Chapter 11
Use of IoT in Net-Zero Smart City Concept in the Indian Context: A Bibliographic Analysis of Literature

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11.1 Introduction

India has a GDP of US$ 2.87 trillion and is home to 1.4 billion people [1]. Census data as available in 2015 displayed a total of 475 cities/urban agglomerations that housed 70% of India"s population [2]. The country has also been involved in global climate agreements since the Rio Earth Summit in 1992—moving from the fringes to playing an active part in combating climate change [3]. Given the rapid rate of urbanization, India"s emissions and energy usage proportionate to its population, and its active involvement in global climate politics [4], it is only prudent for India to have established an advanced body of literature in the fields of net-zero smart cities. The Government of India announced the Smart Cities Mission in 2015, intending to achieve better living condition and economic growth across 100 cities allotting US$ 1 billion for the purpose [2]. The Smart Cities Mission understood the lack of a universal definition for smart cities and defined two components of Indian smart cities, namely area-based development and pan-city development. It emphasized its projects based on the themes of smart environment, infrastructure, citizenship, governance, and economy [5]. The undertaking of such a massive mission demands an equally massive research body relevant to smart cities that is specific to the Indian context as well as updated with the latest technologies.

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This study will analyze the current status of and the existing gaps in Indian research relevant to net-zero smart cities involving IoT technologies. The main research questions can be stated as follows:

RQ1: What factors are considered most important in making a city net zero?
RQ2: How does the Indian research pertaining to "the use of IoT in making a city net zero using urban planning methods" compare with the status of research in the rest of the world?

The study focuses on literature available with the Scopus database and, among them, on those that match the criteria set by a subset of smart city-related keywords. Keywords vary across themes of net-zero concept, IoT, big data, urban planning, energy, transportation, citizen engagement, and community participation.

The answers to these questions have been attempted through a literature review constrained by keywords and a bibliographic study that analyzes themes, keywords, word frequency, authorship, and collaboration of authors between countries. Bibliographic analyses provide an understanding regarding the growth trajectory of research literature and knowledge within a particular field of research [6]. These analyses often use quantifiable data and are therefore considered useful for researchers to study the trends and synergies of literature in their respective fields. This study has used publication counts, use of keywords over time, articles per author, frequency of keywords, frequency of keywords over time, and collaboration between countries as metrics to analyze the body of literature for this study.

The main contribution of this study is the keyword-specific bibliographic literature study performed using the bibliometrix software package in RStudio. This study points out the three primary factors required to make a city net zero: (i) planning factors and use of IoT; (ii) role of citizen engagement and community participation; and (iii) use of IoT in energy and transportation. Additionally, it also sheds light on the evident gaps in research using factorial and thematic analysis (Figs. 11.2, 11.3, 11.4, 11.5, 11.6, and 11.7). Figure 11.8 shows the collaboration of researchers between various countries in the world while suggesting that in order to achieve the level required in Indian research for attaining a stronghold in net-zero smart cities, higher international collaboration is needed.

The structure for the chapter is as follows. Section 11.2 elaborates on the methodology used for the bibliographic analysis. It lists out the nine steps used to shortlist literature for the study and specifies the keywords and combinations used to search articles on the Scopus database. Section 11.3 is the literature review and reads about the three primary factors required to make a city net zero. Section 11.4 discusses the findings of the analysis using the following tests: (i) factorial analysis, (ii) thematic evolution, (iii) three-field plot, (iv) tree mapping analysis, (v) word growth analysis, and (vi) country collaboration statistics. Finally, Sect. 11.5 provides the conclusion.

11.2 Methodology: Bibliographic Analysis of Literature

A bibliographic analysis of relevant literature available under the broad thematic umbrella of "use of IoT in net-zero cities using urban planning approaches" was performed to understand the state of current research being carried out in the field of the net-zero city concerning the use of the Internet of Things in making a city smart using urban planning approaches. The Scopus database was used for the bibliographic analysis, and the keyword-specific article search was carried out in September and October 2020. The same search command was rerun on January 27th, 2021, to add recently published articles. Articles were only considered if they included a particular keyword(s) or combination of keywords in the title, abstract, or keyword section of the articles. The literature search followed ten crucial steps (Fig. 11.1) listed below:

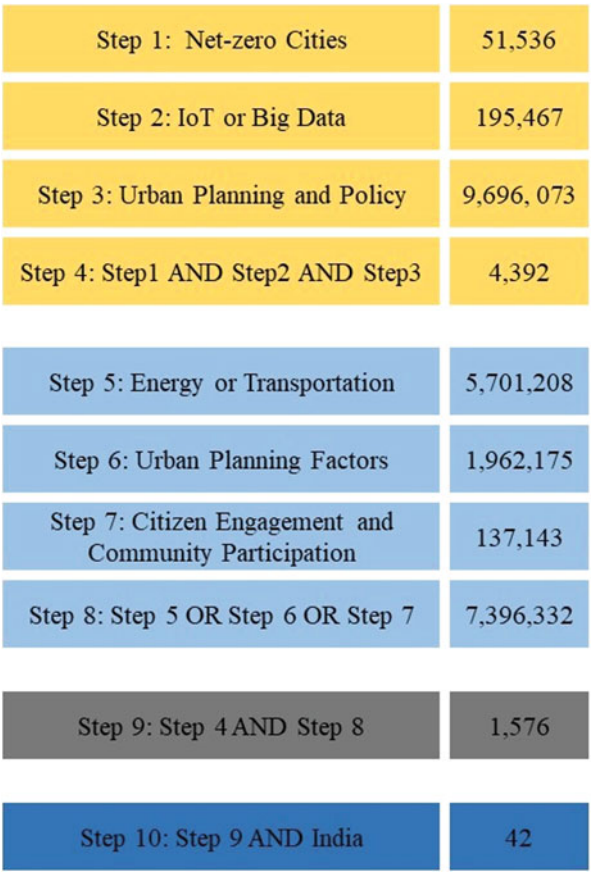

Fig. 11.1 The ten steps followed in the methodology

1. Literature published with the net-zero concept was searched in this step. Articles that had any of the following keywords in their title, abstract, or keyword section were considered: “net-zero city” OR “net-zero city” OR “net-zero energy” OR “zero-energy city” OR “smart city” OR “carbon footprint” OR “zero-carbon city” OR “net zero.” The search produced 51,536 articles.
2. The second step in the bibliographic analysis used the second theme of this chapter: IoT or big data. For this purpose, “big data” OR “bigdata” OR “IoT” OR “Internet of Things” were used as keywords and 195,467 articles came forth.
3. “Urban planning” OR “framework” OR “strategy” OR “solution” OR “policy” were the keywords used to identify the research articles published in the urban planning and policy area. 9,696,073 research articles were found in this area.
4. In the fourth step, only articles that discussed net-zero cities, the Internet of Things or big data, and urban planning and policy were sorted, while the rest of the articles were discarded. In short, the fourth step was the intersection of the results in steps one, two, and three, and 4392 relevant articles were found.
5. Articles that were published with keyword combinations of “energy” OR “urban energy” OR “energy management” OR “sustainable energy” OR “energy consumption” OR “renewable energy” OR “exergy” OR “smart grid” OR “transportation” OR “smart transportation” OR “recycling” OR “resource conservation” OR “sustainable transportation” OR “walk” OR “cycling” OR “public transportation” OR “electric vehicles” were considered for this step and a total of 5,701,208 articles were found to have been available in the Scopus database.
6. “Land use” OR “bye laws” OR “property tax” OR “housing” OR “green” OR “open space” OR “mixed use” OR “recreation” OR “restoration” OR “retrofitting” OR “better housing” OR “conservation” were used to identify the research articles that were published with urban planning factors. 1,962,175 relevant research articles were found in this step.
7. Citizen engagement and community participation factors, namely “local agricultural” OR “agricultural produce” OR “community gardens” OR “deforestation” OR “less meat” OR “open space” OR “food waste” OR “green approaches” OR “green approach” OR “sustainable business” OR “increase awareness” OR “local environment” OR “community engagements” OR “better society” OR “social justice” OR “equal opportunities” OR “equal opportunity” were used to identify 137,143 articles.
8. In this step, any articles that mentioned energy or transportation, urban planning factors, citizen engagement, or community participation were considered. In short, this step was the union of the results identified in steps five, six, and seven. This union of all the articles gave 7,396,332 results.
9. This step is the intersection of the results in steps four and eight. “AND” command was used to identify the articles that talked about net-zero cities, the Internet of Things or big data, and urban planning and policy as well as energy or transportation, urban planning, or citizen engagement or community

participation. 1567 articles were shortlisted for analysis based on keyword-specific criteria.

10. In this final step, among the 1576 articles, only those articles that had "India" in the keyword section, title, or abstract were selected. This step gave 42 articles. This step is essential to understand the level of progress made by Indian researchers in the field of using IoT using urban planning practices to achieve net-zero city in India. This step is essential in developing an understanding of research available in the aforementioned fields established within the contextual constraints of India.

The articles selected in this step were then analyzed in the RStudio software. "Bibliometrix" package in R was used for the bibliometric analysis. The command "biblioshiny()" was used, and then the raw BibTeX data was used for further research. The results of this bibliometric analysis are further discussed in detail in the Sect. 11.4 of this chapter.

11.3 Literature Review

A review of the literature was carried out to identify the main factors that can help a city to achieve net-zero goals. The three broad categories identified under which the factors can be divided are urban planning factors, citizen engagement and community participation, and energy and transportation.

11.3.1 Planning Factors and Use of IoT

Studies have shown that many factors that govern the shape and future of a city such as property tax, land use of a locality in a city, disaster management, solving housing-related issues, and retrofitting and restoration of existing structures can be used efficiently and in a planned manner with the help of IoT-based technology [7, 8]. IoT-based technology in urban planning factors makes the cities across the globe net zero, sustainable, and resilient [7, 9, 10]. Boeing et al. [11] identified that the proper use of technology could help find affordable and livable housing facilities in a town and investment support in real estate, and capture the behavior of landlords or rules imposed on tenants by a particular housing society. IoT technology and the big data generated can help solve housing issues and remove probable human biases by suggesting minimal changes or modifications in the policies rather than significant changes or introducing a completely new policy [11, 12]. Further, IoT sensors and proper planning strategies can help avoid disasters related to city planning by monitoring and surveying the old infrastructure and suggesting renovation and retrofitting works [7, 12–14].

Every element in a city, such as the housing options, rents, commercial values, vehicles, new registrations, educational institutes, religious institutes, and number and type of tourists the city attracts, generates a considerable amount of data; most of the data is unused but using advanced technology will not only help in using the data, but the city administrators can use the data in making a particular city net-zero smart city [14–17]. Thus, the literature review gives three important urban planning-related areas where IoT can help in making a city net zero:

1. Land-use planning and taxes.
2. Affordable and livable housing.
3. Restoration and retrofitting of existing infrastructure.

11.3.2 Role of Citizen Engagement and Community Participation in Net-Zero City

It is imperative to engage citizens in the net-zero city goal and seek their active participation. Staletić et al. [8] observed Serbian citizens' willingness to crowdfunding for incorporating new technology for making their city smart. The study highlights that a project can be successful if it has positive responses from citizens. Moreover, it becomes quite likely that the citizens will accept the new rules and regulations that may be imposed on them, along with the proposed changes [8]. Building information systems widely and popularly used by architects, building system engineers, and urban planners are based on IoT technology and need citizens' support for its successful operation [18–20].

Kristjansdottir et al. [21] observed that the buildings or housing societies with greater community participation had lower net carbon emissions. Encouraging food from local farms, encouraging responsible meat consumption, reducing food wastages, and deforestation can reduce carbon emissions to a great extent [22, 23]. A vital area that is mostly neglected by city authorities and the public is the need to set up local businesses and encourage their consistent survival. These businesses can reduce emissions by reducing the fuel consumption of transporting employees and materials [24, 25]. A city with awareness programs can help make the citizen aware of the benefits of generating less waste, reducing emissions [21, 26]. Based on the above review of literature, the following areas need to be given special care to generate greater citizen engagement and community participation and better use of data:

1. Encourage local agricultural activities, reduce wastage of food, and discourage deforestation.
2. Promote local businesses.
3. Awareness and community engagement and participation programs.
4. Societies with equity, justice, and sufficient growth opportunities.

11.3.3 Energy and Transportation and Use of IoT

Using IoT-based sensors can help design better transportation network and infrastructure in a city, as identified by Barbhuiya et al. [27], and help reduce net carbon emissions as observed by Chuai and Feng [17]. Many cities and transportation departments also use IoT sensors worldwide to check emission levels and propose policy recommendations based on the findings [28]. Vehicular emissions are significant sources of carbon pollution, and to achieve net-zero cities electric vehicles need to be introduced along with stricter emission laws [29]. Bouman et al. [30] demonstrated the need to have modern technologies and regulatory measures to reduce greenhouse gas emissions towards sustainability.

Regular performance analysis of the energy and related systems needs to be carried out to optimize and look for ways to improve performance as carried out by Ascione et al. [28] in Greece. With the world moving towards zero emissions during electricity productions, the city administrators need to find suitable ways to shift to green methods of energy production and carbon emissions [10, 22, 31, 32]. The IoT technology can help save energy from loss during transmission and predict the perfect tilt angles for solar and wind energy production systems during a particular season or point of time in a day [33, 34]. Thus, the areas under energy and transportation, specific to the use of IoT, which can help in reducing the emissions and can be a more significant influence in shaping a city towards a net-zero city are:

1. Use of renewable sources of energy, recycling, and resource conservation.
2. Better transportation facilities like walkability, cycling public transportation, and electric vehicles.

11.4 Findings and Discussions

The bibliometric analysis was carried out to observe the emerging areas in "use of IoT in net-zero smart city concept" and understand the recent trends and gaps in research. Seven necessary checks carried out in RStudio software are the factorial analysis, thematic evolution, thematic map, three-field plot, tree map, word growth, and country collaboration map of the 1576 research articles and 42 Indian specific research articles. Finally, a word cloud was generated to check the most used keywords in this particular field of research.

11.4.1 Factorial Analysis

The multiple correspondence analysis (MCA) was carried out to understand the underlying data set and the significant factors involved in this field of research

[35]. The MCA is represented in two-dimensional Euclidian planes and helps in understanding the present trends in a particular research field [36]. From the top graph of Fig. 11.2, it can be observed that four factors are evident, namely, energy, transportation, automation, and a red cluster covering almost all the elements of a smart city. It can be noted that while three clusters are covering multiple aspects of a technologically smart city, factors like governance, planning, strategy, and policy are still entirely missing. This can be thought of as a massive gap in the research area and needs to be given more attention so that cities with technology are planned and governed in an elegant manner. The bottom graph of Fig. 11.2 also has four factors and accommodates the missing items discussed above. The items are placed in one factor, and it can be mind-boggling for researchers to find specialization-specific research gaps. This could be a reason for having only 42 India-specific articles out of 1576 articles focusing on the use of IoT in a net-zero smart city, even though the Government of India had planned to develop hundreds of smart cities in India [37].

11.4.2 Three-Field Plot

The three-field plot of the "biblioshiny()" command of RStudio software using bibliotex library shows linkages between the important matrix used in a research article such as authors, keywords, sources, country, affiliations, funding and number of authors [38]. Since the objective of this study is to understand the critical study areas in the field of "use of IoT in net-zero smart city concept," the three-field plot of authors, keywords used, and sources for all the articles published were carried out (Fig. 11.3). The main keywords used are smart city or smart cities, IoT or Internet of Things, big data, security, and cloud computing. The three-field plot shows that though the keywords used are very relevant, researchers have not yet wholly directed their focus towards urban planning solutions for achieving net-zero smart cities.

11.4.3 Thematic Evolution and Thematic Map

A thematic evolution helps understand the factors used at the start of the research in a particular research field and the emerging factors that are used recently [39]. The top graph of Fig. 11.4 shows that the factors that were used in early research between 2012 and 2019 are energy efficiency, smart city, intelligent systems, and the Internet of Things, whereas the India-specific articles (bottom graph of Fig. 11.4) that were published between 2015 and 2019 used only two main factors, namely, energy efficiency and Internet of Things. Since January 2020, while India-specific research has been using the Internet of Things and smart city as the two main factors, global articles have started using deep learning, energy utilization, and intelligent systems, and the Internet of Things and smart city. It is worth noting that the research in areas of smart city and Internet of Things has merged into the other fields, thus

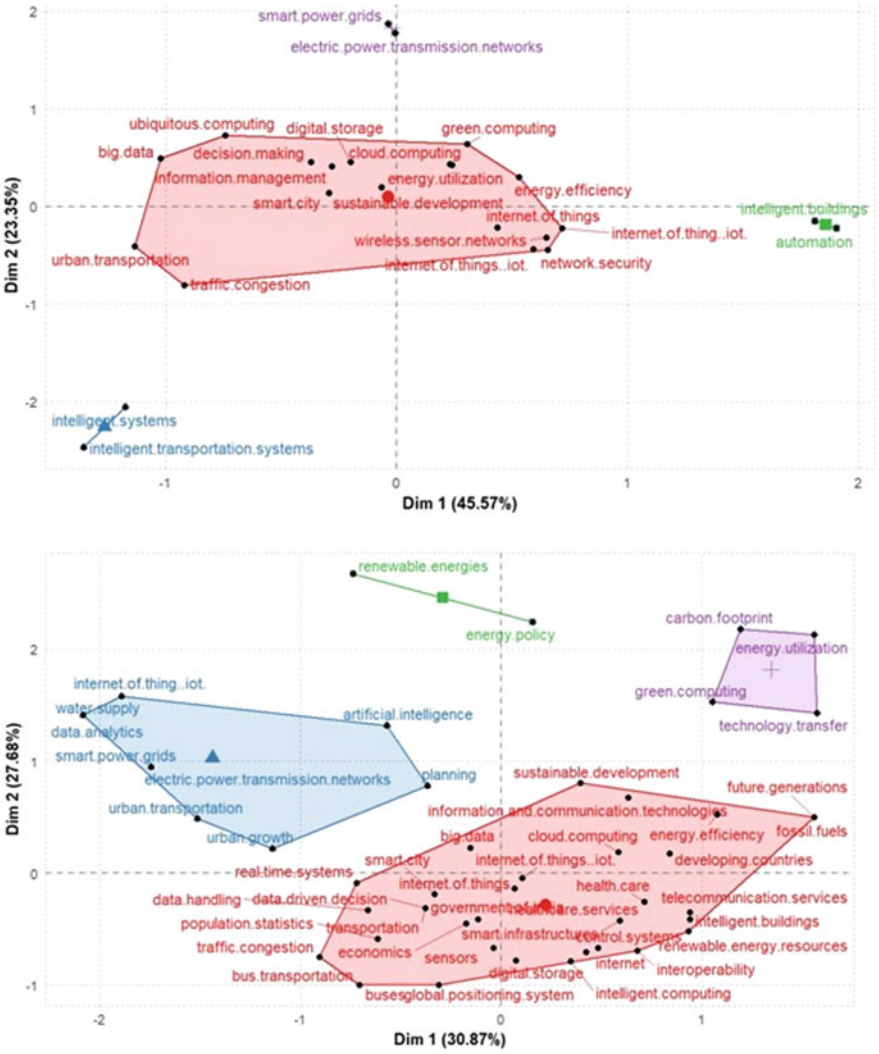

Fig. 11.2 Factor analysis using multiple correspondence analysis. Top: Analysis of all articles. Bottom: India specific

giving a direction for Indian researchers to upgrade and follow the lead. This could greatly help in moving forward in this new and much-needed field of research.

The thematic mapping of factors helps understand the niche along with basic, emerging, and major themes in a research area [40]. Research specific to India uses factors like urban transportation planning and healthcare, which, although relevant in the Indian context, needs to be supplemented with a focus on intelligent systems and automation. Researchers should work with problems specific to

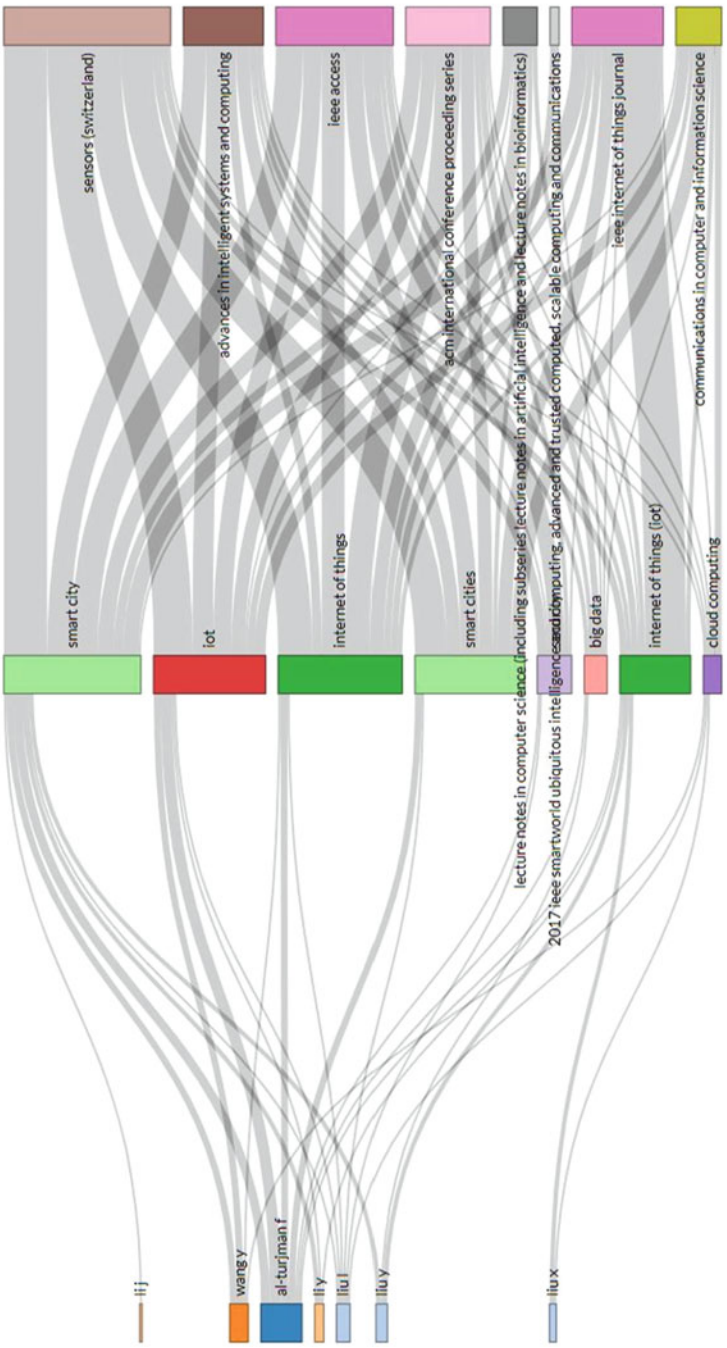

Fig. 11.3 Three field plot of authors, keywords used and sources for all the articles published in "use of IoT in net-zero smart city concept"

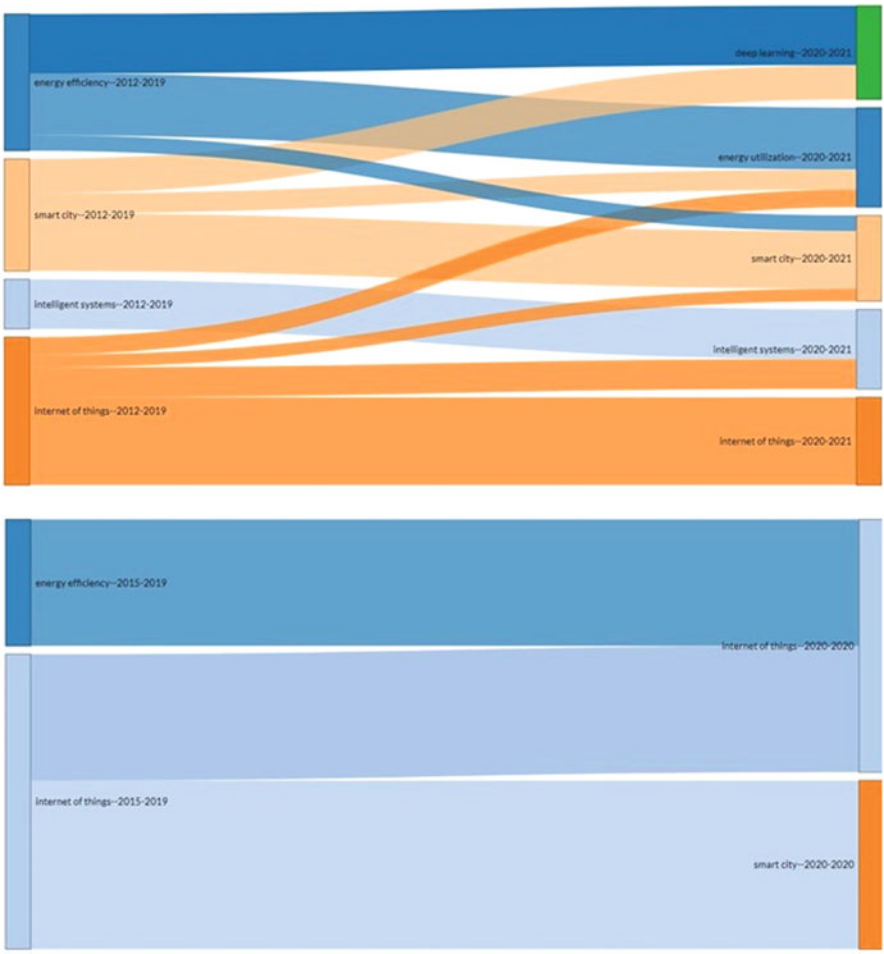

Fig. 11.4 Thematic evolution of factors. Top: analysis of all articles, bottom: India specific

systems (transportation, healthcare, energy, etc.) in India and provide solutions specific to the Indian context without generalizing Western solutions (Fig. 11.5). Yet another notable area in which Indian research is lagging is the "Internet of Things" and "smart city," which are still at a primary level. In contrast, researchers internationally are extensively researching at an advanced level already.

Fig. 11.5 Thematic map of factors showing niche, emerging, major, and basic themes. Top: Analysis of all articles. Bottom: India specific

11.4.4 Tree Mapping Analysis and Word Growth Analysis

Tree mapping analysis is a popular data visualization method in which the data is presented in a hierarchal manner in the form of rectangles [41, 42]. This analysis is used in the present study to understand the objective and relative frequency of keywords used and the existing volume of research. It was observed that apart from the critical areas in which research is already being heavily undertaken, such as energy efficiency, smart city, intelligent systems, and the Internet of Things, a few other exciting areas came into the picture, like intelligent systems, sustainable

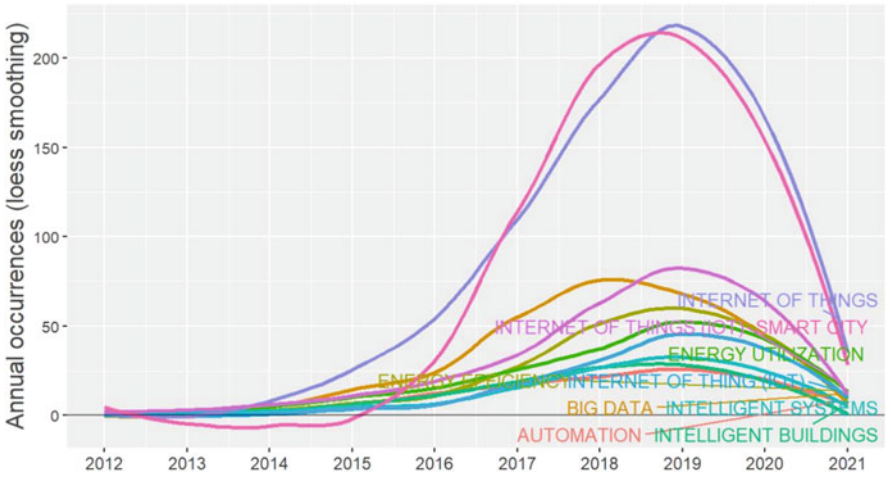

Fig. 11.6 Word growth analysis from 2012 to 2019

development, network security, decision-making, computing, digital storage, and information management.

It should be noted that the graph shown in Fig. 11.6 should be read till 2019, and the "biblioshiny()" tool of RStudio software automatically shows new keyword trends for the last years. It can be easily noted that though all the keywords were almost equally used until 2015, the smart city and IoT outpaced every other research area since 2015.

Figure 11.7 shows that 52% of the research works since 2012 in IoT in the net-zero smart city field have used IoT and smart city as keywords. However, data, security, sensors, intelligence, and storage, which are also essential, were mentioned in a mere 19% of the total research works. Word growth analysis further validates the tree mapping analysis results.

11.4.5 Country Collaboration Map

The country collaboration map (Fig. 11.8) shows how authors from different regions collaborate and participate in collaborative research in IoT in a net-zero smart city. While it is interesting to note that Indian researchers are collaborating with researchers from other nations, the Indian researcher needs to be more focused to come up with policy-level solutions. Only 42 out of 1576 articles were published by Indian authors, which is merely 2.67% of the total publications. Consequently, a significant number of additional researchers need to work in this field. Also, it can be observed from Fig. 11.8 that quite a few countries from Africa, Middle East, and South America, along with Russia, lack international collaboration.

Fig. 11.7 Tree mapping analysis of the published studies. Top: Analysis of all articles. Bottom: India specific

11.5 Conclusion

The literature review gives a clear picture of the three major factors that can help make a city a net-zero smart city, namely, planning factors and use of IoT, role of citizen engagement and community participation in net-zero city, and energy and transportation and use of IoT. This implies that while the focus should be on reducing the overall carbon emissions, city administrators and designers should also give due importance to stakeholders' participation, resilience and vulnerability, safety, and citizens' well-being. The bibliographic analysis showed that while research carried out in the Indian context had only 2.67% of the total

Fig. 11.8 Country collaboration map

publications, the research is heading in the right direction. There is a massive scope for improvement, and as established by thematic mapping, thematic evolution, and factor analysis, research in the Indian field lags behind by 4–5 years. Areas such as intelligent systems, data security, and deep learning in urban planning have not been explored much in the city context. Research in India should collectively try to see sectors such as energy, transportation, and housing as systems and develop policy recommendations and planning strategies rather than trying to solve small issues related to these areas. The three-field plot analysis showed that apart from the keywords Internet of Things and smart city, big data, sensors, and cloud computing are the new emerging topics in this field and should be taken up by urban planning researchers. Tree mapping analysis and word growth analysis indicated that the Internet of Things and smart cities are being used as the keywords in 52% of the articles. Still, only 5% of the selected articles were also using the keyword "net-zero." Thus there is immense scope for exploring this area for all the researchers. Another important observation is the lack of collaborative work with researchers from most of African and many Asian and South American countries. Collaborative works must be encouraged to make the net-zero world as soon as possible.

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