare survey semantic analysis using a Siamese LSTM. Finding survey question duplication was the goal of the model. The detection accuracy that their suggested model achieved was 86.38%. Smart city growth trends were modelled using BPNN by Li et al. (2019b). They identified important factors impacting urban development metrics using ANN. Combining convolutional neural networks (CNNs) with belief networks for urban acoustic classification. A variety of auditory stimuli, including hydraulic hammers, engine noises, and wind noises, can be classified by the model. Comparatively, the integrated model outperformed SVM and ELM with accuracies ranging from 92.88% to 100%.

11.5.4 Housing and Natural Disaster

Only one journal article is devoted to housing, and the category of natural disasters has the fewest. Using a variety of ML methods, researchers estimated home prices. They found that ANN is the most effective in predicting neighborhood-level home prices. In the meantime, RF is the way to go for regional size. The use of ANN in disaster management and hazard identification during natural disasters is possible. Use a convolutional neural network (CNN) model to locate earthquake survivors. After comparing CNN with SVM, they found that CNN accomplished more. By analysing data collected from IoT devices, we were able to forecast potential fire threats in Smart Cities. They used an integrated LSTM and a deep belief network to accomplish their goal. A 98.4% detection accuracy was achieved.

11.6 Discussion

11.6.1 Scopus-integrated SDG Query and Insights on Publishing Trends

Research into ANN as a means to achieve SDG-11 of Smart Cities is anticipated to take an upward trend. Deceleration is not apparent in the publication and citation patterns, which reflect the predicted rise. Clusters forming when published works tackle certain thematic applications boost the expansion. The fact that feature extraction forms the maximum cluster in cluster analysis suggests that it will have a significant influence on future studies. The study of feature extraction is of great importance for future studies, given the widespread use of smart technology in Smart Cities.

A significant quantity of publications were acquired by the integrated SDG query of Scopus. In comparison to authors' keyword search, this query yielded a greater number of documents (2022). The SDGs were referred to as "SDG" and "sustainable development goals" in their description, whereas SDG-11 terms like "disaster risk reduction," "natural heritage," and "collaborative planning" were found in the Scopus search engine. Therefore, the evidence demonstrates that the integrated SDG query is highly dependable.

11.6.2 Analysis of the Principal SDG-11 Themes

The issues of transportation systems, environmental impact, and urbanization are significant concerns for the SDG-11 of Smart Cities. Their significance was highlighted using cluster analysis, content analysis, and most cited publications. The emphasis on Environmental Impact aligns with the concept of Smart Cities as defined by the European Commission (2022). As a result, building Smart Cities must take environmental sustainability into account. Transportation Systems is one of the most well-known publications on the subject. The significance of transportation in Smart City planning is consistent with this discovery. For Smart Cities to be a success, smart transportation must be implemented. The characteristics of Smart Cities are congruent with the centrality of urbanisation to the results of this study. Urbanization and smart cities are highly interdependent on one other. They disagreed on the part of Smart Cities in ecologically conscious urban development.

Sustainable Development Goals (SDGs) 11 of Natural and Cultural Heritage and Green and Public Spaces were not found in either the descriptive analysis or the content analysis. Existing literature suggests the promise of ANN, even though there are study gaps on this issue. Preexisting literature highlighted the importance of parks and other green areas in Smart Cities. We talk about the possibilities of green areas in India's Smart Cities. The benefits of using wireless sensors to keep tabs on city parks and trees were highlighted. They augmented it with the benefit of smart technologies that allow urban woods to self-regulate. The classification of green spaces can make use of big data. Consequently, ANN's potential use in Smart City green space monitoring and management could be the subject of future research. Additional scholarly works on the subject of cultural and natural heritage emphasise the possibilities of ML methods and smart technology. The use of intelligent technology to link individuals with their cultural heritage (for example, augmented reality). It was discovered by them that historical artefacts may be preserved and restored through the use of 3D imaging. Intelligent technological features that can promote heritage sites

as tourist destinations. Relevant for tourism, according to them, are the qualities of being accessible, interactive, educational, and personalised. Using machine learning to recognize monuments and enhance their visual representation of cultural treasures. One of the issues discussed was the utilization of intelligent decision support systems for evaluating historical buildings and providing assistance and recommendations to visitors.

11.6.3 The Results of the Content Analysis

The content analysis revealed a general trend in the use of ANNs. Three takeaways from the content analysis were made note of in this work. To begin, the location of the application was the primary emphasis of the journal publications (such as a city- or region-wide implementation). Research that used ANN made use of both real-world and simulated data. A thorough evaluation of the model's usefulness can be achieved through testing on real-world data. However, there are limitations to real-world data due to its spatial and temporal characteristics. Adoptability to other locations, including undeveloped nations, requires validation of other real-world facts. Additionally, the computational efficiency of ANN is a key component of its use in research. The use of ANN allowed for a simultaneous decrease in computation time and budgetary cost. Several studies have shown that ANN could stand in for a specific compute method's meta-model. Since computing time is crucial in implementing smart technologies, future research is likely to take advantage of this property. Thirdly, the journal articles suggested hybrid models. Despite the availability of ANN structures, some journal publications have suggested hybrid ways to overcome the shortcomings of these structures. When compared to homogenous structures, hybrid models frequently achieved superior performance. If the modelling strategy improves ANN's performance compared to other ML models, it might be useful for comparative research.

11.6.4 Research Prospects about the Distinct Themes of SDG-11

Several aspects of SDG-11 are clarified by the results of the content analysis. The use of ANN yielded mixed results when compared to other machine learning models for predicting energy demand, solar radiation, and environmental effects. It is possible to get better results by evaluating different ANN topologies, such as hybrid models. The content analysis revealed a dearth of applications of ANN in trash management. The sustainability of Smart Cities depends on effective waste management, making its use relevant. Some possible uses of ANN include garbage sorting and the modelling of waste calorific values. It is possible to model municipal waste management systems using ML approaches. Lots of transport systems use convolutional neural networks (CNNs) and long short-term memory (LSTMs). Their application highlights how feature extraction applies to this subject. Environmental Impact and Urbanization were some topics covered in journal articles with this theme. Models in emissions forecasting and transportation-related IoT were created by them. Therefore, future research on transport systems can cover a wide range of SDG-11 topics. Numerous theme applications were the focus of research studies in the field of urbanisation. Almost all studies focus on how to use IoT and other forms of information and communication technology. Their significance corresponds to the fundamental concept of "Smart Cities," which predominantly utilizes intelligent technological solutions. Additional

academic research employing ANN in the field of healthcare infrastructure. There is a wealth of big data related to healthcare stored in healthcare systems. Research in the future can make use of this mountain of data to bolster smart healthcare systems. The journal papers included in Natural Events only covered a small selection of disasters. Further research can examine various natural catastrophes that happen in different parts of the world (for example, typhoons, flooding, and volcanic eruptions).

11.6.5 Additional Paths of Research

While the review did find several uses for ANN, there aren't many examples of them in the literature just yet. The part that companies, namely retailers, play in helping Smart Cities achieve SDG-11 is noticeably absent from the current discourse. The idea and physical space needs of stores will be impacted by smart technologies like e-commerce. The urban system might undergo significant modification as a result of the influence. According to interviews conducted by researchers, smart technologies play a crucial role in ensuring that retail malls are environmentally sustainable. The potential of these technologies to reduce energy and water usage as well as trash generation is something that stakeholders are looking forward to.

Retail businesses can greatly benefit from smart technology that streamlines their organisational processes and enhances their sales activities. Physical establishments can reach more customers with the help of technologies like online platforms. Improving customer happiness and operationalizing tacit experiences are two potential applications of ANN. Production planning and retail control can both benefit from ANN's utilisation. One school of thought in urban planning has looked at Smart City technologies and how they may be used to foretell how retail rules will change and how stores themselves will develop. Applications of smart technology, such as ANN, for the sustainable growth of retail outlets, have also been discussed in the literature. Uribe-Toril et al. (2022) predicted the long-term viability of companies that implement Circular Economy (CE) principles. AI was employed to assess the sustainability hazards associated with the fresh grape supply chain. The literature demonstrates the potential for using smart technologies to promote sustainability in the retail industry. The study's lack of discussion on the relationship between SDG-11, retail locations, and smart cities emphasizes the necessity for more investigation into the topic.

11.7 Conclusion

To gauge progress towards SDG-11, this review surveyed the existing literature on artificial neural networks (ANN) and their potential application in smart city infrastructure. To find the right documents, a methodology based on keywords was utilised. We used descriptive statistics and content analysis to score the papers. The results showed that there is a growing trend of significant research interest in the area. Since groups focusing on certain subject aspects have emerged, we can anticipate an uptick in related research. Based on this analysis, the Sustainable Development Goals (SDGs) that are considered most crucial are Transportation Systems, Environmental Impact, and Urbanization (SDG-11). Shortages in research were found in the areas of Natural and Cultural Heritage and Green and Public Spaces, which are both elements of SDG-11.

The results of the content analysis led to the discussion of three key points. One issue is that applications are usually limited to a specific area. The application needs to be validated in different locations before it can be widely used. The second reason ANN is preferred is that it requires less computing power. ANN may be considered in future research as a means to speed up already-established computation methods. Thirdly, to get beyond the constraints of the current ANN architectures, research efforts have made use of hybrid models. When compared to heterogeneous architectures, hybrid models performed better. The results of this study are constrained by Scopus's ability to disclose bibliometric relationships between documents. Research works inside a cluster will be shown to be relevant through the bibliometric linkages. The primary research works of the created clusters will be brought to light by evaluating the bibliometric relationships. The bibliometric relationships may be revealed in future review articles by using different databases. Most of the research papers offered solutions to the problems raised by SDG-11. To find out how serious they are about reaching SDG-11, we need to see how their implementation turned out. The effectiveness of the implementations and their ability to resolve the aim may be examined in future works using cross-validation.

References

1. Zhang, Q., Liu, S., Wang, T., Dai, X., Baninla, Y., Nakatani, J. and Moriguchi, Y. 2019. Urbanization impacts on Greenhouse Gas (GHG) emissions of the water infrastructure in China: Trade-offs among Sustainable Development Goals (SDGs). *J. Clean Prod.*, 232, 474–486.
2. Ruggieri, R., Ruggeri, M., Vinci, G. and Poponi, S. 2021. Electric mobility in a smart city: European overview. *Energies* (Basel), 14(2).
3. Kadaverugu, R., Dhyani, S., Dasgupta, R., Kumar, P. and Matli, C. 2022. Urban sustainability and resilience building: Blue-green infrastructure for air pollution abatement and realizing multiple co-benefits. *In:* Blue-Green Infrastructure Across Asian Countries: Improving Urban Resilience and Sustainability. 397–417.
4. Anand, J., Aasish, C., Syam Narayanan, S. and Asad Ahmed, R. 2023. Drones for disaster response and management. pp. 173–196. *In:* Saravanan Krishnan, M. Murugappan (Eds), *Internet of Drones,* 1st Edition. CRC Press.
5. Sharma, A., Mohapatra, S., Pawar, T. and Ji, S. 2023. Aligning the criteria of UNSDG's Goal 11 with vernacular habitats of North-East India. *In:* Smart Innovation, Systems and Technologies. 1205–1213.
6. Goel, R.K., Yadav, C.S. and Vishnoi, S. 2021. Self-sustainable smart cities: Socio-spatial society using participative bottom-up and cognitive top-down approach. *Cities*, 118.
7. Bailey, J., Ramacher, M.O.P., Speyer, O., Athanasopoulou, E., Karl, M. and Gerasopoulos, E. 2023. Localizing SDG 11.6.2 via earth observation, modelling applications, and harmonised city definitions: Policy Implications on Addressing Air Pollution. *Remote Sens* (Basel), 15(4).
8. Maranghi, S., Parisi, M.L., Facchini, A., Rubino, A., Kordas, O. and Basosi, R. 2020. Integrating urban metabolism and life cycle assessment to analyse urban sustainability. *Ecol Indic*, 112.
9. Rodriguez-Spahia, D. and Barberet, R. 2020. Inclusive and safe cities for the future: A criminological analysis. *In:* The Emerald Handbook of Crime, Justice and Sustainable Development. 223–241.

10. Jain, A., Gue, I.H. and Jain, P. 2023. Research trends, themes, and insights on artificial neural networks for smart cities towards SDG-11. *J. Clean Prod.*, 412.
11. Malik, M.U., Rehman, Z.U., Sharif, A. and Anwar, A. 2024. Impact of transportation infrastructure and urbanization on environmental pollution: Evidence from novel wavelet quantile correlation approach. *Environ Sci. Pollut Res. Int.*, 31(2), 3014–3030.
12. Moyeenudin, H.M., Narender, M., Amutharaj, J., Hari Kumar, S. and Jose Anand, A. 2023. Comparative Analysis of Video Transmission in Vehicular Networks using IEEE 802.11g and IEEE 802.11p Standards. *In:* 2023 First International Conference on Advances in Electrical, Electronics and Computational Intelligence (ICAEECI). 1–7.
13. Maheswari, R., Pughazhandhe, M., Ragavan, S., Sasikaran, R., Siva, S. and Jose Anand, A. 2023. Augmented Reality Home Automation Using AR Switches with IoT. *In:* 2023 International Conference on Self Sustainable Artificial Intelligence Systems (ICSSAS). 1681–1688.
14. Singh, A., Kanaujia, A., Singh, V.K. and Vinuesa, R. 2023. Artificial intelligence for Sustainable Development Goals: Bibliometric patterns and concept evolution trajectories. *Sustainable Development*. https://onlinelibrary.wiley.com/doi/full/10.1002/sd.2706
15. Guo, J. and Peng, X. 2023. Status of research on Sustainable Development Goal 11: A visual analysis using citespace and ArcGIS. *International Journal of Sustainable Development and World Ecology,* 30(6), 713–725.
16. Bathla, A., Aggarwal, P. and Manaswi, K. 2023. The role of digital technology in achieving Sustainable Development Goals (SDGs): A systematic literature review, bibliometric analysis and content analysis. *In: Fostering Sustainable Development in the Age of Technologies*. 1–22.
17. Ligorio, L., Venturelli, A. and Caputo, F. 2022. Tracing the boundaries between sustainable cities and cities for sustainable development. An LDA analysis of management studies. *Technol Forecast Soc Change*, 176.
18. Schraven, D., Joss, S. and de Jong, M. 2021c. Past, present, future: Engagement with sustainable urban development through 35 city labels in the scientific literature 1990–2019. *J. Clean Prod.*, 292.
19. Liu, Z., Zhang, M. and Osmani, M. 2023. Building Information Modelling (BIM) Driven Sustainable Cultural Heritage Tourism. *Buildings*, 13(8).
20. Liu, Z., Han, G., Yan, J., Liu, Z. and Osmani, M. 2022. The relationship between social mentality and health in promoting well-being and sustainable city. *Int. J. Environ Res. Public Health*, 19(18).
21. Raman, R., Lathabhai, H., Pattnaik, D., Kumar, C. and Nedungadi, P. 2024. Research contribution of bibliometric studies related to sustainable development goals and sustainability. *Discover Sustainability*, 5(1).
22. Sreenivasan, A., Suresh, M., Nedungadi, P. and Raghu Raman, R. 2023. Mapping analytical hierarchy process research to sustainable development goals: Bibliometric and social network analysis. *Heliyon*, 9(8).
23. Pandey, S. and Kumari, N. 2023. Prediction and monitoring of LULC shift using cellular automata-artificial neural network in Jumar watershed of Ranchi District, Jharkhand. *Environ. Monit. Assess*, 195(1).
24. Trinder, J. and Liu, Q. 2020. Assessing environmental impacts of urban growth using remote sensing. *Geo-Spatial Information Science*, 23(1), 20–39.
25. Ehiagwina, F.O., Surajudeen-Bakinde, N.T., Afolabi, A.S. and Usman, A.M. 2023. Development of neural network-based spectrum prediction schemes for cognitive wireless communication: A case study of Ilorin, north central, Nigeria. *In:* 2023 International Conference on Science, Engineering and Business for Sustainable Development Goals, SEB-SDG 2023.
26. Liu, M., Song, T. and Gui, G. 2019. Deep cognitive perspective: Resource allocation for noma-based heterogeneous IoT with imperfect SIC. *IEEE Internet Things J.*, 6(2), 2885–2894.

27. Li, D., Deng, L., Bhooshan Gupta, B., Wang, H. and Choi, C. 2019. A novel CNN based security guaranteed image watermarking generation scenario for smart city applications. *Inf Sci* (NY), 479, 432–447.
28. Moustafa, N., Turnbull, B. and Choo, K.K.R. 2019. An ensemble intrusion detection technique based on proposed statistical flow features for protecting network traffic of Internet of Things. *IEEE Internet Things J.*, 6(3), 4815–4830.
29. Huang, C.J. and Kuo, P.H. 2018. A deep CNN-LSTM model for particulate matter (Pm 2.5) forecasting in smart cities. *Sensors* (Switzerland), 18(7).
30. Rahman, A., Srikumar, V. and Smith, A.D. 2018. Predicting electricity consumption for commercial and residential buildings using deep recurrent neural networks. *Appl Energy*, 212, 372–385.