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Trajectory of urban sustainability concepts: A 35-year bibliometric analysis

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ABSTRACT

In recent decades, our cities are increasingly expected to become more sustainable urban forms, with many added determinants. A multitude of city concepts has therefore been contrived. The most time-honored and prominent concept is the "sustainable city," which is depicted as a model urban form and thereafter more city concepts have come into being. However, it is not clear for all the concepts, for instance, "eco-cities," "smart city," "sustainable city," and "resilient city," what are the underpinning building blocks within each concept and how these concepts correlate with each other. This bibliometric study organizes this in conducting a descriptive summary, a clustering analysis, and multidimensional scaling of major city concepts, by establishing a co-word matrix of high-frequency keywords occurring in the Science Citations Index (SCI) and Social Science Citations Index (SSCI) databases. In addition to summarizing the evolution of these concepts, it analyzes the composition of each city concept and the core issues addressed by each city type. Also investigated are the correlations between the city concepts with a statistical analysis of the clusters of literature in one concept that overlap or connect to other clusters in another. From this, it is shown that, under the two umbrella terms of "sustainable city" and "smart city," the "? -city" literature has developed in a variety of distinctive ways.

1. Introduction

It has become common practice to contrive a city concept for transforming our cities into a more sustainable urban form. The salience of these terms has been mutually reinforced whenever it is advocated in the policy discourse or seriously elaborated in the academic field. To date, a multitude of city concepts intending to depict a more sustainable and prosperous urban future have been contrived and debated. Of these concepts, the "smart city" and "sustainable city" are the most outstanding and persistent. However, other, comparatively less, prominent city types have also received much attention, although some have lost momentum with the vicissitudes of urban discourse. "Eco-city," "low-carbon city," "green city," and "digital city," for example, are all representatives as their prime might be in the past. There are also less popular terms, such as "livable city" and "information city" as well as other concepts, whose day may yet come but are overwhelmed by competing new terms. Yet, as their names indicate, they are still endowed with grand expectations for a more sustainable future. In general, these concepts focus on at least one aspect of the social–eco–economic urban discourse.

It is true that all these city types have a different, although sometimes overlapping, genesis. For instance, the "sustainable city" concentrates more on the tripartite relationship of social-eco–economic realms (Jabareen, 2006), while "smart city" has a more technological genesis and deals more with the social–economic realms of cities. However, they can all be considered as potential sustainable urban forms in a broad sense and focus on one particular aspect of urban development. These concepts form a complex web with each having its own distinctive characteristics. As Kamalski and Kirby (2012) argue, bibliometrics is a useful tool to examine how concepts are connected (or unconnected) within one research field. As a result, bibliometrics (clustering analysis) will be adopted in this study to identify the underpinning clusters under each city concept and how they correlate with each other across each city concept (the overlapping of different concepts), clarifying the relationship between all the concepts.

Section 1.1 provides an introduction of the genesis and evolutionary trajectory of some of the major concepts. Section 2 outlines the method adopted in analyzing the popularity and intensiveness of subthemes of all the concepts that promote urban sustainability in some way. As most current literature does, a thesaurus of terms is established before moving to the clustering analysis of the major city concepts (Liu, 2005; Wang et al., 2012; Kamalski & Kirby, 2012). As to the clustering analysis, a co-word matrix is established based on the keywords of

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"sustainable city," "eco-city," "low-carbon city," "green city," and "smart city," to reveal how each cluster connects with each other under the same concept and how different clusters receive different weights of research attention. That is to say, to identify the core research themes and their relationship with other themes in the myriad of articles associated with one concept. In this section, we also build a multidimensional scaling (MDS) diagram to show the inner relationships between the keywords in a city type and the possible trends for the future development of the city concepts that promote a more sustainable urban form. The findings in this section provide an unprecedented perspective for dissecting the vast volume of research in the model cities we have promoted, illuminating the real trends and focus of the research area. The results are also analyzed across different concepts to see how these concepts overlap with, or differ from, each other, drawing a clear map of the composition and trends of the whole literature. The final section draws the conclusions of this study and further explains the implications of the findings for future research.

1.1. Evolutionary trajectory of major city concepts

In recent decades, promoting a more sustainable urban future has become the focus of urban studies and, as a result, a multitude of city concepts have been contrived to promote urban sustainability in some way. The concept of sustainable urbanization is not new and recent decades have witnessed a proliferation of innovations by municipalities and city authorities in its promotion worldwide. As early as the 1980s and 1990s, the research on sustainability in urban areas gradually gained momentum in both academic and policy discourses. Van der Ryn and Calthorpe (1986) were the first in bringing the issue of pollution control to the process of economic development, depicting a prospect of more livable cities that depend less on fossil fuels. Meanwhile a string of conferences and international initiatives focusing on the problem of unsustainability has also highlighted the salience of sustainable urbanization, generating many concept ramifications. The Brundtland Commission (World Commission on Environment and Development, 1987) provided an early definition of urban sustainability, which was consistently improved and completed at international forums. Since then, research on sustainable urbanization has been evolving into a more detailed and complicated form, suggesting the need for a systematic compendium for moving toward sustainability. A comprehensive set of principles of urban planning concepts and strategies was introduced by urban planners to keep traditional planning and designing practice in alignment with the renewed and updated notion of sustainability (Walter, Arkin & Crenshaw, 1992).

However, in the early 2000s, the notion of urban sustainability gradually variated into a subset of concepts as the result of burgeoning "smart green technological solutions" (Joss, Cowley, & Tomozeiu, 2013). Although the planners were equipped with new technological innovations and policy tools, the way to sustainable urbanization was far from clear after the three-decade endeavor. Rather, the notion of sustainability had multiplied and become dramatically enriched, with the requirements for achieving sustainability becoming much more demanding than hitherto (Joss, 2011; Ni & Jie, 2014; Yigitcanlar, O'Connor, & Westerman, 2008). The notions and concepts of urban sustainability on the one hand are inspired by technological innovations and, on the other, go beyond technological advancements. To date, urban sustainability has become an umbrella concept covering "ecological modernization," the "green economy," "regenerative sustainability," "the ecological city as economic city," "social justice," and so on (Barton, 2000; Cole, 2012; Mol, 2003; World Bank, 2010). Technological innovations have significantly enriched the meaning of sustainability, leading to a myriad of discussions over the dynamics of the conflicts among, and priorities of, the social–economic–ecological triangle (Rotmans, van Asselt, & Vellinga, 2000; Berke & Conroy, 2000). The research and practice of urban sustainability, instead of being discarded as hackneyed jargon after decades of intensive attention, flourished and generated a set of subcategories of new terms. The traditional term "sustainable cities," which is still in its prime in current theoretical and practical discourses, has been attracting attention over other newly innovated notions such as eco-cities, low-carbon cities, and smart cities (Caragliu, Del Bo, & Nijkamp, 2011; Liu, Dai, Dong, & Qi, 2009; Roy, 2009).

The emergence of these city concepts is the result of the development of sustainable discourse. The emergence and thriving of eco-cities was largely the result of refining the sustainable city as an "ecological healthy city" and the "ecological city as economic city," promoting a new generation of study of the planning of eco-cities as well as the relevant qualitative and quantitative evaluation measures involved (Register, 1987, 3; World Bank, 2010; Joss, 2011). Neoliberalization in the global context facilitated the knowledge transfer of eco-cities (together with other subcategories of sustainable cities and relevant technologies and policy tools), rendering private companies, research institutes, and governments at all levels competitors and partners in their joint efforts in greening cities worldwide (Harvey, 2005, 2006; Pow & Neo, 2013; Joss, Cowley and Tomozeiu, 2013). This has bred a new focus of research into green standards, green technology, and green knowledge transfer. Also, worth mentioning is the fact that the booming of green standards, such as the American LEED, UK BREAM, and other similar versions throughout the world, is the by-product of the evolving process of sustainability discourse and global knowledge transfer (Joss, Tomozeiu, & Cowley, 2012). This ongoing process of evolution of meanings in urban sustainability has shaped and reshaped contemporary research and taken it to new frontiers.

In parallel, the rising salience of carbon discourse in the 21st century has also left its mark in the theory and practice of urban sustainability. The early literature of Register (1987) and Roseland (1997), although advocating ecological and environmental protection, did not deliberate on the issue of CO_2 emission reduction and solutions to climate change. It was not until the adoption of the Kyoto Protocol (1997) that "low carbon" or "carbon neutral" gradually became accepted as a universal standard by almost all the cities in the world. A string of global summits, including the UN Climate Change Conference in Copenhagen in 2009 and the Paris Conference in 2015, stressed the responsibilities of all cities to reduce their carbon emissions and urged coordinated collective action worldwide. Cities, which are estimated to account for almost 70% of all global carbon emissions and energy consumption, are seen as the key to sustainability (UN HABITAT, 2011). In accordance with this trend, sustainable and eco-city initiatives have integrated the clear and specific goal of carbon emission reduction into their policy statements and future plans. The carbon discourse not only provides the low-carbon city as the new approach to achieving a more sustainable urban form, but also introduces a series of terms such as "low carbon," "carbon neutral," "zero carbon," and "carbon footprint," further expanding the sustainable urbanization research field with a new dimension (Chen & Zhu, 2009; Gossop, 2011; Liu et al., 2009). Quite distinct from eco-city research, the low-carbon literature concentrates more on technical issues, especially the innovations in technological and policy tools for reducing energy consumption and increasing efficiency (Storch & Downes, 2011; Premalatha, Tauseef, Abbasi, & Abbasi, 2013).

Very recently, the term "smart city" is gaining maturity and becoming more popular, and with the quantity of published papers with the keyword "smart city" even surpassing those containing "sustainable city" (De Jong, Joss, Schraven, Zhan, & Weijnen, 2015). In the literature of "smart city," the tripartite eco–economic–social relationship deliberates less on ecological sustainability than on economic–social sustainability with the expectation that digital information technologies will upgrade the social and economic performance of cities to create a more prosperous future, with high-tech industries and efficient social services for future generations (Joss, Cowley and Tomozeiu, 2013). This advancement has steered research toward a new direction. The most recent trend on the studies of the "smart city" has articulated

numerous social–economic issues, ranging from improving economic and administrative efficiency with better networks and technologies to advocating urban development to be business oriented; and from the inclusion and cohesion of all social classes to the sustainable and generative development of a tripartite social–eco–economic structure (Leydesdorff & Deakin, 2011; Caragliu et al., 2011; De Jong et al., 2015). The research dimensions have been extended far beyond the traditional boundaries of the social, economic, and eco-triangle, discussing sustainability in a more complicated matrix that includes good governance, implementation of information technology, and a more convenient living environment (Hassan & Lee, 2015a).

From a theoretical review, it seems that some of these concepts share a similar focus, while others are more concerned with different aspects of urban sustainability. It is safe to conclude that both the research and practice of sustainable urbanization are quite well developed, yet there is still one problem left. That is, although the research focus has been changing and developing over the last three decades and it is possible for us to map its evolutionary progress, it is not yet known exactly which dimensions or subfields are the most extensively explored and what the future focus of these city concepts will be. Current reviews provide a general, but unclear, picture of research trends in the development progress of these concepts (De Jong et al., 2015), while this study moves one step further by specifically examining, among the vast volume of research, how each dimension, be it green techniques, smart governance, or planning techniques, has made its contribution to the overall sustainability research effort.

2. Methods

A thesaurus of terms is first established, which is the basis for further analysis of subterms (Kamalski & Kirby, 2012). De Jong et al. (2015) provided a comprehensive summary of the city concepts that promote more sustainable urban forms so it is used here for further analysis. However, it is impossible to find a general keyword that covers all these city concepts and, at the same time, still maintains close links to each of them. If their connection with the broad concept is weak, the comparison would be less meaningful. Furthermore, the issues (subclusters) discussed under each city concept were investigated, as well as the clusters across these concepts were correlated, removing the necessity to discuss these concepts under one broad but vague concept. As it is, all these city concepts may or may not be closely connected to one meaningful broad concept. Instead, we search all these popular city concepts in both the Science Citations Index (SCI) and Social Science Citations Index (SSCI) databases, which are the most robust and frequently used sources for bibliometric research. They are high-quality multilanguage databases, containing journals with different types of languages. A general and panoramic statistic review of the results is provided to serve as the thesaurus for the subsequent clustering analysis of each city concept.

A descriptive summary, including the number of publications of each city concept, their regional characteristics, and a timeline showing the vicissitudes of the concepts, is provided as a thesaurus for further analysis. However, given the number of terms used in urban sustainability research, it is almost impossible to choose all of them as the target for clustering analysis. If the publications were very few in number, the clustering analysis would be less meaningful. Therefore, the research only focuses on the major concepts contained in most publications. Accordingly, the establishment of a co-word matrix and the following clustering analysis focuses on five keywords[1]: “sustainable city,” “eco-city,” “low-carbon city,” “green city,” and “smart city.” As de Jong summarizes in his recent 2015 paper, these five types of cities are the most prominent in the number of papers published. In addition, these five categories are not only frequently the focus of theoretical discussions, but are also enthusiastically adopted by policy makers and incorporated into practice worldwide. Moreover, the number of publications with other less popular keywords such as “resilient city” and “knowledge city” is very few for statistical analysis. Other categories such as the “digital city” and “information city,” focusing on the implementation of information technologies in modern cities, have an inadequate number of associated publications, but share a similar genesis with “smart city,” and thus the clustering analysis of “smart city” would, to some extent, shed some light on the issues addressed in these city concepts. Fig. 1 depicts the process and methods of analysis used in this study.

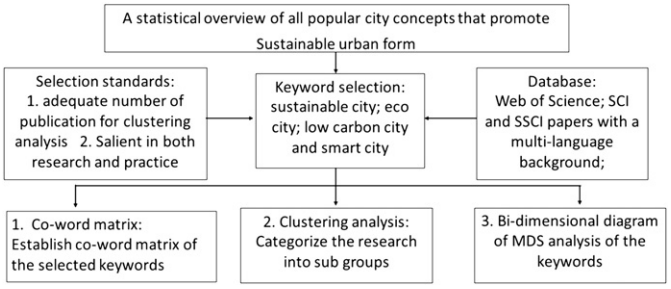


Fig. 1. Research methodology flow chart.

2.1. Data source and processing methods

The Web of Science databases (including all SCI and SSCI listed papers) are used to establish the co-word matrix of keywords, as it has a multilanguage background. The SCI and SSCI are also the most well-accepted standard for robust research papers. The papers were published from 1980 to 2015, reflecting the relatively contemporary nature of research into currently popular city concepts that promote urban sustainability in some way. With the assistance of the scientometric software, BibExcel, the frequency (also known as occurrence) of a keyword can be calculated and numbered. The keywords are ordered according to their frequency, and those with high frequency are selected for analysis in the following steps:

1. The software builds a co-word matrix to quantify the frequency of two keywords (co-occurrence/concurrence) appearing together in one paper.

2. Clustering analysis with UCINET is performed on the co-word matrix, by which the keywords are divided into several clusters, each signifying a particular subfield of urban sustainability research.

3. In order to provide a more direct and clear illustration of the intensity and attention each cluster has received from academia, each subfield is put into a bi-dimensional diagram by MDS to reveal the most frequently discussed issues, as distinct from the more marginal topics in each cluster.

De Jong et al. (2015) carried out a comprehensive review of all these concepts, but did not identify the clusters of each city concept. In order to complete this task, a subtler investigation is made of the literature for each city type, as it helps divide the current literature into subclusters. Examining the similarity, disparity, and correlation between each cluster of literature enables a detailed map to be drawn of the current urban sustainability research. The clustering analysis of the co-occurrence of high-frequency keywords, compared to simply numbering the appearance of each city type, provides a reliable means of systemizing the literature.

On the basis of the previous studies conducted by De Jong et al. (2015); Joss, Cowley and Tomozeiu (2013), and also the descriptive summary provided in Section 3.1, this study focuses on the five major city types that promote a more sustainable urban form, namely the “sustainable city,” “smart city,” “low-carbon city,” “green city,” and

[1] Although it is recognized that these are phrases rather than individual words, the common term *keyword* is nevertheless used throughout.

"eco-city," as the first two concepts have always been the main focus of the literature while the latter three significantly overlap with the first two and can even be seen as their evolutionary protégés. On the contrary, other less deliberated concepts such as the "information city," "livable city," and "resilient city," although closely connected to the "smart city," are very few in number for clustering analysis and hence are omitted here. As it is, the five chosen concepts constitute >90% of all the literature concerning the city types and therefore provide a reasonably comprehensive explanation of the basic composition of the literature.

2.2. Establishment of the co-word matrix

The five city concepts were searched individually in the Web of Science database and the results were stored in a plain text document for processing using BibExcel. The threshold of high-frequency keyword selection is based on Donohue's formula: $n = \frac{1}{2}(-1 + \sqrt{1 + 8I_1})$ (Donohue, 1972), where I_1 denotes the number of keywords with one-time frequency. High-frequency keywords of the five concepts are selected accordingly (Table 1 is an example of "sustainable city"). Some of the similar high-frequency keywords in the co-word matrix are merged before they are put into UCINET for visualization as shown in Table 2.

The next stage is to build a matrix of the co-occurrence of the selected high-frequency keywords, revealing how the keywords of each city type are interlinked with each other. The co-occurrence of (explained in Fig. 2) the frequent keywords sheds light on how the keywords within one category cluster and is crucial for the visualization of the results in the following stage. A panoramic review of high-frequency keywords in each city type allows the subgroups to be demarcated and hence provides a clear picture of the composition of the literature. Finally, five co-word matrices were established for each of the five city concepts (too large to be shown here).

Table 1
Occurrence of keywords relevant to "sustainable city".

Frequency (F)	Keywords (K)	F	K	K
78	Sustainable city	6	Sustainable cities	Smart cities
31	Sustainability	6	City logistics	Environment
27	Sustainable development	6	Urban design	Urbanization
15	Urban planning	6	Governance	Architecture
12	Sustainable urban development	6	Compact city	GIS
11	Eco-city	6	Cities	Sustainability indicators
10	Industrial ecology	6	Urban metabolism	Quality of life
9	China	5	Sustainable	Mobility
7	Urban sustainability	5	Urban agriculture	Urban sprawl
7	City	5	Urban	Urban environment
7	Climate change	5	Smart city	…(CONTINUE)

Table 2
Example of how words are merged to facilitate analysis.

Keywords	Merged from
Sustainability indicators	Sustainability KPI, sustainability indicator…
Low carbon city	Low-carbon city; low-carbon cities; low carbon cities; low-carbon urban area

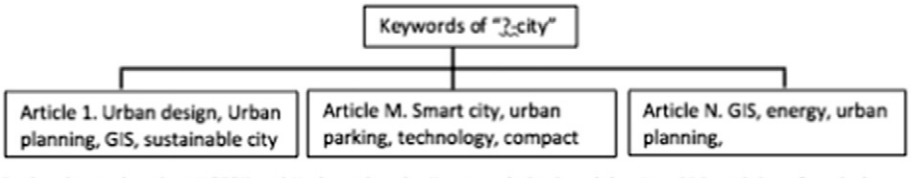
2.3. Clustering analysis and the MDS model

With the assistance of UCINET, a hierarchical (tree) diagram is produced, showing how the frequent keywords cluster into one group and the number of clusters in each city type. Keywords, in most cases, are powerful indicators of one particular article to reveal the main article topics or issues involved, and therefore the clusters of co-occurring keywords should identify the most frequently mentioned concepts, giving a clue to the most discussed issues in the research field. By calculating the co-occurrence of each city concept, De Jong et al. (2015) measures the distance between each pair of city concepts and establishes a network structure to show the linkage between each city type. The intertwined network, however, is not sufficient to dissect the literature within each city concept to reveal exactly what the city-type literature comprises. Clustering analysis of each city type bridges this gap and makes it possible to divide the research into specific subgroups, and therefore makes comparisons between the subgroups in one city type. It even enables us to move one step further to compare subgroups in different city categories, which is more revealing than simply discussing the overlaps and connections in meanings and the theoretical evolutionary track of each city type. A detailed analysis is therefore given on comparing the content of each city concept.

Subsequently, the data are input into the software program to produce an MDS model. This is then developed into a two-dimensional diagram as, although the clustering analysis is effective in dividing each city concept into subgroups of literature with specific content, it is less able to illustrate which subgroups (clusters) are the most preeminent. Moreover, the internal relationships (whether or not with strong internal links) cannot be revealed directly in the clustering analysis chart. The bi-dimensional MDS diagram, on the contrary, provides a precise illustration of the relationship within and without each subgroup (cluster). Combining the clustering analysis and the MDS diagram together helps to map out the most frequently discussed issues in each city concept and expound on the interrelationship within and beyond each city category in terms of their specific literature content.

3. Analysis and results

This section provides the results of a descriptive summary and the clustering analysis and MDS of all city concepts that promote a more sustainable urban form. Section 3.1 serves as a thesaurus of all the popular "?-cities." This shows that these concepts receive different levels of attention in different regions in the world and they reach their prime in academic discourse in distinctive periods. The figures in Section 3.2 provide a direct, concise, and accurate picture of how the literature concerning each city type is composed and the internal and external relationships involved.



In the above situation, "GIS" and "urban planning" appear in both articles 1 and N, and therefore their co-occurrenceis 2.

Fig. 2. Co-occurrence of keywords.

3.1. Descriptive summary

All current popular city concepts (De Jong et al., 2015) are summarized in Table 3 and are searched in the SCI and SSCI databases. A total of 2145 articles were retrieved, with "smart city" (469) and "sustainable city" (887) being the most common. The theoretical genesis in Section 1.1, together with the statistical summary, reveals that the multiple concepts can be categorized into two clusters, with one (led by "sustainable city") stressing on eco–economic issues and the other (led by "smart city") focusing more on social–economic realms.

From the name of each city concept, it seems that they are at least supposed to fulfill one or more aspects of the social–eco–economic triangle (SEE). Fig. 3 shows the development timeline of all the city concepts and their own particular focus in the SEE triangle. It is clear that some of the concepts, such as eco-city and green city, for example, have a time-honored origin, tracing back to the early 1980s and 1990s, while the cluster led by "smart city" did not become popular until the 1990s and the early 2000s. This is largely because the boom in information technology at that time equipped people with more advanced tools to improve social and economic performance. It is noted that the cluster led by "sustainable city" stays in the first two layers, addressing environmental and economic issues, while the "smart city" cluster remains in the lower two layers of social and economic issues. However, they share one commonality, which is that almost all the city concepts reach their peak after 2010, indicating the suddenly increasing salience of research focusing on these city concepts that promote sustainability in some way.

It is meaningful to examine the regional characteristics of each of the multitude of concepts (Fig. 4). The countries/territories of these publications are merged into four groups: America, Europe, Asia, and others. Many of these concepts are marked with distinctive regional traits. The two leading concepts of "smart city" and "sustainable city" are mostly discussed in Europe and America, respectively. Nevertheless, they have also received considerable attention from other regions. By contrast, "eco-city" and "low-carbon city" are largely discussed in Asia, especially in China, yet the former receives more attention in Asia than the latter. Some of the concepts are extremely popular in one country and less so in other countries. For instance, "ubiquitous city" is a term largely discussed in South Korea, occupying >80% of the existing literature, while "knowledge city" is typically Australian and could be interpreted as their version of "smart city."

From the descriptive summary, it can be concluded that, in promoting a more sustainable urban future, our cities are given one or more particular focus, and the two clusters led by "sustainable city" and "smart city" generally deal with two distinctive realms. There are also regional overlapping and distinctiveness across all the city concepts. The general similarities and differences of these concepts in promoting a certain type of sustainable urban form can be concluded from this descriptive information. However, a clustering analysis of each concept is still required to reveal the underpinning building blocks of each concept and how they connect with, or differ from, each other.

3.2. Clustering analysis

3.2.1. Sustainable city

The analysis of the high-frequency keywords in "sustainable city" articles indicates the presence of six clusters. The first of these mainly concerns the concepts of urban environment, urban sprawl, and indicators to evaluate its sustainable performance, while the second focuses on the more technical and concrete issues of sustainable governance and urban transport. The third involves only four keywords, largely addressing urban form and agriculture. Although these keywords co-occurred more than thrice, this likely indicates that they are still less important than the other clusters of issues for this city type. The fourth and fifth clusters form the two most significant subgroups that include a large number of concepts, in which the former indicates intimate connections with the "eco-city" (in China) and urban planning, while the latter reveals a distinct link to the "smart city" and energy issues that affect the urban environment quality. The last cluster is similar to the first, also dealing with the more general issue of sustainability and urban design. These six clusters are summarized in Fig. 5, which suggests that the first and last clusters are related to more general ideas but involve fewer concepts, while the fourth and fifth clusters contain more concepts and link the "sustainable city" to "eco-city" and "smart city."

The bi-dimensional diagram of MDS in Fig. 6 further clarifies the relationships between the "sustainable city" subgroups. This indicates that the issues at the center receive more attention from academia and are therefore "eco-city" is more often linked with other keywords than "smart city" (in the fourth and fifth clusters, respectively). "Smart city," although a high-frequency keyword in the "sustainable city" literature, has only a marginal place in the

Table 3
Number articles of each city concept retrieved from the SCI and SSCI databases.

Sustainable city	Smart city	Eco city	Low carbon city	Green city	Resilient city	Information city	Knowledge city	Ubiquitous city	Livable city	Total
469	887	241	199	110	46	33	95	48	17	2145

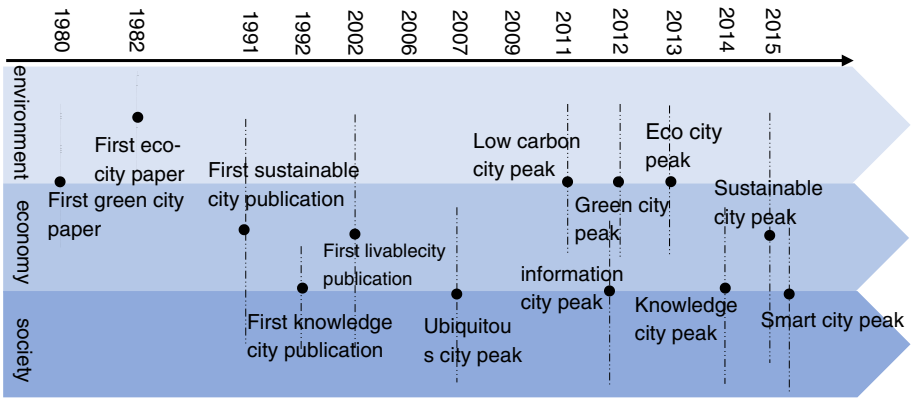


Fig. 3. Development timeline of the city concepts.

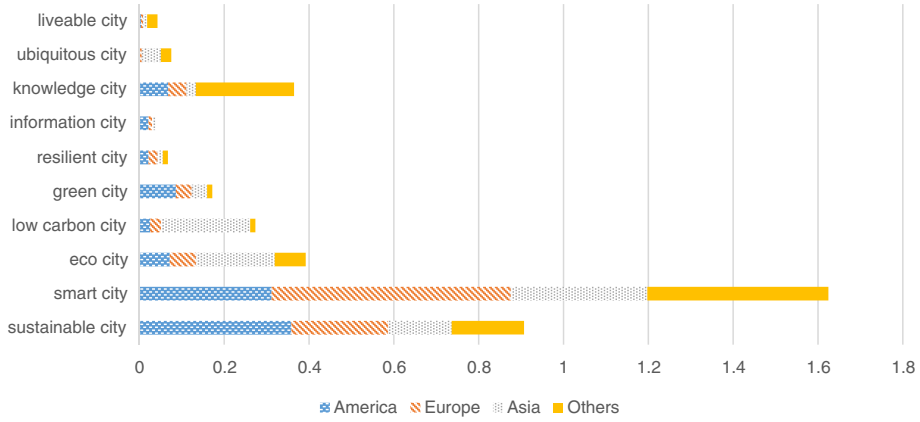


Fig. 4. The regional characteristics of city concepts.

overall picture. The literature mainly revolves around the issues of urban planning, eco-city, energy management, carbon emission, and ecological modernization, which in turn suggests that the fourth and fifth clusters are the most important issues. From the location of each keyword in the bi-dimensional diagram, however, it can also be argued that the eco-city and urban planning are more prominent in cluster 4, while the energy issue plays an outstanding role in cluster 5. The "smart city" concept, therefore, although appearing as a highly frequent "sustainable city" keyword, is not closely related to the literature and is probably only related to efficient energy management methods.

3.2.2. Smart city

The analysis of the "smart city" literature provides a detailed illustration of its composition (Fig. 7). Similar to the "sustainable city" clusters, it can be easily seen that the first and last subgroups are comparatively small insignificant clusters. These two clusters are particularly devoted to technical discussions and are quite distinctive from the other "smart city" clusters. The four middle groups all contain complicated concepts in comparison. The second group focuses on the facilitation of urban mobility and the application of the Internet and wireless sensor networks. It might be argued that it is in this subcategory that the concepts of "sustainable city" and "smart city" are connected, yet the MDS diagram is still needed to show that this is the case. The large majority of concepts in this cluster revolve around computing and Internet technology. The next cluster mainly deals with geographic information system (GIS), data mining, urban traffic, and urban mobility, but from a different technical perspective in focusing more on data processing technologies. The fourth cluster introduces new concepts such as knowledge management, innovation, cloud computing, urban planning, and another city concept of the "ubiquitous city," stressing management and urban governance as well as a technical perspective. The fifth cluster contains the concepts of energy management and urban governance, and yet is quite distinct from the "sustainable city" literature in deliberating on management and governance issues by introducing the concepts of big data and Internet technologies such as constrained application protocol (CoAP) and wireless sensor network (WSN).

Placing the six clusters into the MDS diagram (Fig. 8) enables a more precise conclusion to be drawn. The first cluster contains only two high-

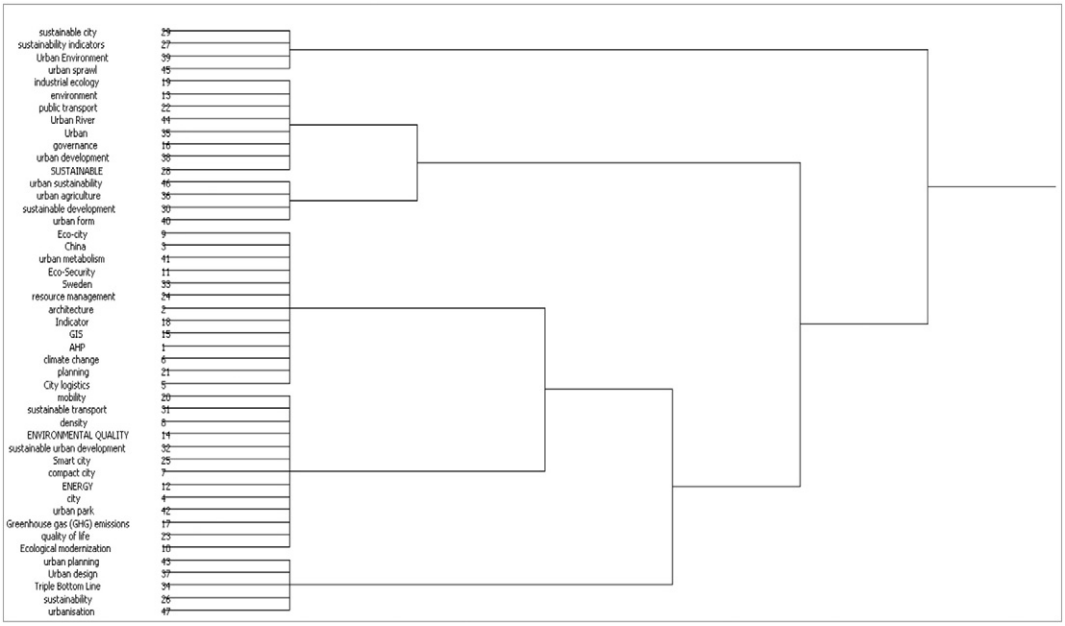


Fig. 5. Clustering analysis of the frequent "sustainable city" keywords.

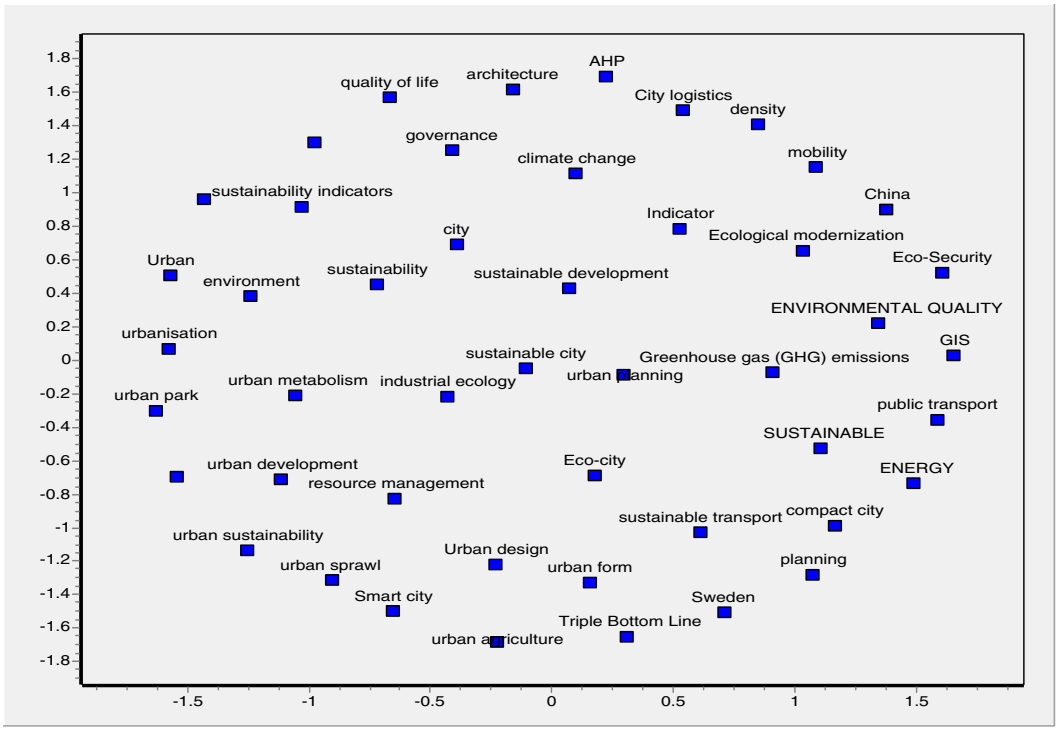


Fig. 6. Bi-dimensional diagram of MDS ("sustainable city").

frequency keywords and addresses the core concept of the "smart city," which connects all the other keywords together under this umbrella concept. However, the other keyword algorithm is located in the corner of the diagram, indicating that the importance of the first cluster is because it contains the central concept of the "smart city." In parallel, the last cluster is less so, as it is far removed from the center of the diagram. While the "Internet of things," energy management, energy efficiency, and urban mobility are the keywords with the strongest links to the central "smart city" concept. Also of note is that a huge number of technologies (data mining, cloud computing, ICT, etc.) are crucial in the "smart city" literature and locate at the center of the diagram too. In comparison, more traditional technologies, such as GIS, are less important. In addition, although sustainability is mentioned in only one of the six clusters, it is at the center of the diagram and therefore confirms that the two concepts of sustainability and "smart city" are connected. On the contrary, the concept of the "sustainable city" does not appear at all. In other words, the notion of "sustainability" is promoted in the "smart city" literature as a central issue, but not the "sustainable city."

3.2.3. Eco-city, low-carbon city, and green city

Unlike the literature on the "sustainable city" and "smart city," articles relating to the "eco-city," "low-carbon city," and "green city" are less proliferated. Of these three relatively minor concepts, there are 212 and 178 articles relating to the "eco-city" and "low-carbon city," respectively, with only 98 on the "green city." For the sake of brevity, the MDS diagrams are contained in Appendices I–III, while a network

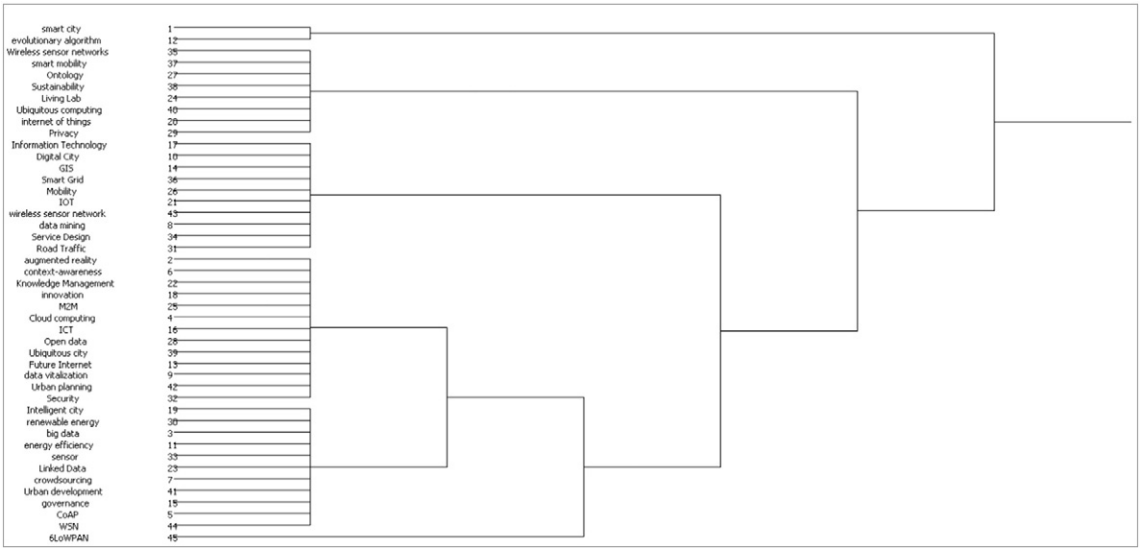


Fig. 7. Clustering analysis of frequent "smart city" keywords.

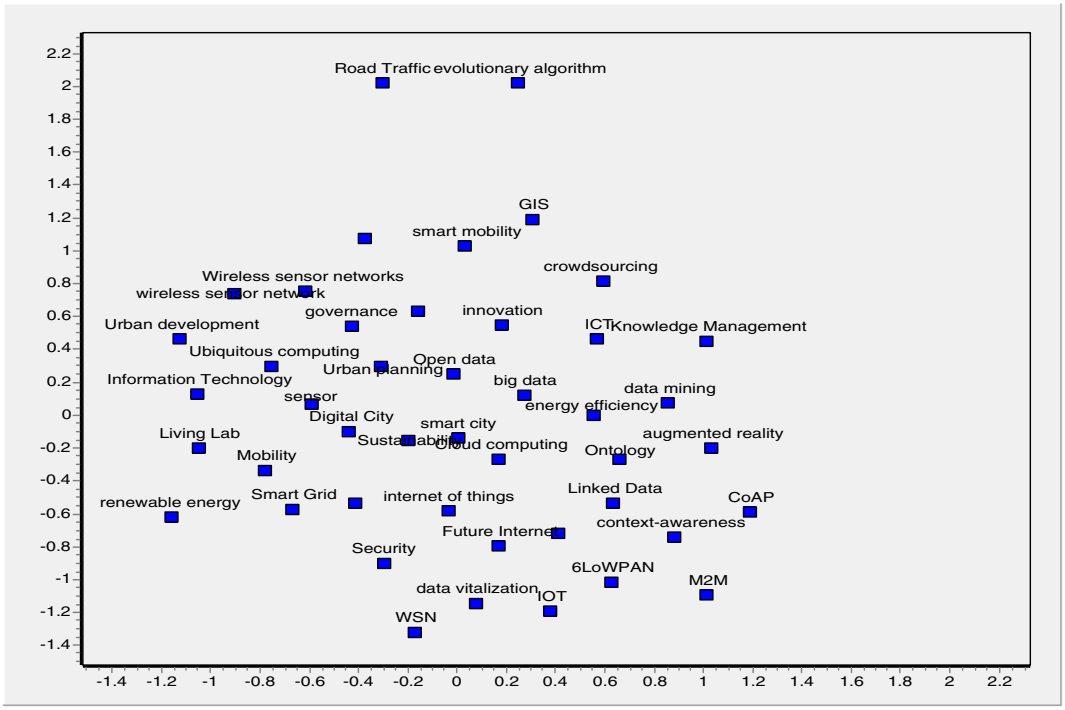


Fig. 8. Bi-dimensional diagram of MDS ("smart city").

diagram of the "eco-city" is provided in Fig. 9 for a more direct but less systematic visualization. For the same reason, the diagrams for the "low-carbon city" and "green city" are also omitted, although the results of the analysis are still summarized in this section.

There are five clusters of high-frequency "eco-city" keywords under this concept. Of these, four are linked to the "low-carbon city," "sustainable city," and "smart city." The strongest link is between the "sustainable city" and "eco-city," as there are two clusters particularly revolving around the concepts of sustainability and sustainable development, one of which also includes the concept of "low-carbon city." Nonetheless, the "smart city" does appear in one of the clusters but all the other keywords in that cluster relate to the eco-city and ecological civilization, signifying that "smart city" is not a central concept in the "eco-city" literature. Another feature is that two of the clusters are highly involved with China, which indicates that the concept of "eco-city" is disproportionately prominent in China in comparison with other regions in the world. The intense connections between the eco-city and China could be the result of the Chinese government using the ecological city and ecological civilization as a means of counterbalancing the toll on the environment. Alternatively, it could be a massive propaganda campaign by the government for environmental protection with the huge construction projects associated with the process of rapid urbanization (Hassan & Lee, 2015b; Hu, Wu, & Shih, 2015; Wang, Ding, & Zhuang, 2015). Another manifestation of the massive eco-city construction program in China is that such keywords as "planning," "construction," "evaluation," and "governance" are in the same cluster as China,

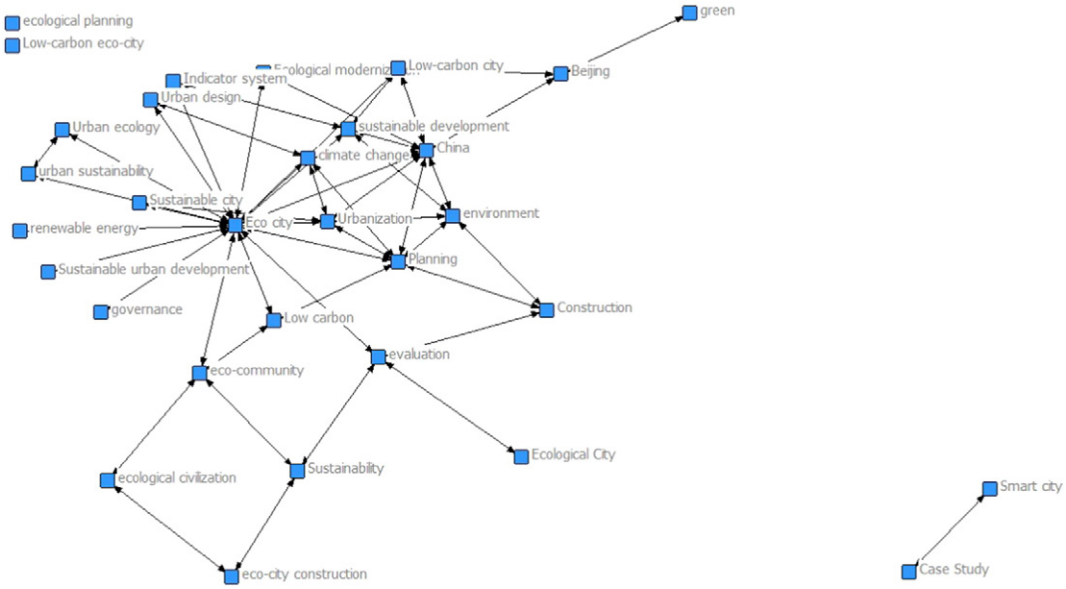


Fig. 9. Network of high frequency keywords ("eco city").

revealing that a large proportion of the current literature focuses on eco-city construction and operation in China. From the network diagram in Fig. 9, it can be concluded that China, which is the keyword second only to the "eco-city," is the most intersecting with other keywords and therefore the most outstanding subconcept in the eco-city literature. It can also be seen that, of these five city concepts, "sustainable city," "low-carbon city,"(Zhang, Shen, Feng, & Wu, 2013) and "eco-city" are clustered together as a whole, while the "smart city" is largely disconnected from the other concepts.

There are four clusters in the "low-carbon city" literature. The first centers on the core issue of the low-carbon city and urban development, suggesting that low-carbon discourse is interweaved with the concept of urbanization, and these concepts generally link to almost all other high-frequency keywords in this category. Issues such as evaluation, sustainable development, and land use are addressed in this section, in which the keywords involved, such as "eco-city," reveal a close linkage with China. The next section is mainly concerned with the low-carbon economy, industrial symbiosis, and the corresponding strategies in urban planning. The last cluster, however, involves many keywords, mainly dealing with issues of renewable energy and carbon footprint, countermeasures to climate changes, and the city of Beijing. It is in this cluster that the concepts of the "eco-city" and "low-carbon city" overlap with each other. By placing all the keywords into a bi-dimensional MDS diagram, it is easy to see that the "low-carbon" city concept also reveals strong connections with China. Although the "low-carbon city" and the "eco-city" discourse both engage heavily in research in China, the former pays more attention to the development of a low-carbon economy and energy efficiency in China while the latter is focused more on construction, evaluation, and governance in the process of rapid urbanization (Shen, Ochoa, Shah, & Zhang, 2011; Ye et al., 2015; Zhang, Zheng, Yang, Liu, & Su, 2015).

The "green city" is not as much discussed as in the previous elaborated concepts of cities. This is perhaps due to the small number of publications involved and the encroachment of other prevailing city concepts – what the "green city" keywords address is not very different from the other "cities." All the keywords can be largely attributed to three clusters, with each cluster linking the "low-carbon city," "smart city," and "sustainable city," respectively, with terms such as "low-carbon green city" and "smart green city." It seems that this city concept connotes the greening of every other city type. Although the term "sustainable green city" is not used in discussions in the "green city" literature, there is still much effort being made to turn the "sustainable city" greener by addressing the issues of urban greening, heat island, and public transportation against the backdrop of global warming. One interesting point to note is that, in this type of literature, the keywords do not revolve around the "green city" keyword, but rather that more connections are established with the keyword "climate change," which also goes some way to explaining the indistinctiveness of this particular city type. Instead of creating a research focus of its own, this city type is more issue-oriented, addressing this issue in the larger discourses of the "sustainable city," "smart city," "low-carbon city," and "eco-city." It focuses on the problem of climate change and tries to make every other city type greener by solving this problem.

4. Discussion

The previous section offered a descriptive summary of all the concepts and analyzed the clusters and their relationships with each other within each city type, concluding that, of the five distinctive city concepts, the "sustainable city" and "smart city" occupy the major proportion of the literature concerning all ideal city types that promote a sustainable urban form. The analysis also provided hints of quite distinctive differences in the meanings of these two major city concepts. In order to investigate this further, it is necessary to carry out a comprehensive analysis that goes beyond each type. In this section, the intercategory relationships between the city concepts are discussed. In contrast with the literature, which mainly focuses on the originality, evolution, and underpinning of these categories of concepts, the overlapping, interplay, and differences between the city concepts are investigated (De Jong et al., 2015; Neuman, 2005; Hassan & Lee, 2015a, 2015b).

If we place all the clusters for each city concept into a broader picture, it is easier to identify the similarities, differences, and links in this complicated net of concepts. At first glance, it can be argued that all five concepts are to some degree linked with each other, however fragile the linkage may be. At least one of the clusters of each city concept leads to another city type. Nevertheless, as the details of each cluster have been investigated in Section 3, their meanings beyond the boundary of each city type may be compared to draw a general map of the "?-city literature." First, of the two major sections of the literature concerning the "sustainable city" and "smart city," only one cluster in the former overlaps with the latter, while the latter mentions the notion of "sustainability" only, instead of the "sustainable city." The vast majority of the literature relating to these two city types does not overlap at all. The "sustainable city" is a more traditional concept that evolved from the early 1990s, with the first article dating back to 1991 (Haughton, 1999). This has constantly gained momentum throughout the new century and is still experiencing a moderate publication rate each year. By contrast, the origin of the "smart city" occurred by the turn of the 21st century, its number of publication suddenly leaped in 2013, and it has comprised the largest share of literature thereafter. Unsurprisingly, all the clusters in the "smart city" are heavily interwoven with Internet technologies and their application in the operation and governance of cities, whereas the "sustainable city" literature continues on its original track, deliberating on the social-eco–economic tripartite structure of urban sustainability. It also includes various technologies that are newly developed in the planning, construction, operation, and governance of contemporary cities, but these new technologies, particularly information technology (big data and cloud computing), is never the center of the "sustainable city" literature (Batty et al., 2012; Zubizarreta, Seravalli, & Arrizabalaga, 2015). The technology nucleus of the "smart city" literature explains why its publication numbers prevail over the "sustainable city" literature, as these papers are more likely to be listed in SCI journals, which far outnumber the SSCI journals in which much of the sustainable city literature is contained. As the two principal umbrella concepts in urban sustainability, they continue to develop on two distinctive and rarely intersecting tracks.

What then are their relationships with the other three city concepts? The clusters in the "eco-city" and "low-carbon city" literature indicate that the two concepts are hybrid terms that link all the popular urban sustainability concepts. For instance, the clusters connect the "sustainable city," "smart city," and the keyword "green" in both city types and establish strong mutual connections between each other. However, these two literature groups are still in keeping with the "sustainable city" literature, seldom focusing on the application of information technology, as does the "smart city." The themes of their clusters vary, yet they are quite similar to those of the "sustainable city" discourse in addressing urban planning, urban governance, energy consumption, evaluation, and sustainable development. Indeed, their foci are not identical, but they have adapted the sustainability discourse to contemporary situations, enriching the meaning of the "sustainability city" against a new background of the rising salience of the "low-carbon" and "ecological modernization" discourses (Jabareen, 2006; Zhang, Feng, & Chen, 2011). Another outstanding feature is that both the groups are closely related to the China context, which may probably be explained by China's rapid urbanization process on an unprecedented scale, with environmental pressure constantly urging for more sustainable development. In fact, the global ecological and low-carbon discourses are mainly contrived to address the environmental problems induced by the urbanization and industrialization process in developing countries, especially China. It is unsurprising, therefore, that the "eco-city" and "low-carbon" literature, bred by the ecological and low-carbon

discourse, has China as its main focus. These new variations of the traditional concept of the "sustainable city" are expected to fulfill the grand ambition of urban sustainability, however bleak their prospects may be at present (Li, Wang, Paulussen, & Liu, 2005; Ren, Zhou, Nakagami, Gao, & Wu, 2010). This is very much another issue that needs to be dealt with separately, however. To summarize, therefore, the thriving of the "eco-city" and "low-carbon city" is the reincarnation of the decades-old concept of "sustainable city" and helps to adapt this old theme to the current situation and the constant enrichment of its meaning.

Finally, the "green city," as discussed in Section 3, can also be treated as a hybrid of various discourses. It is less prominent than the "low-carbon city" and "eco-city" literature and fails to develop a research theme that can be adopted by other city types. Rather, it focuses on the issue of climate change, making an effort to green all other city categories (seen in Appendices). As the number of articles involved is <100, most of the "green city" keywords are closely related to "sustainable, smart, eco-, and low-carbon" cities, and thus this literature group can hardly be considered an independent theme with its own outstanding features. It borrows the concepts of other city types and tries to focus on the issue of climate change from the perspectives of the other city concepts. This explains why terms such as "low-carbon green city," "smart green city," and "eco-green city" have been created.

5. Conclusion

The city concepts that promote a more sustainable urban form can be divided into two basic groups. One is led by the "sustainable city" literature with its variations in different temporal and spatial contexts, and the other is led by the "smart city." Each city concept has a distinctive development timeline and regional characteristics, with the former focusing more on eco–economic realms while the latter is more concerned with social–economic fields. Although the "information city" and "knowledge city" are excluded from the analysis because of their insufficient numbers of articles for establishing a co-word matrix and clustering analysis, many reviews have shown that they overlap more with the "smart city" concept, which stresses the application of information technology in facilitating the efficiency of urban services. Thus, the "smart city" has to break the boundaries of traditional urban sustainability discourse and probe into various other aspects (such as business, urban life, communication, mobility, and governance) to explore the new possibilities that information technologies can engender. On the contrary, the "sustainable city" literature has always been the most important in focusing on the issue of urban sustainability. Nonetheless, its vitality has not diminished with time, but, instead, has constantly adapted to new variations that particularly address the most contemporary issues of the time. There is little doubt whether a booming in the "?-city" literature will be seen in the future. It will also be natural to see more "smart city" articles in applications of information technology for urban life, while the traditional concept of the "sustainable city" will surely survive as a sustainable urban form demands the constant renewal of urban planning, operation, and governance.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.cities.2016.08.003.

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