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A Comparison of a Smart City's Trends in Urban Planning before and after 2016 through Keyword Network Analysis

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Received: 6 May 2019; Accepted: 2 June 2019; Published: 4 June 2019

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Abstract: The aim of this study was to explore the keywords related to smart city concepts, and to understand their flow. This research used a keyword network analysis by collecting keywords from papers published on the web from Scopus, which is an international scholarly papers engine. The data were collected from before and after 2016, and since the amount of data has been growing rapidly after global agreements such as the United Nations' Sustainable Development Goals (SDGs) in 2015, we attempted to focus on adjacent years of publication. In order to understand the flow of research, we conducted a central analysis, which is widely used in quantitative research relating to social network analysis, and performed cluster analysis to identify relationships with related research. The results of the analysis are represented in the form of network maps, and the role of each keyword was clarified based on these network maps. In addition, the overall flow explained the change of flow through discarded and emerging keywords, and the relationships with related fields were explained through cluster analysis. The findings could serve as a basis for policymakers, urban managers, and researchers seeking a comprehensive understanding of the smart city concept in urban planning areas.

Keywords: smart city; smart city concepts; urban planning; keyword analysis; network map

1. Introduction

A smart city may be considered an advanced concept related to the concepts of the information city, digital city, intelligent city, and sustainable city [1,2], and has been widely cited and studied, along with the sustainable city concept, since 2013 [3,4]. According to Google trends regarding the "smart city" (accessed on 13 March 2019) (Figure 1), the smart city's search terms have been on the rise since 2004 and peaked in 2015, but have remained high, suggesting many studies and discussions are occurring on the smart city concept [4,5]. However, the concept of a smart city is controversial, and no exact agreement has been reached on its definition. Despite efforts to conceptualize the smart city in many research fields and studies, most definitions of the smart city have been ambiguous or duplicated [3,6]. For example, many studies have used smart city, smart sustainable city, sustainable smart city, and so on interchangeably. These terms need to be clearer because they have the potential to be confused with specific and related terms, often interactively used by policymakers, planners, and researchers, when considering the common aspects of urban sustainability [3]. It is not yet possible to establish a comprehensive approach that addresses the various dimensions of sustainability at the urban level [7]. However, in general, the smart city is understood as an ideal model for urban planning and development, adaption to environmental issues such as climate change and global warming, and efficiently utilizing and managing energy. In addition, Information and Communication Technologies (hereafter ICT) will extensively and effectively help cities achieve a comparative edge [4,8,9], and be used as the tools and means to develop Intelligent Transport Systems (hereafter ITS) with mobility information and the Internet of Things (hereafter IoT) [10–12], as well as to achieve urban policy making based on governance and open data [13–15]. Accordingly, in improving the urban quality of future urban areas, the term smart city is considered as an umbrella concept that includes various sub-concepts such as sustainable smart environments, smart technology, smart energy, smart transportation, smart mobility, and smart government [16–21].

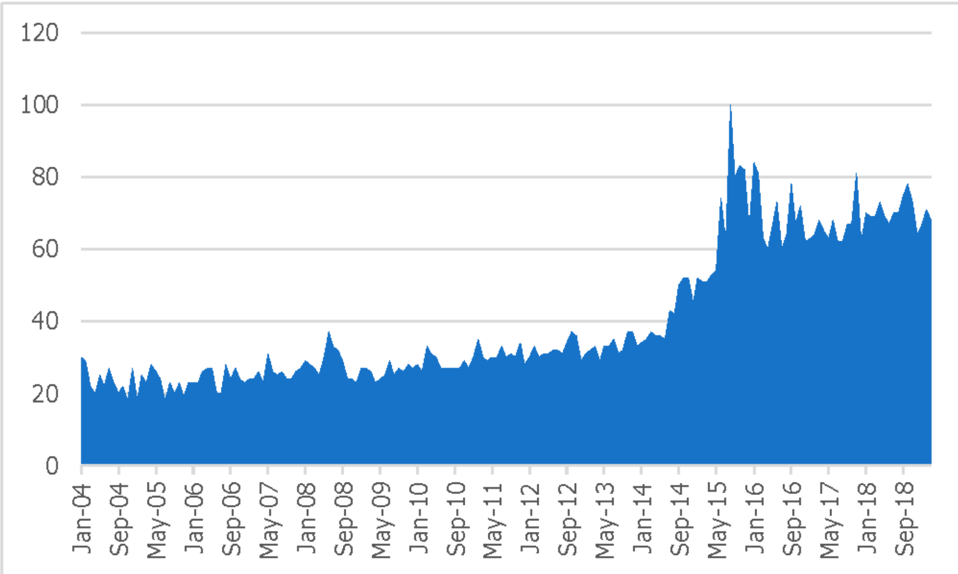

Figure 1. The trend of the concept of the smart city on Google trends (accessed on 13 March 2019).

The concept of the smart city has emerged over the past decade through ideas of ways to improve the functioning, efficiency, and competitiveness of cities, and solve their environmental challenges. Early on, it was speculated that ICT would play a key role in the smart city [22–24]. With the development of ICT, the functions of urban management were improved in various fields, such as transportation, energy, health care, and water [2], and the use of ICT facilitated the development and delivering of information and knowledge generated in daily life, promoting citizens' participation in e-governance and e-services [25]. Additionally, ICT is a technical platform for the process of collecting and processing massive amounts of data, called big data, enhancing digital devices, Internet services, the IoT, and the Internet of people's societies [25], and these techniques and technologies have been recognized as tools of urban planning to create innovative, intelligent spaces and improve urban sustainability [26]. In this way, the information gathered by these processes is accelerated to achieve intelligence and efficiency in managing urban resources and settings [27–29]. Collectively, ICT-based predictive analytics can demonstrate the best implements for gaining insight into data for future decisions [30,31], and enhance the outcomes for other stakeholders in the smart city area [2].

A new and important flow in ICT is the identification and utilization of meaningful data collected from information systems [32], and the analysis of the data in various applications in smart cities [33]. ICT is being spotlighted in urban planning as one of the key components of the urban infrastructure that enables access to a smart city [34], and the smart city concept relies on the IoT technology's visions of pervasive computing and related big data applications [20,35]. Many process technologies have been introduced to understand and analyze a lot of the information connected to the IoT, among them data mining which is one of the most valuable technologies [36]. Technological and technical advancements in ubiquitous computing, wireless sensor networks, cloud computing, and machine learning have adopted by big data analytics as supporting tools [37–39]. Moreover, smart devices share their own information and access with other devices, and generate information with internal applications by themselves [40]. Through these computing and ICT processes as core enabling technologies, the information is used for understanding, analyzing, evaluating, and monitoring, and this contributes towards the goals of sustainable development in the sustainable city [35]. Predictions and outcomes analyzed from information gathered through ICT may be efficiently reflected in various aspects within urban areas, and help the decision-making process in urban service policies, such as those around the environment, education, and well-being. In light of this, ICT is deeply involved in the need for smart, data-centric technologies for dynamic and evolving urban plan systems aiming towards sustainability for the management and development of urban functions [35–41].

The concept of the smart city with advanced technologies is not certainly complete to achieve optimal sustainability in urban development and planning yet [20,42,43]. However, ICT analytics, including big data, are considered to be fundamental ingredients for urban analyses [20,42,43]. In addition, ICT is being considered to achieve long-term goals of sustainable development, as a way to mitigate increasing social-economic concerns and complex environmental challenges in modern cities in their various forms of sustainability, infrastructure, data analysis, and services [20,23]. The applicability of smart systems in contemporary cities requires the comprehensive understanding of the possibilities of how unpredictable and unprecedented urban issues, such as population growth, environmental pressure, and human welfare and safety, can be efficiently handled [41,44]. In this regard, the Smarter Cites Challenge program of IBM achieved smart city projects in 100 cities around the world, with essential themes for urban management such as urban planning, transportation, environment, civic engagement and civil management, and public safety [45]. Its program has helped global cities to significantly improve quality of life through data analytics [46]. Huawei, a technologies company in China, published a report in 2017 comparing the 20 cities in the United Kingdom in detail, with themes such as digital innovation, social management, urban mobility, energy education, and sustainability, to address challenges facing cities and communities moving towards strategic smart cities [47].

Cities are absolutely required in the process of urban planning; utilizing their infrastructure and technologies, and cooperation from citizens, will be needed in order to approach the optimal smart city, because the ultimate goals of urban planning based on sustainable development are to improve the quality of life of citizens [48]. Citizens are deeply involved in urban initiatives and governance, and contribute to disseminating smart devices and Internet sharing, and generating information [49]. In implementing smart city projects, citizens should be considered as important decision makers, with their priorities for the strategies and goals to be understood as relating to the needs and challenges in their own city; the government should support their initiatives and governance [50]. In fact, a study supported by the EU reviewed 300 initiatives in smart cities and the community highlighted that governance, which consist of citizens, government agencies, private companies, and investors, should be important in the processes of resolving problems and making policy decisions [51]. The positive effect of governance frameworks based on citizens, companies, and governments should not be understated in smart urban planning, and smart governance frameworks that are established must be credible to community members, stakeholders, and experts.

While various indicators of urban functions and development have been used, few studies have indicators for assessing the smart city [52]. At a time when the definition of perfection is not yet agreed upon, the assessments of smart cities have been conducted differently in the ICT-centered approach and the people-centered approach [53]. Moreover, the form, size, and funds for each city are considered priorities as fundamental dimensions; small cites are not guaranteed to have an effective understanding of innovative strategies, and smart strategies should be harmonized with government policies [9]. In this regard, the reflection of smart strategies should require a considerate approach depending on the degree of urban development, the latest technologies, and the composition frameworks of governance with the community [54].

In light of the above, smart cities have the potential to provide better urban services to urbanities than urban planning in the past. Existing cities would be applicated by the smart systems as they become accustomed to new technologies that trigger a new paradigm shift in urban planning. Many cities around the world are considering approaches to achieve sustainability in their respective urban environments. Smart concepts are not inherent to the building of cities, but should be considered as the root of a big urban concept. Therefore, cooperation in various research fields is required to address challenges arising in real time based on ICT, utilize data, and reflect this in urban planning. However, few studies have been performed in collaboration or in joint study with other research fields on the actual application of smart functions. Most of the literature is on the advanced technology of urban planning, focusing only on specified fields such as transportation, building, and energy, where ICT was applied to existing cities to emphasize a new city brand [55]. Others have noted that an effective smart policy is required to develop suitable infrastructure, along with governance by a watchdog and collaborator through public–private partnerships [5,9,56]. However, a smart city cannot be led by just any organization or government, nor can it be achieved in one study area.

Understanding the smart city based on the literature requires identifying the concepts of the evolving process of urban planning. In particular, we attempt to highlight a new, feasible urban planning system based on the smart concept with other studies areas, and identify the flow of the application of smart systems in other research areas. However, most of the studies on smart trends so far are qualitative research projects. Quantitative and comprehensive research is required to adapt to rapidly evolving cities. We aimed to comprehend how the smart concept can be applied to urban planning. This paper provides the flow of the smart city and connection of other study areas, in terms of urban policies.

2. Literature Review

2.1. The Concept of the Smart City

Research has been conducted on diverse aspects of the smart city in various research areas. There are many definitions of a smart city; none have been widely recognized, although they can be summarized to concepts. Through some review papers, we came to our understanding of the concept of the smart city of urban planning. Trindade et al. [4] used qualitative methods to identify information about research, models, frameworks, and tools, considering 'smart city' and 'sustainability' as keywords in published web papers. Their paper emphasized that the smart city affects the concept of sustainable urban development. D'Auria et al. [57] examined the concepts and relevance of the 'smart city' and 'sustainable city', utilizing a systematic review through H-index on the Web of Science. The smart city has the goals of urban planning reflected in a new philosophy and approach, but the two concepts cannot be considered in contrast, although it was stressed that the principle should be aligned with sustainable development. Yigitcanlar et al. [58] reviewed 35 academic works about smart cities and insisted that cities could not be smart without sustainability. They highlighted that smart cities need to have appropriate technology, complex city management, and consensus on concepts of sustainability for future sustainable cities. Meijer et al. [59] presented technologies, human resources, and governance as the concepts of the smart city through qualitative analysis of three phases (search, paper selection, and review). They defined that the smart city is human capital, as attracting human capital among various individuals and governance, and these human resources, are used to operate and maintain the smart city through the use of ICT. Yigitcanlar et al. [60] did a systematic review based on literature aimed at conceptual development of smart cities. They addressed the idea that smart cities are more than a technology concept, with goals such as productivity, sustainability, accessibility, well-being, lifestyle, and governance linked to communities, technologies, and policies. Albino et al. [50] attempted to clarify the meaning of the concept of the smart city through a literature review of papers published after 2008. The results stressed that because the concept of a smart city is not universal and is too complex, the visions and conditions of a certain city should be reviewed to approach the idea of a smart city. Arroub et al. [61] noted people, infrastructure, and operations as core to the concept of the smart city, which depends on the geographical, environmental, economic, and social constraints of each city. As a sub-concept, they highlighted education, health-care, and social programs in terms of human service; energy, water, and transportation in terms of infrastructure; and governance, public safety and managing urban resources in terms of the operation concept. Giffinger et al. [19] evaluated 94 small and medium-sized cities in Europe through the smart city indices. They also pointed out the ambiguity of the concept of understanding, stressing that it should be intelligently integrated into the areas of industry, education, civic engagement, and technology infrastructure, and applied to citizens. Accordingly, a smart city was considered to reflect two major trends; one was integration networks as a collection of smart devices, sensors, and real time big data with ICT related to human life, and the other was a new paradigm in urban planning polices related to governance and the economy [62]. Nam and Pardo [63] argued that the key components of a smart city are the technologies, the people resources such as creativity, diversity, and education, and the institutions such as policy and governance. To sum up, the smart city may be considered to be deeply involved in various planning and areas within a city, based on ICT technologies such as infrastructure, education, environment, public welfare, safety, and participation, with the goal of sustainability, and maintained by human resources such as governance and frameworks.

2.2. ICT in the Smart City

A smart city should provide a network of integrating technologies, systems, services, and capabilities for sufficiently multi-sectorial and flexible future development that is open-access [50]. All governments and public institutes at all levels should aim to improve strategies and programs by reflecting the concept of smartness in their existing policies [63,64]. This would mean that ICT is the foundation for promoting new forms of technology, and is the facilitator for more broadly and innovatively balanced development [65]. Therefore, it is important to have a better understanding of in which areas ICT development provides the best advantages for society and the environment, because it has great potential for urban system management and urban sustainability [66]. ICT can be applied from a regional level to the national and world level, such as in the forecasting of environmental pollution and weather, energy transportation, and transport management [67–69]. Indeed, ICT has adopted a broader approach to the most important aspects of people's everyday lives, stimulating smartness in the components of city [19], and also allows the smart ecosystem to expand its smart space from a personal context to a large community or the city as a whole [70]. In fact, data generated by ICT are used in data analytics in various urban fields, generated by smart devices such as smartphones, smart sensors, social network services, wearable smart devices, Internet, and the IoT through data mining techniques, and analyzed and utilized by data analytics such as machine learning and deep learning. The processes and results of ICT can be reflected throughout the entire city, and used to predict urban challenges. Sanseverino et al. [71] comprehensively reviewed the smart urban concept, and compared the smart city concept of Europe to cities in China. The authors stressed the integration of cities through ICT infrastructures with smart initiatives and a smart governance system in urban intelligent solutions for energy, agriculture, transportation, buildings and urban services, and advised moving away from a government-led top-down approach, and to invest in ICT infrastructures in the long view. IoT applications such as smart grids, environment monitoring, and intelligent lighting were emphasized as a good example to reduce the environmental impact of pollution and energy consumption [72]. Governments around the world are adopting and utilizing big data in ICT as part of moving towards smart cities, to improve the living conditions for citizens. Big data is a technology with enormous potential to improve smart city services, which could be reflected in national and urban policies [69]. In fact, data mining techniques can collect real time data generated by smart devices, including smartphones, wearable smart devices, smart applications, and the Internet. The IoT is also being developed for deep learning technologies with machine learning that can analyze and utilize collected data from cloud computing.

2.3. Governance with Smart City

Since ICT cannot transform cities without human capital, ICT should not be distinguished from human capital in the smart city [24]. The importance of governance is increasing, in order to manage initiatives or projects to make a smart city. According to Meijer et al. [59], smart city governance is required as new forms of human collaboration through utilizing ICT is beginning to create better results and more open governance processes. These authors emphasized that smart city governance should not be a technical issue, but studied from a social, political, and institutional point of view. Odenddal [73] argued that smart governance promotes data exchange, service integration, collaboration, and communication. Besides, the frameworks of human capital and governance are emphasized, which play important roles individually, as well as in the community, groups, and components of the entire city [74]. Smart governance is considered a core component of smart city initiatives, because it promotes interaction between people, policies, information, and technologies [75]. Smart governance enables creativity and innovates implementation for the smart city, and all initiatives require collaboration, disclosure, and participation based on smart governance models, which are essential components for the smart city [76]. Thus, smart governance is a new channel of communication between governance and citizens, such as e-governance, and requires cooperation from government departments and local communities [19,74]. In fact, creations and data from initiatives and governance should not finish with analysis and prediction. Government servants will continue to communicate with citizens, so that they should co-produce and create more new services [75]. The participation and cooperation of private technologies is also considered to be an important element of smart governance, because different stakeholders are involved in the development of technologies for the smart city. Accordingly, models of smart governance with government, business companies, and citizens are proposed to promote the transparency of society. Citizens are able to suggest opinions or express complaints about government policies through various communication channels, such as the Internet, apps on smartphones, and telecom services [77,78]. Business companies are willing to acquire new knowledge and information in line with the government's policies, and can contribute to government policies through analysis of real-time data and technology development [79]. Based on ICT tools, governments are able to perform tasks with other departments online more quickly, with immediate access and sharing of data available to officials [80]. After all, the overall governance framework should be built for a sustainable smart city.

3. Materials and Methods

3.1. Data Collection

2016 is considered important as a time when new national policies have implemented to achieve goals under international agreements. The United Nations' Sustainable Development Goals (SDGs), agreed in 2015, specified inclusively sustainable urban society and residences (target 11). In particular, Mauritius published a report in which a smart city scheme reflected on the SDGs in Feb 2016. A new climate change strategy was adopted in the Paris agreement in December 2015, and the Sendai framework was adopted by the United Nations Office for Disaster Risk Reduction in 2015 to reduce and mitigate damage of disasters. Therefore, we noted the global debates around 2016 in the data collection process.

We investigated "Scopus", a representative international thesis search engine that provides bibliographic information, to grasp the research flow of a smart city. Using "smart city" search terms, keywords from a total of 5526 articles were extracted from 1970 to 13 March 2019, focusing on the social sciences and environmental science subject areas. These two fields were described as areas where the social, economic, and environmental aspects of urban planning have been studied extensively [81]. These subject fields needed to be addressed in terms of urban planning because these three aspects influence the living conditions of urbanites [82]. In this process, a total of 4281 articles were used in the study, excluding articles that did not include keywords information. As illustrated in Figure 1, the data used in the analysis increased rapidly from 2015.

The collected keywords were refined in Excel to prepare for overlapping meanings of words due to the problems of singular and plural forms, upper-case and lower-case letters, abbreviations, and full words written together. Although prominent authors expressed that they wanted their articles to be included as keywords, the refining process was inevitable because the purpose of this study is to grasp the overall flow and related research fields, and the form of keywords varies depending on each journal style. For instance, "Information and Communication Technologies (ICT)", "Internet of Things" and "cities" were changed to "ICT", "IoT", and "City", and the phrase "smart city" was removed due to it being related to other words. Figure 2 shows the amount of data for each year in this study.

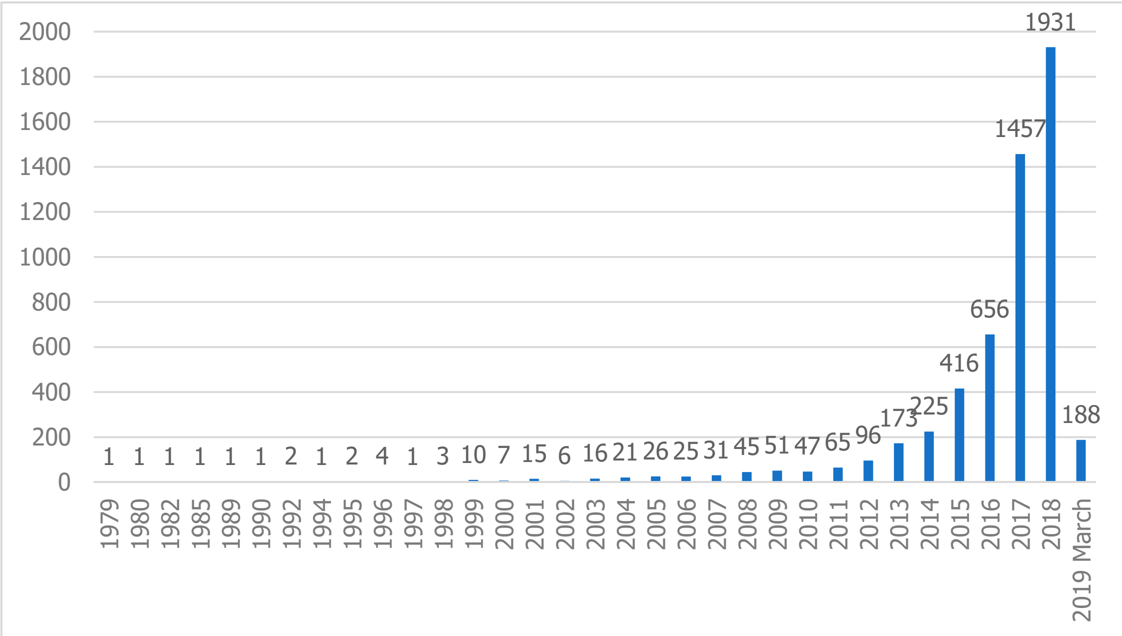

Figure 2. A mount of annually collected data.

3.2. Methods

Keyword networks analysis, one of the social network analysis methods, was used to explore trends and the relationship between research topics in many study fields, including information science [83], medical research [84], computer science [85], and science research [86]. Recently, studies have gone beyond analysis of relationships between individuals and organizations used to identify individuals and other networks. Related information or opinions on social media, such as Twitter for certain people, things, and even presidential speeches, have also been used for analysis [87–89]. In addition, this analysis process contributes to greatly reducing the effort and time required for a traditional literature review, and can be applied to all fields of science [90,91].

A process should be performed for the extra analysis of identifying meaningful keywords, because keyword network analysis relies on searched keywords. There is a variety of verification analysis methods, but this study conducted co-occurrence keyword network analysis. It focuses on co-occurrence of links between keywords in literature, and is useful in understanding components and knowledge structures in the scientific and technical fields [82,85,90].

The co-occurrence keyword network represents the number of times a pair of words simultaneously occurs in multiple articles, and constitutes the weight of the link that connects the pair [83,84]. A network map of this analysis consists of nodes and links, in which each keyword is a node, a pair of co-occurrence words is a link, and the number of times a pair occurs simultaneously in multiple articles explains the weight of the link that connects the pair. In this study, keywords with a co-occurrence frequency above 10 were used as data (Figure 3).

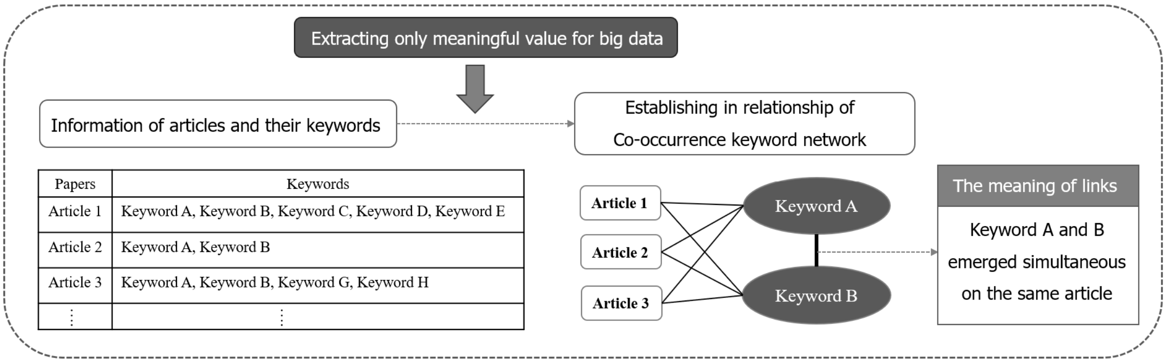

Figure 3. Co-occurrence keyword analysis.

This study is designed to identify the trends and flows related to research on the smart city concept through keyword analysis. In this study, keyword network analysis includes the process of constructing the network using the relationship of the collected keywords within research articles, and analyzing their structure. Our analysis consists of two methods; degree centrality and betweenness degree, which are useful to identify the role of words in the overall network map. Centrality analysis measures the importance of a node (word) and has the potential to interpret its structures and express the key properties. Betweenness analysis measures the number of times the shortest link between nodes and explained words acted as bridge between nodes; a node with a high betweenness value may have a significant impact on the overall network [90]. These analyses express trends in the latest studies with the centrality degree, and relevance to other studies with the betweenness degree [92–95], and are useful in understanding the properties of words and the flow of the entire network in the co-occurrence networks using Netminer 4 software (social network analysis software, CYRAM, Seongnam, Korea).

4. Results

4.1. Keywords Analysis

4.1.1. Keywords before 2016

We analyzed the keywords of papers, conference proceedings, and books from 1979 to 2015. Significant keywords were identified based on a frequency above 10, representing nodes, and links were identified via degree centrality and betweenness degree analysis. A frequency of more than 10 meant that one keyword appeared in more than ten papers, and the number of keywords used in the analysis was 381 (21 types). The total number of papers is 1294. Over 36 years, the frequency of the words in decreasing order was as follows: smart growth (59), sustainability (32), ITS (26), mobile application (25), urban sprawl (22), and Internet of Things (22). The degree centrality of the words in decreasing order was as follows: smart growth (0.25), sustainability (0.15), big data (0.15), sustainable development (0.15), urban planning (0.15), and GPS (0.15). The betweenness degree of the words was as follows: climate change (0.526316), big data (0.542105), governance (0.521053), urban development (0.521053), and mobility (0.510526) (Table 1).

Table 1. Frequency and the centrality value of the degree and betweenness of each word up to 2015. ITS: Intelligent Transport Systems; IoT: Internet of Things.

Keywords	Frequency	Degree Centrality	Betweenness Degree
Smart growth	59	0.25	0.057895
Sustainability	32	0.15	0.22807
ITS	26	0.05	
Mobile application	25	0.2	0.5
Urban sprawl	22	0.2	0.057018
IoT	22	0.1	0.1
Big data	21	0.15	0.542105
GIS	18	0.05	
Governance	17	0.1	0.521053
Sustainable development	16	0.15	0.189474
Urban planning	15	0.15	
City	13	0.1	0.521053
Mobility	12	0.05	
Urban development	12	0.2	0.510526
Smart grids	11	0.05	
Urban form	10	0.2	0.057018
Climate change	10	0.1	0.526316
Renewable energy	10	0.1	0.1
GPS	10	0.15	0.194737
Cloud computing	10	0.05	
Open data	10	0.05	

Overall, the network map was linked by main flow with the words "city", "climate change", "governance", and "big data", with a high betweenness degree, and the words "urban development" and "mobile application", with a high degree of centrality, were located at both sides of the main flow, wherein two keywords were linked to other related words. Focusing on these two words, the words "urban development" were related to the words of "overall urban planning and development", and the words "mobile application" were related to words related to the tools and technologies of using mobiles. In other words, over 36 years, many studies have been conducted involving urban development, city, climate change, governance, big data, and mobile applications, and in particular, urban development studies were considered to be primarily studied with the urban planning, sustainable development, urban sprawl, urban form, and sustainability words centered on the words "smart growth". Further, sustainable development studies had been conducted based on smart grids with renewable energy and big data with open data research, and mobile applications had been utilized in research on ITS, the IoT with cloud computing, and GPS with GIS and mobility (Figure 4). In the network map, the properties of the words were represented as nodes. The larger the size of a node, the higher the degree centrality, and the darker the color of a node, the higher the betweenness degree.

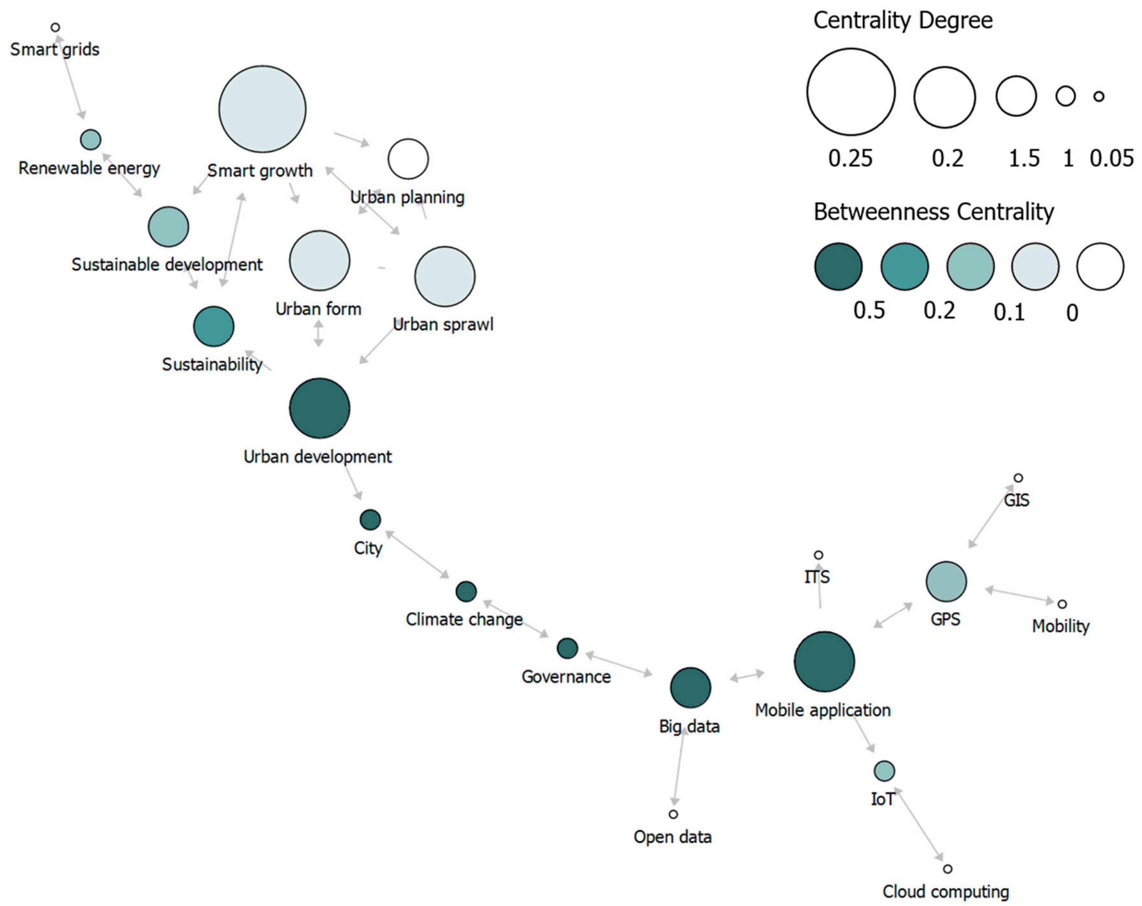

Figure 4. The keywords network map up to 2015.

The words that largely make up the flow of the research trend in the analysis were urban development, city, climate change, governance, big data, and mobile application, which had a high betweenness degree. These words were keywords in areas related to the smart city concept up to 2015. In particular, urban development and mobile applications play significant roles in understanding the flow of related research, as important keywords that connect other keywords in the overall structure. 'Smart growth' was the highest in frequency, but is not highly relevant to related studies in the network, while climate change, on the other hand, was one of the lowest-frequency words, but its relevance to related studies is very high in the network. In addition, the words smart growth, urban form, and urban sprawl, which has a high degree centrality, were studied actively as keywords, but mainly in large frames belonging to urban development. The study of mobile applications was conducted in relation to big data, ITS, the IoT, and GPS, and was particularly relevant to big data. In other words, studies on the concept of the smart city up to 2015 were the most active in urban development, and some studies were conducted with mobile applications and big data as keywords. Overall, given the study of relevant areas, it can be expected that studies of conceptual approaches have been conducted more often, rather than studies of active applications or utilization.

4.1.2. Keywords after 2016

We also analyzed the keywords of papers, conference proceedings, and books from 2016 to 2019. Significant keywords were identified based on a frequency above 25, represented as nodes and links via degree centrality and betweenness degree analysis, and the number of keywords used in the analysis was 1164 (22 types). The total number of papers is 4232. Over more than three years, the frequency of the words in decreasing order was as follows: IoT (248), big data (133), sustainability (81), smart grids (71), ICT (51), and cloud computing (48). The degree centrality of the words in decreasing order was as follows: data analytics (0.238095), sustainability (0.190476), ICT, cloud computing, data mining, machine learning, and urban planning and innovation (0.142857). The betweenness degree of the words was as follows: urban planning (0.666667), data analytics (0.500794), sustainable development (0.495238), ICT (0.466667), and sustainability (0.456524). Through this result, it could be inferred that words such as data mining, innovation, and IoT, with a high degree centrality, have been used widely in research, and that words such as urban planning, sustainable development, and ICT, with a high betweenness degree, have been used in many research projects together with other keywords with a high betweenness degree. In particular, for data analytics and sustainability, the high centrality and betweenness degree played a key role in the flow and direction of the research (Table 2).

Table 2. Frequency and the centrality value of the degree and betweenness of each word after 2016.

Keywords	Frequency	Degree Centrality	Betweenness Degree
IoT	248	0.142857	0.097619
Big data	133	0.095238	0.077778
Sustainability	81	0.190476	0.459524
Smart grids	71	0.095238	0.095238
ICT	51	0.095238	0.466667
Cloud computing	48	0.142857	0.093651
Data mining	44	0.142857	0.011111
Energy efficiency	43	0.095238	0.180952
Machine learning	43	0.142857	0.095238
Governance	41	0.095238	0.007143
Urban planning	39	0.142857	0.666667
Security	34	0.047619	
Sustainable development	33	0.095238	0.495238
Innovation	30	0.142857	0.221429
City	30	0.095238	0.040476
Data analytics	30	0.238095	0.500794
Open data	29	0.095238	0.095238
Optimization	29	0.047619	
Deep learning	28	0.047619	
GIS	27	0.095238	0.257143
Renewable energy	27	0.047619	
E-Government	25	0.047619	

Overall, the network map was linked by the main flow of the words sustainable city, ICT, sustainable development, urban planning, and data analytics, with a high betweenness degree. The words urban development and mobile application, with a high degree centrality, were located at both sides of the main flow, and two keywords were linked to other related words. In particular, the urban planning word played a significant role as a keyword; it had a low degree centrality value, but a high betweenness degree value. Sustainability was related to innovation, city, and renewable energy, and urban planning was related to data analytics and geographic information systems. Data analytics was deeply related to bid data, cloud computing, data mining, and machine learning (Figure 5).

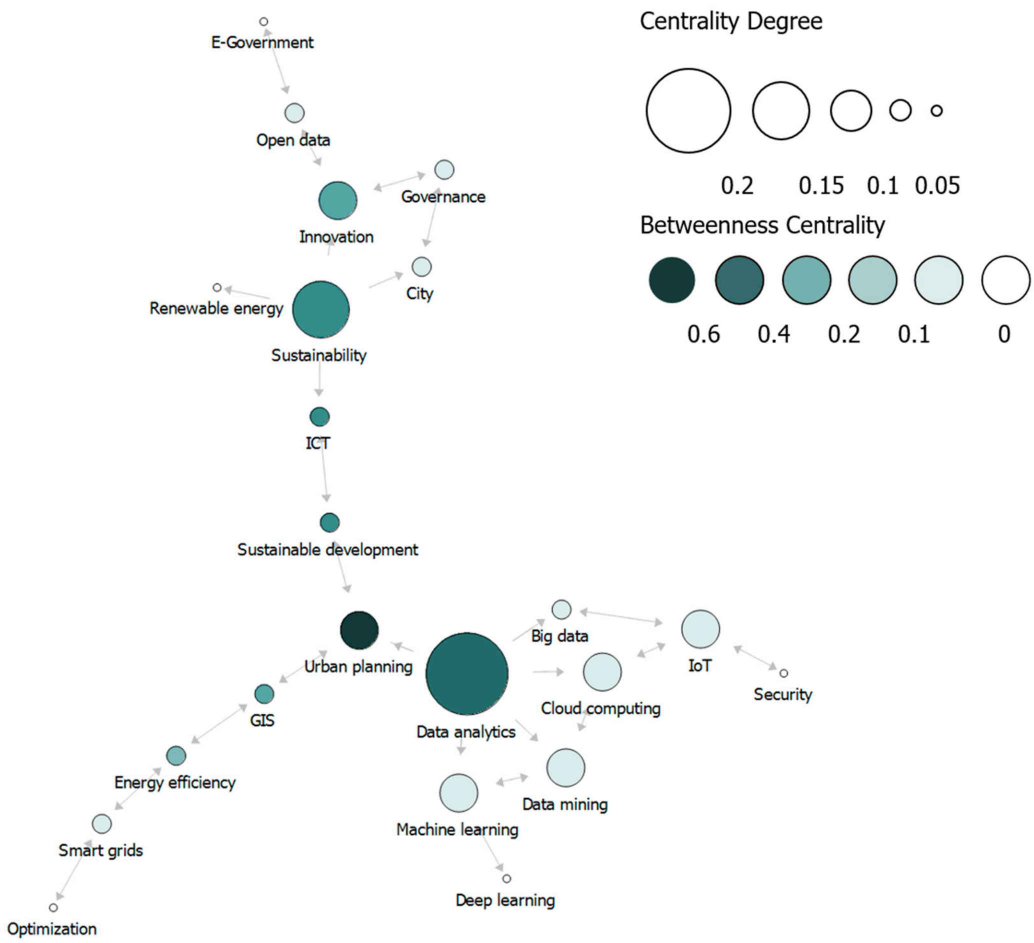

Figure 5. The keywords network map after 2016.

The words that made up the flow of the research trend in the analysis were sustainability, ICT, sustainable development, urban planning and data analytics, which had a high betweenness degree. These words were keywords in areas related to the smart city concept after 2016. Among them, the research relating to sustainability and data analytics have been the most active, and the relevant fields of research of these two words have been identified. In particular, the urban planning word, which had the highest value in the network map, was considered important in understanding the flow of the smart city concept, as it was located at the center of the network map while playing an important role in connecting the words of data analytics, sustainable development, and GIS. On the other hand, the IoT word had the highest frequency and the highest degree centrality, but did not have a high betweenness degree. This means that there have been studies using IoT as the keyword, but few related to other deep studies. Overall, compared with previous studies in 2015, the studies after 2016 have been more actively focused on collecting and analyzing data to apply the smart city concept to urban planning.

4.2. Cluster Analysis

4.2.1. Keywords before 2016

To further analyze the relevance of the words, we conducted a cluster analysis. This analysis was useful for understanding the related research in a large framework. The cohesion index describes the concentration within the group. At a value of above 1, the concentration density inside the group is greater than outside the group. This analysis was based on the cohesion of each word, organized into groups with high cohesion. In other words, the words in a group were considered keywords for related studies, and can be used to interpret the flow of research with group cohesion. As a result of the modularity cluster analysis, the related research projects were confirmed. Cluster 1 included words related to "related fields" such as "climate change", "governance", and "big data". Cluster 2 included words related to "smart technologies" such as "mobile application", "GPS" and "Internet of Things". Cluster 3 included words related to "smart concept of urban planning and development" such as "urban development", "sustainability", and "sustainable development" (Figure 6).

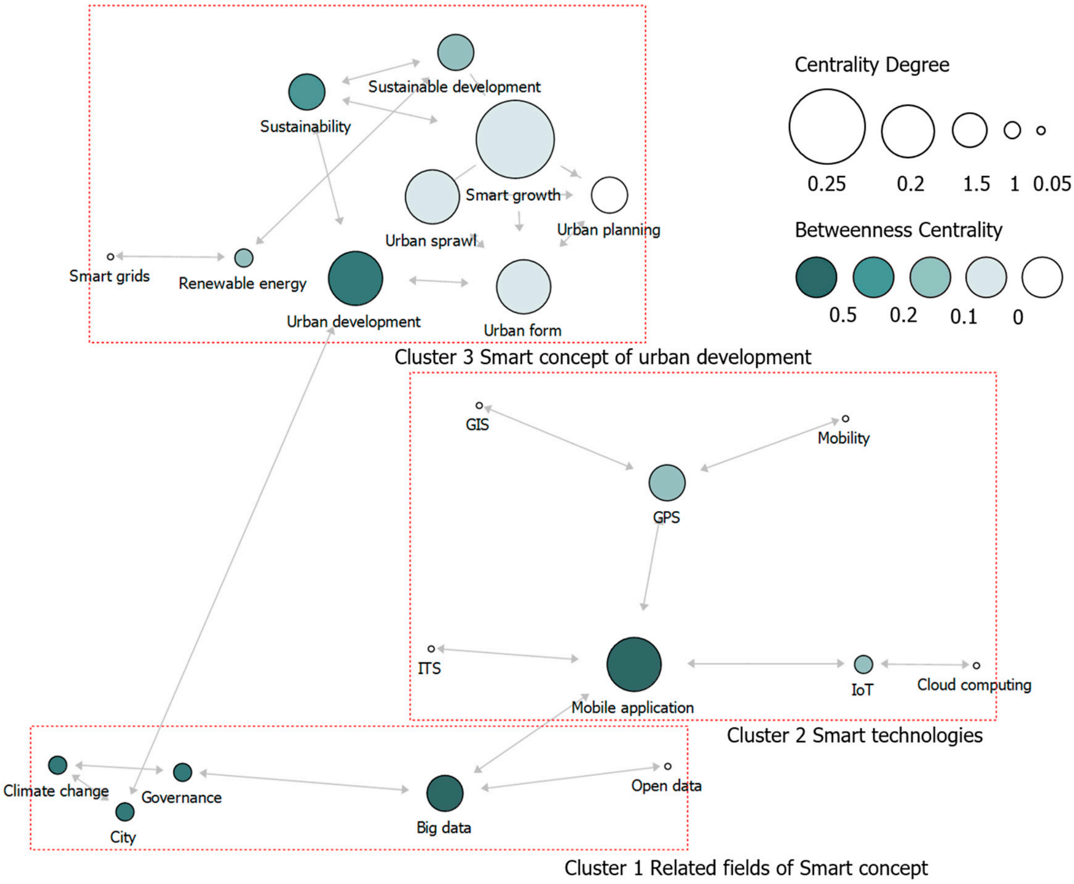

Figure 6. The cluster network map up to 2015.

Up to 2015, studies can be considered as introducing and applying specific areas of smart concepts. Overall, the words that were included in Cluster 1 contained words from the higher concepts of the studies. Cluster 2 was considered as a means of utilizing the "big data" of Cluster 1, and Cluster 3 was also considered a sub-concept based on the "city" of Cluster 1. Cluster 1 consisted of words with a high value of betweenness degree, but the properties of clustering were the lowest. This suggested that many studies have been conducted with the words as the main keywords, mainly in the higher concept, while the sub-studies involved were less. The words in Cluster 2 consist mainly of "mobile applications", suggesting that many studies related to the big data of Cluster 1, or consisting of its sub-concepts, had been carried out. The value of each cohesion index was the highest for Cluster 3, related to the "city" of Cluster 1. This suggested that many studies that were deeply related to words in the same cluster were actively carried out. As a result, many studies based on words and their combinations in Cluster 3 were conducted, mainly focusing on the conceptual application of the smart city concept, and its introduction to existing cities. In addition, interpreted in terms of the cohesion index, Cluster 1, with the lowest index value, was mainly used as an important keyword for the studies as a higher concept, but was studied with other keywords. On the other hand, Cluster 3, with the highest cohesion value, suggested that words from the same cluster were studied together as keywords. Combining the trends of studies up to 2015, the urban studies and technology fields had been the main fields investing in the study of the smart city, and the concept of the smart city was still seen as being in a period before being actively introduced and applied to urban areas (Table 3)

Table 3. The cluster context based on research up to 2015.

Clusters	Words	Cohesion Index
C1 (Related fields of smart concept)	5	8
C2 (Smart technologies)	7	14
C3 (Smart concept of urban development)	9	21

4.2.2. Keywords after 2016

After 2016, the related research was confirmed. Cluster 1 included words related to “sustainable smart city”, such as “sustainability”, “innovation”, and “open data”. Cluster 2 included words related to “data analytics”, such as “machine learning”, “big data”, and “cloud computing”. Cluster 3 included words related to “smart urban planning”, such as “sustainable development”, “ICT”, and “energy efficiency”. Overall, the words that were included in Cluster 1 contained words of concepts related to a smart city based on sustainability, which was linked to ICT in Cluster 3. Cluster 1 studies based on sustainability implied that they were related to ICT. Cluster 2, which included words from the process of utilizing and applying data, was associated with the urban planning of Cluster 1, and implied that many studies based on collecting and analyzing data were conducted related to urban planning. Cluster 3 contained urban elements words around urban planning related to sustainability and data analytics, and suggested that many studies have been conducted in fields related to the urban planning elements for a smart city (Figure 7).

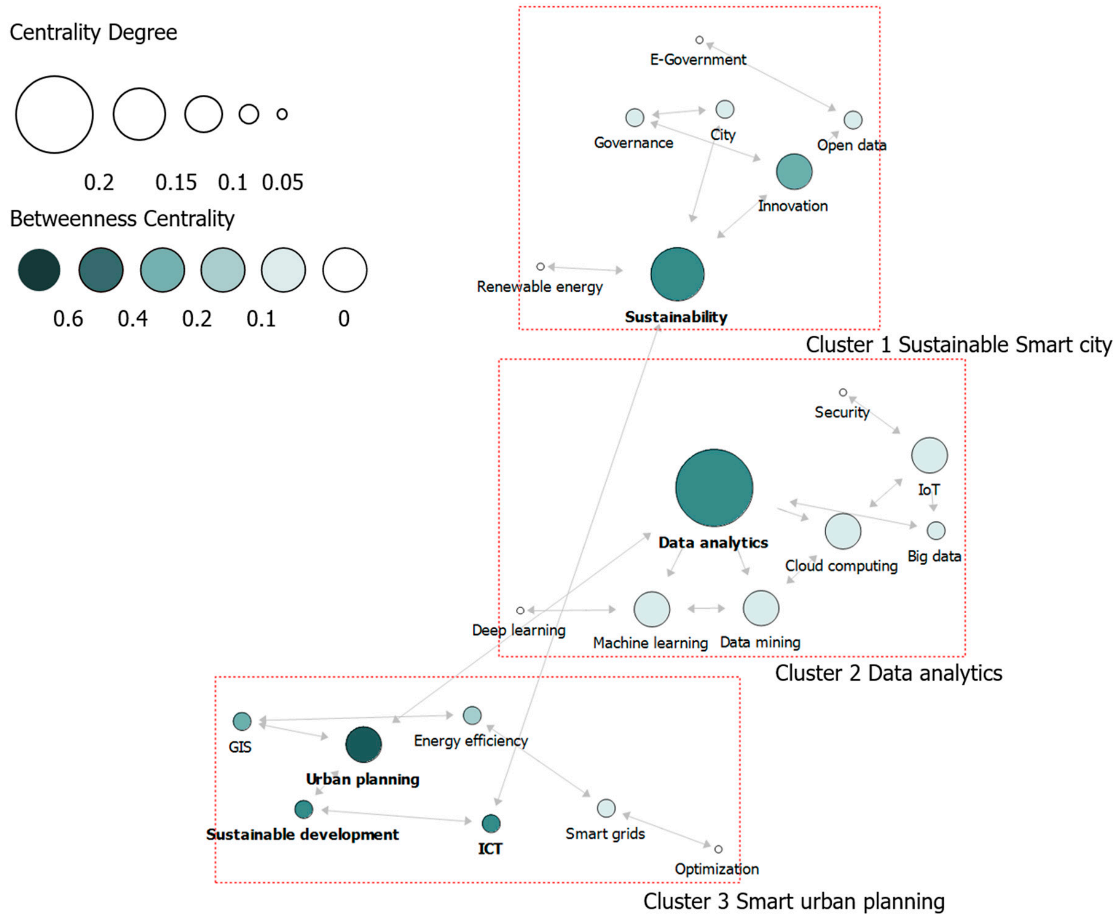

Figure 7. The cluster network map after 2016.

In terms of the cohesion index (Table 4), Cluster 3, with the lowest index value, was mainly used for an important keyword in the related studies as a higher concept, ICT was related to sustainability and urban planning was related to data analytics. On the other hand, Cluster 1 and 2 were high in the entire network, which implied that most of the studies involved in data analytics have been performed in conjunction with the words in their own cluster. Since 2016, many studies related to the words of Cluster 2 have been conducted as keywords for the studies, which consisted of technologies and the process of data analysis research projects. Combining research trends after 2016, smart city research has been more specific and detailed than in the past. In particular, data analysis suggests that various data collection methods and analysis techniques were studied as important elements. This confirmed that traditional data analysis was used on an open data basis, as a large concept, and that related research was used as a basis for mobile applications. Information gathered from existing GPS and smart devices can now be expected to gather information more automatically. In doing so, data analysis is considered to be the most important element in smart cities, and the most advanced area. In addition, open data has also been more usable than in the past, and can be expected to be more utilized as data.

Table 4. The cluster context based on research after 2016.

Clusters	Words	Cohesion Index
C1 (Sustainable smart city)	7	17.5
C2 (Data analytics)	8	20
C3 (Smart urban planning)	7	7.5

4.3. Comparing the Keywords

The words appearing in the studies until 2015 were as follows: climate change, ITS, mobile application, mobility, GPS, smart growth, urban sprawl, urban development, and urban form. Among them, smart growth was researched as the keyword with the highest frequency and degree centrality, and mobile application, mobility and climate change were the keywords with the highest betweenness degree related to other research. In particular, up to 2015, many research projects on smart growth were implied too much addressed as keywords. On the other hand, the words that appeared after 2016 were as follows: energy efficiency, innovation and E-government, data mining, machine learning, security, deep learning, data analytics, ICT, and optimization. Among them, data mining and machine learning were researched as keywords with a high centrality degree, and data analytics, ICT, and innovation were keywords with a high betweenness degree related to other research. In particular, after 2016, data analytics and ICT were frequently used as keywords (Figure 8).

Words addressed as keywords up to 2015 were used in research as big concepts in related fields to the concept of the smart city, such as climate change, used in mobile applications through geographical information and mobility, and as concepts of overall urban development fields such as smart growth and urban sprawl and form. On the other hand, the words that emerged after 2016 have reflected, in many research projects, elements of the sustainable smart city, such as innovation and E-government, and in the words for data analytics such as data mining and machine learning, as well as in the words for elements of urban planning for the smart city, such as ICT and energy efficiency.

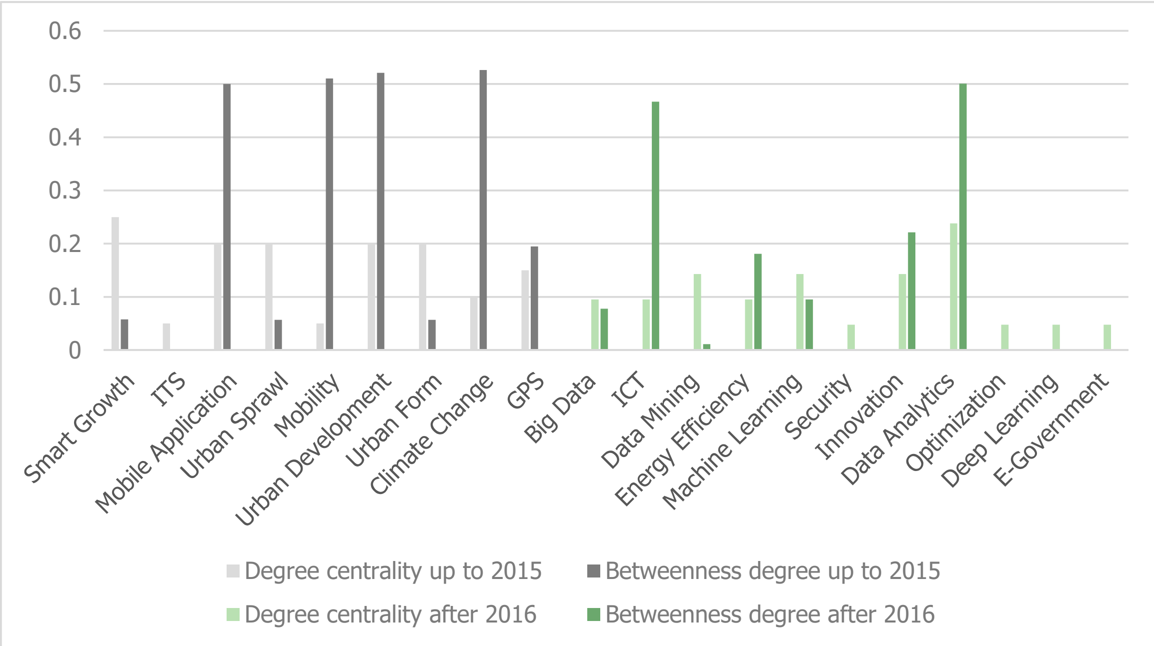

Figure 8. Disappeared and emerged keywords after 2016.

5. Discussion

5.1. Comparison of Keywords on Smart City

In the whole flow of the emergence and disappearance of words, up to 2015, studies had been carried out focused on the concept and introduction of a smart city, related to adaptation and mitigation to climate change, and applied to transportation systems based on mobile applications and geographic information, such as that derived from GPS. Since 2016, studies have evolved towards research based on sustainability with the Internet, information, and technologies as key focuses. The compositions of the clusters were added to the words such as E-government and ICT in order to apply the smart city concept, and various processes such as machine learning and data mining were added to the data analysis process. In other words, previous research focusing on conceptual and specialized fields was conducted, and recent research has focused on actively applying smart urban planning based on big data of broader fields, with the development of information technologies (Figure 9).

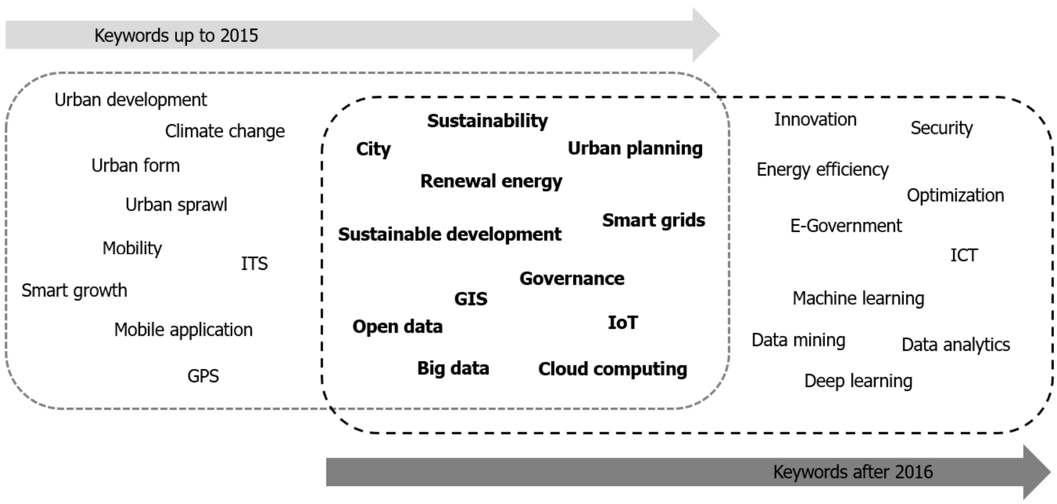

Figure 9. Comparison of keywords before and after 2016.

We can also identify keywords that should be highlighted in the current smart city concept, based on keywords appearing continuously. Firstly, a smart city also aims for sustainable development as a part of urban planning with sustainability. Secondly, open data, IoT, cloud computing, GIS, and smart grids as a basis for collecting big data can contribute to energy fields and governance. Thirdly, if all the secondarily mentioned words are considered as the basis for big data collection, they would all contribute to the smart city. In the end, big data will play the most important role in smart cities, however, if the condition of the environment and infrastructure varies from city to city, these above interpretations are debatable. However, we emphasize that the constantly used keywords should be reflected in the basic concepts and systems of a smart city.

5.2. The Flow on Smart City Based on the Articles and Conferences

We analyzed the information of the analyzed data and verified the publication year of the articles. There were 2327 documents (54.36%), followed by 1538 (35.93%) article documents, 223 (5.21%) book chapter documents, 97 (2.27%) review documents, 77 (1.8%) articles in press, and 29 (0.44%) other types of documents, such as editorials, erratums, letters, and notes (Figure 10). It was confirmed that by 30 March 2019 more than half of the documents studied for keywords relating to the concept of the smart city were published in conference papers. This means that conferences have become more frequent and popular in many areas under the theme of the smart city.

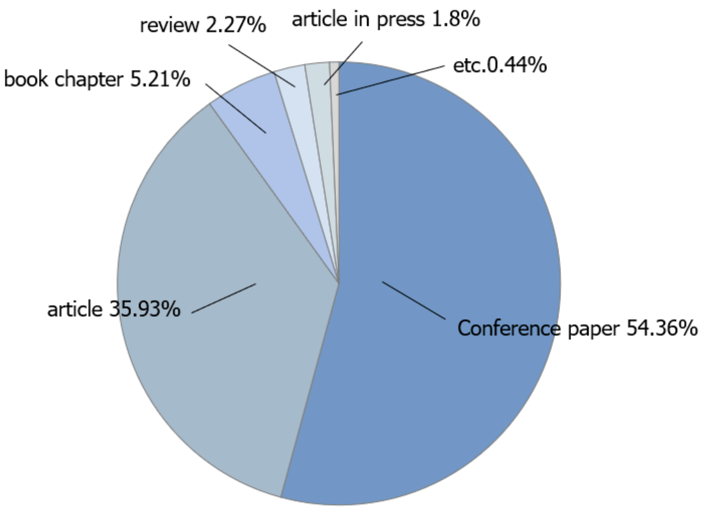

Figure 10. Composition of the article information.

A total of 544 journals have been published in the form of papers, including articles, articles in press and reviews. Among them, journals with quantities above 25 are listed in Table 5. Most of them were in Elsevier, but the sustainability journal of MDPI had the hifghest value. The scope of these journals mainly covers sustainability of the urban environment, data collection and analysis, and technical energy. Given the scope of research pursued by these journals, Figure 9 includes most of the keywords that appear continuously, which can help predict research flow and related areas in the smart city concept.

Table 5. Information of journals with quantities above 25.

Journals	Papers	Publication	Impact Factor
Sustainability	97	MDPI	2.075
Sustainable Cities and Society	81	Elsevier	3.073
Cities	58	Elsevier	2.704
Journal of Cleaner Production	48	Elsevier	5.651
International Journal of Engineering and Technology	37	SCImago	
Journal of Urban Technology	35	Taylor & Francis	2.19
Energy	27	Elsevier	4.968
Applied Energy	25	Elsevier	7.9
ISPRS International Journal of Geo-Information	25	MDPI	1.723

A total of 298 conferences have been published in the form of proceeding papers, and conference papers are presented in Table 6 if quantities are above 50. Most of the conferences were held in Asia, especially in China. Most are international conferences on the concept of the smart city and various other topics, ranging from general international issues to regional associations studying a country's issues. Additionally, most of the conferences have been held since 2016, and most of the venues were in Asia, especially China. Other than those shown in Table 6, some conferences are held annually, such as the Intelligent Transport Systems (ITS) World Congress. In addition, the keywords emerging after 2016 in Figure 8 are deeply related to the theme of the conferences held after 2016, and are expected to have been discussed a lot at the conferences.

Table 6. Information of conferences with quantities above 50.

Conferences	Papers	Venue
Smartworld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI, 2017 IEEE, SmartWorld Ubiquitous Intelligence and Computing, Advanced and Trusted Computed, Scalable Computing and Communications, Cloud and Big Data Computing, Internet of People and Smart City Innovation	215	San Francisco, United States
ICITBS 2018, 3rd International Conference on Intelligent Transportation, Big Data and Smart City	192	Xiamen, China
ICSCSE 2016, International Conference on Smart City and Systems Engineering	162	Zhangjiajie, China
ICITBS 2016, International Conference on Intelligent Transportation, Big Data and Smart City	141	Changsha, China
ICSCET 2018, International Conference on Smart City and Emerging Technology	137	Mumbai, India
TENSYMP 2017, IEEE International Symposium on Technologies for Smart Cities	115	Kochi, India
ISC2 2017, International Smart Cities Conference	93	Wuxi, China
ICSESP 2018, International Conference on Technologies for Smart City Energy Security and Power: Smart Solutions for Smart Cities	86	Bhubaneswar, India
ICSCSE 2017, 2nd International Conference on Smart City and Systems Engineering	61	Changsha, China
ISC2 2016, IEEE 2nd International Smart Cities Conference: Improving the Citizens Quality of Life	61	Trento, Italy
ICSGSC 2017, IEEE International Conference on Smart Grid and Smart Cities	59	Singapore, Singapore

We note that there have been many conferences in China since 2016. According to the Deloitte China report published in 2018 [96], China's government proposed new smart society initiatives in their national strategy in 2016, and embarked on self-assessment of the smart city to achieve high urbanization growth globally. The people-centered approach was first introduced as an element of the smart society in the 19th CPC National Congress in 2017. Since 2016, 95 percent of small and medium level cities have made an effort to introduce smart concepts, with many research projects underway. China ranks first in the international community, with 500 pilot cities which form a smart city cluster near the Yangtze and Pearl rivers under smart city construction. Many related studies are also being conducted within these cities on index developments that may be able to be applied to each city. Further, the Chinese government has stepped up efforts to introduce and apply smartness. This smartness has been highlighted in the government report, "The 13th Five-Year Report for Economic and Social Development of the People's Republic of China (2016–2020)", and is considered as the future of Chinese urban planning through more technologically organized urban areas [71,97]. Therefore, many studies on the smart city concept are being conducted with investments from the Chinese government, and many conferences held in China can be expected to be utilized as a venue for academic information exchange.

So far, we have analyzed the flow of the smart city through keywords analysis, based on papers and conferences. Although it is not possible to accurately define the flow of research through analysis of the keywords, this process is useful to understand and identify the flow of research, rather than review papers by qualitative methods. In addition, the relationship between words based on keywords is visualized by numerical and network mapping, which is more flexible to understand and interpret, and is useful in order to grasp the overall context by analyzing the association of words through cluster analysis. However, the time required for analysis relies on the format or form of the data.

5.3. The Flow of the Smart City

Considering various analyses based on keywords, this paper emphasized the following four points. First, the sustainable concept should be considered important in a smart city. Sustainability should be reflected not as a disparate concept to the smart city, but as the underlying concept that should be most fundamental. Sustainability has been a consistent keyword for a long time, and its role has increased further since 2016. Therefore, the controversy over sustainable smart cites and the smart sustainable city should be considered in each city's urban planning. In addition, renewable energy and energy efficiency should be considered important in maintaining urban sustainability. Second, as of 2016, the overall trend of research on the smart city has changed from urban development to urban planning. In the past, conceptual research on the smart city was undertaken to solve environmental challenges such as climate change or urban development. However, after 2016, the smart concept was more emphasized and detailed in urban planning, and the utilized and practical application of big data analytics. In addition, active words in the flow of adoption, such as open data and E-government, have been identified as keywords, and the role of governance is expected to change more significantly as it is linked to the innovation keyword. Third, in the past, the utilization of big data was concentrated in specific areas, such as ITS using GPS and smart devices. However, as of 2016, more technical flows with the advent of various big data collection and interpretation technologies were emphasized than in the past. Finally, the reason the number of studies has increased as of 2016 is likely to be the hosting of many conferences. More than half of the data has been published at conferences at which many researchers exchanged and presented information to the international community. In particular, China has held many international conferences, and big companies such as Huawei are investing in smart city research.

6. Conclusions

The smart city has been regarded as an ideal city for solving the challenges that have arisen in various fields, such as the environment, energy, and transportation, within existing cities. However, many scholars and papers have questioned the difference between a smart city and a sustainable city, the latter of which many cities in the world have been pursuing. In order to introduce the concept of a smart city, various questions around the challenges to be reconciled have first been addressed as an agenda in international society. This is a result of the unclear definition and concept of the smart city, and it is necessary to grasp and understand the flow of research that has been carried out so far, because the smart city is related to various urban elements. Therefore, this study analyzed the comprehensive flow of the smart city, using keywords of papers that have been published so far.

Smart cities, which have been heavily researched for conceptual introduction in the past, are increasingly being studied in terms of sustainable urban planning. In particular, with advanced ICT, much research is being carried out on the utilization aspects of big data. However, because the research fields of the smart city concept are wide and diverse, it requires governance based on communication and cooperation of citizens, governments, stakeholders and private companies. All must think together to promote higher urban services, and should work hard to apply smart concepts that are appropriate for each city.

Besides, the fact that more conference papers than articles exist in this area indirectly suggests that more research is still needed. This would enable the interpretation, discussion, and exchange of information on individual studies at conferences, as the studies which have been carried out so far are limited in their comprehensive application to urban areas. This process will contribute to smart city projects and papers of high quality in the future.

The limitations of our study were that, while keyword analysis was useful for overall flow understanding and quantitative analysis, it may not represent the whole content because it relies on keywords in the analysis process. What the authors wanted to express in each paper might not be used as keywords, and there was a possibility that the smart city concept was used as a trend-sensitive keyword. If the composition of the keywords does not represent the author's paper, the analysis results are likely to be misinterpreted. Second, the keywords that had important meaning in each paper are collected and analyzed, but the results were not compared to review papers written through other qualitative methods. If the relationship between keywords is unclear, or there is no connection point, the interpretation of the analysis results might be incorrect or misinterpreted.

We propose two studies of keyword analysis in future research. The first involves a comparative analysis of keywords in papers on how smart concepts play a role in devolved and developing countries undertaking new urban planning. By analyzing developed countries, the results would propose processes that are first required for developing countries, and by analyzing developing countries, the results provide an important guideline for cities that will apply smart concepts in the future. The second is to select specific cities as the study areas, collect keywords relating to the smart city from web-based big data, and analyze how smart concepts are being utilized within urban areas. These results will also be a good guideline for cities that consider smart concepts in new urban planning.

Author Contributions: K.M. and K.F. proposed the research question and K.M. and M.Y. designed the research framework. K.M. analyzed data and wrote the paper.

Funding: This first author of this manuscript is a scholarship doctoral candidate at Chiba University, and his financial support has been given by MEXT (Monbukagakusho) in Japan.

Conflicts of Interest: The authors declare no conflict of interest.

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