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# Sustainable–smart–resilient–low carbon–eco–knowledge cities; making sense of a multitude of concepts promoting sustainable urbanization

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ABSTRACT

Over the last couple of decades, metropolitan areas around the world have been engaged in a multitude of initiatives aimed at upgrading urban infrastructure and services, with a view to creating better environmental, social and economic conditions and enhancing cities' attractiveness and competitiveness. Reflecting these developments, many new categories of 'cities' have entered the policy discourse: 'sustainable cities'; 'green cities'; 'digital cities'; 'smart cities'; intelligent cities'; 'information cities'; 'knowledge cities'; 'resilient cities'; 'eco cities'; 'low carbon cities'; 'liveable cities'; and even combinations, such as 'low carbon eco cities' and 'ubiquitous eco cities'. In practice, these terms often appear to be used interchangeably by policy makers, planners and developers. However, the question arises whether these categories nevertheless each embody distinct conceptual perspectives, which would have implications for how they are understood theoretically and applied in policy. In response, this article investigates, through a comprehensive bibliometric analysis, how the twelve most frequent city categories are conceptualised individually and in relation to one another in the academic literature. We hypothesize that, notwithstanding some degree of overlap and cross-fertilization, in their essence the observed categories each harbor particular conceptual perspectives that render them distinctive. This is borne out by the findings, which demonstrate robustly for the first time the conceptual differences and interrelationships among twelve dominant city categories. The 'sustainable city' is the most frequently occurring category and, in a map of keyword co-occurrences, by far the largest and most interconnected node, linked closely to the 'eco city' and 'green city' concepts. Recently, the more narrow concepts of 'low carbon city' and 'smart city' have been on the rise, judging by their frequency of occurrence in academic journals; the latter in particular appears to have become an increasingly dominant category of urban modernization policy. On their part, 'resilient city' and 'knowledge city' represent distinct concepts, albeit with comparatively low frequency. Overall, the findings point to the need for rigor and nuance in the use of these terms, not least if one wishes to comprehend their implications for urban development and regeneration policy and practice.



## 1. Introduction

The motto of the 2010 World Expo in Shanghai: 'Better City – Better Life', reflects the growing recognition by municipal authorities of the crucial role they play in securing a living and working environment in which their citizens can thrive. The Shanghai declaration, (31 October 2010), summarizes the aspirations of establishing 'Cities of Harmony', which it regards as urban environments where people live in harmony with nature, society and themselves, and in harmony between generations (UN, 2011). This also implies showing respect for nature by promoting the use of renewable energy resources and building low-carbon eco-cities, pursuing inclusive and balanced growth and preserving an optimal relationship between social equity and economic efficiency. The declaration includes quite an extensive range of propositions aimed at improving the quality of life in urban environments, such as

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addressing scientific and technological innovation, building a smart and accessible information society, establishing friendly and liveable communities and promoting balanced urban-rural development. Beyond the declaration, metropolitan areas around the world are engaged in a multitude of initiatives variously aimed at upgrading urban infrastructure and services, in an effort to create better environmental, social and economic conditions and to enhance cities' attractiveness as well as their competitiveness (Yigitcanlar and Velibeyoglu, 2008; Caragliu et al. 2011; Campbell, 2012; Joss et al. 2013; Newton and Newman, 2013; Viitanen and Kingston, 2014; Ni and Jie, 2014). Reflecting these developments, a plethora of new city categories has entered the policy discourse: 'sustainable cities'; 'green cities'; 'liveable cities'; 'digital cities'; 'intelligent cities'; 'smart cities'; 'knowledge cities'; 'information cities'; 'resilient cities'; 'eco cities'; 'low carbon cities'; and even combinations, such as 'low carbon eco cities' and 'ubiquitous eco cities'.

Each of these terms apparently seeks to capture and conceptualize key aspects of ongoing urban sustainability efforts. Closer examination, however, reveals that policy makers, planners and developers often use the terms interchangeably. For example, the French city of Grenoble recently embarked on an *ÉcoQuartier* initiative – suggesting a main focus on environmentally sustainable development – but many of the initiative's policy intentions appear to be based on a technological innovation approach with as much focus on social and economic development (Charlot-Valdien and Outrequin 2011; Renauld, 2012; Laurent, 2013). On its part, the Australian city of Melbourne is considered a world leader among 'knowledge cities', yet its profile is defined to an important extent in terms of greenery in the built environment (Ergazakis and Metaxiotis, 2010; Yigitcanlar et al. 2008; Dvir and Pasher, 2004). In its latest City Council Plan 2013–2017, policy makers even explicitly strive to combine a variety of urban development concepts, including the 'eco city' and the 'knowledge city' (City of Melbourne, 2013). Elsewhere, the Chinese city of Guangzhou has undertaken a large-scale urban development program in collaboration with the Singaporean government going by the name of 'Guangzhou Knowledge City', yet the indicators used to support the program are referred to as 'eco city' indicators (Crane et al. 2012; de Jong et al. 2013a). Even if the application of these terms may at times be context-dependent and responding to specific policy developments, it seems there is ample potential for terminological fuzziness, or even confusion, unless these terms can be clarified as distinct conceptual categories and in relation to specific applications.

Hence, the question arises whether these city categories are in fact interchangeable – subject to policy preferences, even marketing fashions of the day – and, thus, by and large denoting the same or similar principles and characteristics; or conversely, whether they each harbor distinct ideas and features, with only limited overlap between them. The answer to this question has ramifications for how these terms should be understood and applied. If the terms are largely interchangeable this would imply that 'sustainable', 'smart', 'resilient' etc. cities are informed by an overarching common understanding of urban development and regeneration which seeks to interrelate social, economic and environmental dimensions in a balanced and mutually beneficial way. Indeed, there is evidence of the influence of a few key paradigms on the conceptualization of these terms. *Sustainable development*, emerging in the 1980s, was arguably the single most important paradigm that originally shaped thinking about urban development and gave it high-level policy recognition globally, and continues to be influential today (Barton, 2000; Wheeler and Beatley, 2009; Rydin, 2010). Resulting from it, the notion of the 'triple bottom line', which articulates the interrelationship between and co-dependence of environmental, economic and social dimensions, has become mainstream in research, policy and practice and, some would say, a core thematic principle of much of what passes as 'sustainable', 'eco', 'liveable' etc. city concepts. Needless to say, the debate about how exactly the triple bottom line is to be understood, and how this applies to urban contexts, is far from resolved. From this perspective, then, the plurality of terms observed can be seen as repeated attempts to articulate, specify, and even popularize, the concept of sustainable urban development.

In similar vein, *ecological modernization* has increasingly shaped urban policy and practice since the turn of the century (Hajer, 1996; Mol, 2001; Mol et al. 2009). This paradigm places particular emphasis on reconciling and mutually enhancing economy and ecology: productive use of natural resources and ecosystems can be a source of future growth and development in a similar way as through labor and capital productivity. This includes improvement in energy and resource efficiency as well as product and process innovations, such as sustainable supply chain management, clean technologies, benign substitution of hazardous substances, and environmental product design. Radical innovations in these fields can not only reduce quantities of resource turnover and emissions, but also change the quality or structure of industrial production. More recently still, the emergent – and as such, yet to be fully tested – paradigm of *regenerative development/sustainability* has begun to posit what is arguably an even more ambitious goal of supporting socio-economic development that not only preserves environmental stocks, but moreover restores and regenerates these from previous losses (du Plessis, 2012; Cole, 2012; Cole et al. 2012; Mang and Reed, 2012; Girardet, 2013; Robinson and Cole, 2015; Gabel undated). According to its advocates, regenerative development is possible in no small part due to the potential of recent scientific-technological advances and 'smart' innovation, which should help overcome the lingering trade-offs between environmental and socio-economic development associated with previous sustainable development efforts.

Based on these three overarching conceptualizations – sustainable development, ecological modernization, and regenerative sustainability – the various city categories mentioned could be understood as implying major overlap: 'intelligent', 'low carbon', 'resilient', 'liveable' etc. cities would essentially all point in the same direction, whereby comprehensive human-supported technological interventions benefit social well-being, economic growth and ecological regeneration in the city. However, should these city categories individually harbor more distinct conceptual perspectives, then different processes and outcomes may be expected to result from each of them. In that case, 'knowledge', 'eco', 'smart', 'green' etc. cities may have different theoretical points of departure, and the policy application of each of these city categories could be expected to be different, too. In turn, such divergence may bring into question the relevance and viability of overarching paradigms, such as ecological modernization and regenerative sustainability, at least when applied to the urban context.

Against this background, this article seeks to interrogate the conceptual relationship between salient city categories denoting sustainable urbanization used in the academic literature. The reason for focusing on the academic discourse, as opposed to the wider policy debate, is that this is the primary place where one would expect to see the articulation or not – whichever may be the case – of any conceptual differentiation among various city categories. Our research hypothesis is that there is indeed some degree of overlap and cross-fertilization – not least because of the influence of major paradigmatic narratives, such as mentioned above – but that in their essence the observed city categories nevertheless each harbor particular conceptual perspectives that render them

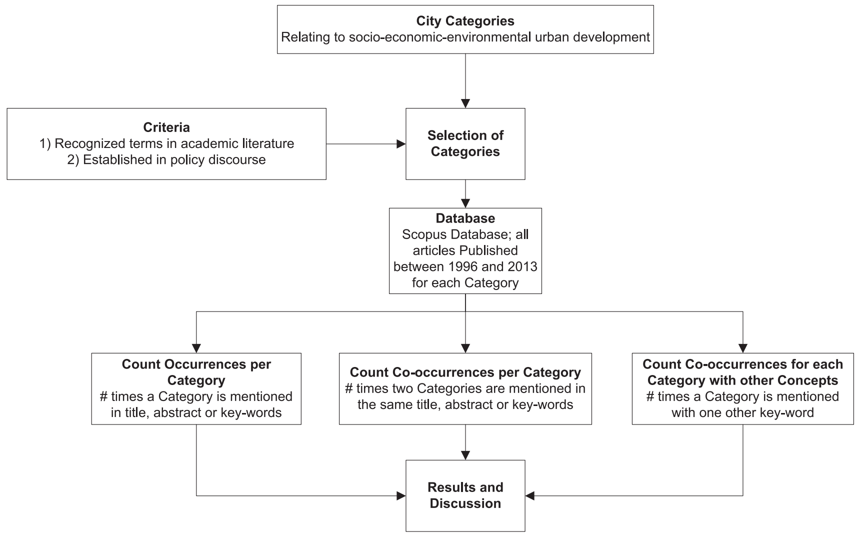


**Fig. 1.** Research design.

distinctive. If this assumption turns out to be correct then this points to significant differences in how urban development is understood, and what related approaches, innovations and solutions are offered through the application of categories, such as 'information', 'ubiquitous', 'green' etc. cities. Consequently, the aim of this paper is to elucidate the meaning of these categories and their implications for urban development programs by tracing their conceptual roots, revealing underlying norms and conceptions, and pinpointing where their policy prescriptions converge as well as diverge.

To do so, we systematically analyze the ways in which various city categories have been deployed in academic publications. The repository of academic articles in Scopus is a comprehensive source from which we can extract the different conceptual underpinnings of these terms. By mapping the academic use of relevant terms that link cities with sustainability and regeneration in one way or another, underlying meanings and interrelationships can be revealed and clarified.

The following section outlines the methodology informing this research, and especially the empirical approach used to identify both salient city categories and their academic terminology, and to analyze bibliometrically the extent to which they individually may contain distinctive conceptual perspectives. This is done on the basis of a comprehensive data set of 1430 scholarly articles. The following, third section presents the results emerging from this bibliometric exercise. The findings provide unprecedented insight into the conceptual relationships at work among twelve city categories. The subsequent, fourth section provides an in-depth discussion of both conceptual similarities and differences among the analyzed categories, as well as the related implications for how urban development is addressed, respectively. The final section draws overall conclusions on the hypothesis at the center of this article and discusses the implications for future research and policy.

## 2. Methodology

Fig. 1 (below) outlines the research design and methodology underpinning this study. First of all, given the apparent multitude of terms related to urban development, it is important to specify on what basis the selection of city categories in our bibliometric research was made. The two criteria used are: (1) that the selected city categories are recognized terms in the relevant international academic literature; and moreover (2) that they have been taken up, and resonate, in the wider policy discourse. The following twelve categories meet these selection criteria: 'sustainable city', 'eco city', 'low carbon city', 'liveable city', 'green city', 'smart city', 'digital city', ubiquitous city', intelligent city', 'information city', 'knowledge city', and 'resilient city'. In contrast, several categories do not fully meet the criteria, including: 'slim city', due to its lack of academic recognition and wider policy resonance; 'creative city', for lack of substantive academic discussion to date; 'transition town', due to its sub-category status of urban resilience and its limited application mainly in Great Britain; and 'compact city', due to its weak connection as an urban design concept to wider socio-economic-environmental development issues.

### 2.1. Occurrences per category

In order to establish the prevalence of each of the twelve categories of sustainable urban development, we made an inventory of their frequency of appearance (=occurrence) in the academic literature over time. Out of the two large academic databases, Web of Science and Scopus, we concluded that Scopus best meets the aim of this study, because this database includes the publication records of journals since 1996, irrespective of a changing ISI status; this makes it a more consistent repository to search academic publications. The search period was delimited to the period between 1996 and 2013, since Scopus provides full records from 1996 onwards, and 2013 was the most recent completed publication year at the time of writing. As the categories are referred to in articles either in their singular or plural form (e.g. 'eco city' and 'eco cities'), both these forms were included in the search.[1] The analysis was limited to academic journal articles and reviews as internationally

[1] We used the following search query: "TITLE-ABS-KEY("eco city") OR TITLE-ABS-KEY("eco cities") OR TITLE-ABS- KEY("smart city") OR TITLE-ABS-KEY("smart cities") OR TITLE-ABS-KEY("knowledge city") OR TITLE-ABS-KEY("knowledge cities") OR TITLE-ABS-KEY("sustainable city") OR TITLE-ABS-KEY("sustainable cities") OR TITLE-ABS- KEY("resilient city") OR TITLE-ABS-KEY("resilient cities") OR TITLE-ABS-KEY("low carbon city") OR TITLE-ABS-KEY("low carbon cities") OR TITLE-ABS-KEY("green city") OR TITLE-ABS-KEY("green cities") OR TITLE-ABS-KEY("ubiquitous city") OR TITLE-ABS-KEY("ubiquitous cities") OR TITLE-ABS-KEY("intelligent city") OR TITLE-ABSKEY("intelligent cities") OR TITLE-ABS-KEY("digital city") OR TITLE-ABS-KEY("digital cities") OR TITLE-ABS-KEY("information city") OR TITLE-ABS-KEY("information cities") OR TITLE-ABS-KEY("liveable city") OR TITLE-ABS-KEY("liveable cities") AND DOCTYPE(ar OR re) AND PUBYEAR > 1995 AND PUBYEAR < 2014".

accepted standard for publishing peer reviewed research outputs. The overall search results produced 1430 articles. The thus selected articles can be used to track the frequency of individual categories' occurrence across time; this is a further indicator of their relative significance. Results will be shown in Fig. 3 in Section 3.

### 2.2. Co-occurrences per category

The next step in the analysis focused on the mutual connections among the twelve categories within the dataset of 1430 articles. Here, we aimed to establish whether the authors of the articles regard their study relevant to more than one city category. This was done by measuring their co-occurrence – that is, where two or more categories are used concurrently – in the most prominent places where readers expect key descriptions of an article: titles, keywords and abstracts. By identifying instances where categories are used in conjunction with other categories, this helps establish a relationship among the twelve categories, which can be visualized. The greater the number of co-occurrences, the more central the position of a given category turns out to be within the web of relationships. Results will be shown in Fig. 4 in Section 3.

### 2.3. Co-occurrences for each category with other concepts

A further, important step in the analysis consisted of exploring the extent to which the twelve categories are connected with other key disciplinary terms and concepts in the academic literature. This

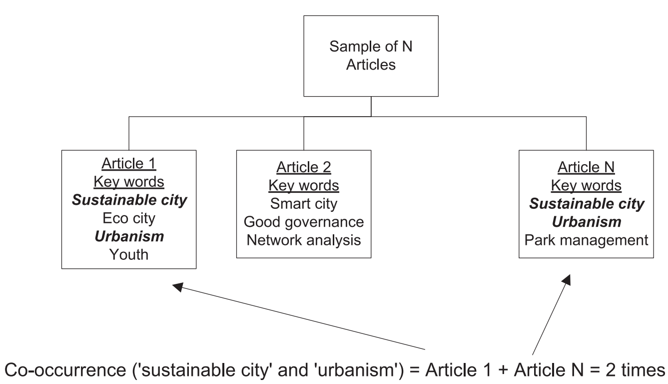


**Fig. 2.** Method for counting co-occurring keywords.

part of the analysis was carried out by focusing on the 'keywords' entries as they appear in the articles. Keywords are powerful indicators for conceptual and discipline-related associations made by authors themselves to describe their study with great parsimony. This analysis produced a 'conceptual field' spanning the 1430 articles retrieved from the Scopus database, depicted as a network of conceptual relationships among the categories and keywords used in these articles. By counting the co-occurrences of keywords, which in this part of the analysis included the terms denoting the twelve city categories, we acquired a comprehensive picture of the theoretical and empirical concepts relating to each one of the twelve categories. It must be noted here that in 415 articles the authors did not use keywords to describe their study, which compelled us to treat these articles as blank responses. The remaining 1015 articles (71%), however, are deemed sufficiently representative of the total to characterize the closely associated terminology for the city categories in question.

This methodological procedure generated a complex network structure, which was difficult to interpret as most keywords, including the twelve categories, appear in multiple forms. A bibliometric counting algorithm is not designed to cope with the textual nuances of e.g. “low-carbon cities”, “low carbon city” and “low carbon city strategies”, as a result of which it produces separate listings for what are effectively identical keywords (or categories). Consequently, in order to ensure clarity, readability and interpretability of the produced web of connected keywords, we simplified the overall figure by substituting the many variations in the data with a single term for each concept (category and keyword) that denotes our study of interest (see Table 1).

Technically, this reduced all the textual variations of a given category or keyword to one single location in the network of conceptual relationships, with many of the categories turning out to be intricately linked with other concepts (categories and keywords). In comparison with our previous analysis of co-occurrence of categories, the analysis of co-occurrence of categories and keywords gives us a far richer picture of the concepts that are related to a specific category, how closely they are related, and to what extent other categories share the same concepts.

To arrive at an insightful graphical representation of the results, all the linkages between concepts (categories and keywords) were calculated with a so-called 'spring embedded algorithm' as developed by Kamada and Kawai (1989), using the PAJEK software program (Batagelj and Mrvar, 2011). This positions the most connected keywords in the center and the more sparsely connected ones

**Table 1**
City categories (single terms) and corresponding variations.

| | |
|---|---|
| 'Eco city' referred to as: | “eco city”, “eco-city planning”, “eco-city”, “sino-singapore tianjin eco-city”, “ecopolis (eco-city)”, “low-carbon eco-city”, “dongtan eco-city”, “eco-city index”, “u-eco city”, “zhong-xin eco-city”, “eco-cities”, “eco cities under construction”, “comparative analyses of eco cities”, “chinese eco-cities”. |
| 'Sustainable city': | “sustainable city”, “sustainable city development”, “sustainable city planning”, “sustainable city paradigm”, “sustainable city plans”, “sustainable city management”, “sustainable city-building”, “sustainable city region”, “sustainable cities”, “international centre for sustainable cities”, “sustainable cities index”. |
| 'Smart city': | “smart city”, “3d smart city”, “amsterdam smart city”, “smart city components”, “smart city model”, “smart city planning and development”, “smart city development”, “smart cities”, “placemakingsmart cities”, “smart cities and smart buildings”. |
| 'Low Carbon city': | “low carbon city (lcc)”, “low carbon city”, “shenzhen sino-dutch low carbon city”, “low carbon city strategies”, “low-carbon city”, “low-carbon cities”, “healthy and low-carbon cities”, “low carbon cities”. |
| 'Knowledge city': | “knowledge city”, “most admired knowledge city”, “knowledge city index”, “knowledge city framework”, “knowledge cities”, “most admired knowledge cities”. |
| 'Intelligent city': | “informative global community development index and intelligent city”, “intelligent city”, “post intelligent city”, “intelligent city-region”, “intelligent cities”. |
| 'Digital city': | “digital city”, “digital city facility”, “digital city management system”, “digital city planning”, “digital cities”. |
| 'Ubiquitous city': | “ubiquitous city”, “ubiquitous city (u-city) logistics”, “ubiquitous city development”, “ubiquitous cities”. |
| 'Resilient city': | “resilient city-regions”, “resilient cities”, “disaster resilient cities”. |
| 'Green city': | “green city”, “low carbon green city”, “green cities”. |
| 'Information city': | “information city”. |
| 'Liveable city': | “liveable city”, “liveable cities”. |

outward. The figure that resulted was extremely dense and complex; in order to make it more legible and focus it on the most salient relations, the linkages denoting only one co-occurrence between concepts were removed. The links depicted in the resulting network, shown in Fig. 5 in section 3, all refer to a minimum of two co-occurrences between the connected concepts.

## 3. Results

This section discusses the results for each of the different outputs: the occurrence and co-occurrence of the selected city categories, as well as the co-occurrence of these categories with other concepts.

### 3.1. Occurrences per category

The twelve city categories each have different levels of significance in the academic literature searched. Table 2 (below) shows the overall count of the identified categories. This finding shows that the 'sustainable city' category is by far the most frequently found, followed at notable distance by 'smart city', 'digital city', 'eco city' and 'green city', each of which still reach counts above 100. 'Low carbon city', 'knowledge city' and 'resilient city' end up in the middle, with 'intelligent city', 'ubiquitous city', 'liveable city' and 'information city' forming the bottom of the table.

It should probably come as little surprise that 'sustainable city' is the most frequent category in the academic literature, given its broad scope, long history and strong resonance in policy. The appearance of 'intelligent city', 'ubiquitous city', 'liveable city' and 'information city' at the lower end of the spectrum indicates an as yet limited resonance as stand-alone concepts among scholars. The position of 'smart city' and 'digital city' above 'eco city' and 'green city' in this table is remarkable and begs the question whether this is a recent phenomenon given their relatively short existence. An answer is provided in Fig. 3. This figure indicates the development in the use of the twelve categories of terms over time.

It appears that 'sustainable city' has been widely used since 1996 (and presumably even before, but that is beyond the records analysed here). The graph also shows that 'digital city' has taken off since the early 2000s, whereas 'low carbon city' and 'resilient city' have both emerged strongly since 2009, which is most likely in response to the global climate debate and related discussion about cities' implication in both climate change mitigation and adaptation. The use of 'smart city' has also exponentially increased since 2009, to the extent that by 2012 it has even managed to eclipse 'sustainable city'. The evolution in the use of the other terms over time seems less significant and largely in line with the findings shown in Table 2.

**Table 2**
Total number of retrieved articles per city category.

| Category | Number of articles |
|---|---|
| Sustainable city | 546 |
| Smart city | 222 |
| Digital city | 166 |
| Eco city | 133 |
| Green city | 105 |
| Low carbon city | 93 |
| Knowledge city | 82 |
| Resilient city | 47 |
| Intelligent city | 33 |
| Ubiquitous city | 29 |
| Liveable city | 26 |
| Information city | 23 |

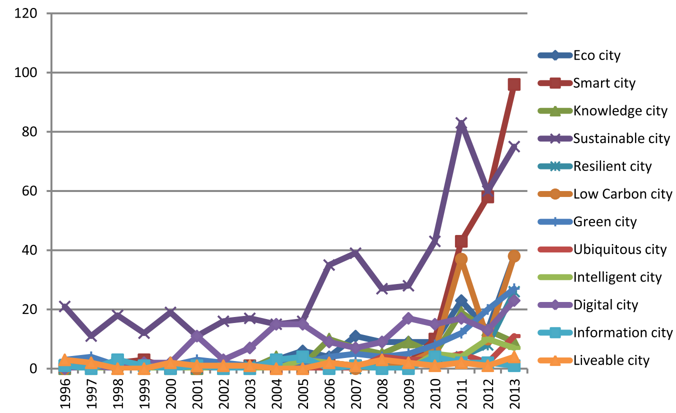


**Fig. 3.** Evolution of twelve city categories over time (frequency in Scopus articles).

### 3.2. Co-occurrences per category

The connections among the twelve categories are illustrated in Fig. 4. The numbers indicated stand for the number of articles retrieved: for example, seven articles mention both 'smart city' and 'digital city' in either title, abstract or key words; while there is only one article featuring 'liveable city' and 'green city' at the same time. As mentioned in Section 2, the greater the number of co-occurrences, the more central the position of a given category within the web of relationships. In addition, Fig. 4 indicates the relative frequency of categories (number of retrievals) in terms of differing circle sizes.

'Sustainable city' turns out not only to be the most common category, but also quite centrally placed in the network, with direct connections to all other categories except 'digital city', 'ubiquitous city' and 'information city'. Although the co-occurrence graph of relationships turns out to be a meshed network, 'sustainable city' still remains the most connected node. One could in fact consider it something of an umbrella category in which much of the content of many of the others is contained. 'Eco city' occupies a similarly central position, albeit with lower frequency than 'sustainable city' (not having connections with 'digital city', 'information city', 'resilient city' and 'liveable city'); on its part, 'smart city' has a higher frequency than 'eco city' and has a similar centrality as the previous two (missing connections with 'resilient city', 'liveable city' and 'knowledge city'). What this analysis further reveals is that 'smart city', 'information city', 'intelligent city', 'ubiquitous city' and 'digital city' jointly constitute what may be considered a sub-network of their own. 'Digital city', in spite of its high frequency, only has connections with 'smart city', 'ubiquitous city' and 'intelligent city' and is thus clearly situated away from the center. As such, it should be considered as something of a major satellite within the smart city 'stellar system'. Similarly, 'green city' can be seen as a large satellite of the 'sustainable' and 'eco city' categories, although it does have additional weak links with some of the other categories. Finally, 'resilient city', 'liveable city', 'knowledge city' and 'low carbon city' occupy peripheral positions in the network, which suggests that they are either of lesser importance or constitute their own independent conceptual worlds.

### 3.3. Co-occurrences for each category with other concepts

Fig. 5, which demonstrates the network structure of article keywords associated with the twelve categories, confirms the above findings, yet adds more detail to them. Significantly, 'liveable city' and 'information city' disappear completely in this network graph because the two terms are mentioned less than twice in the

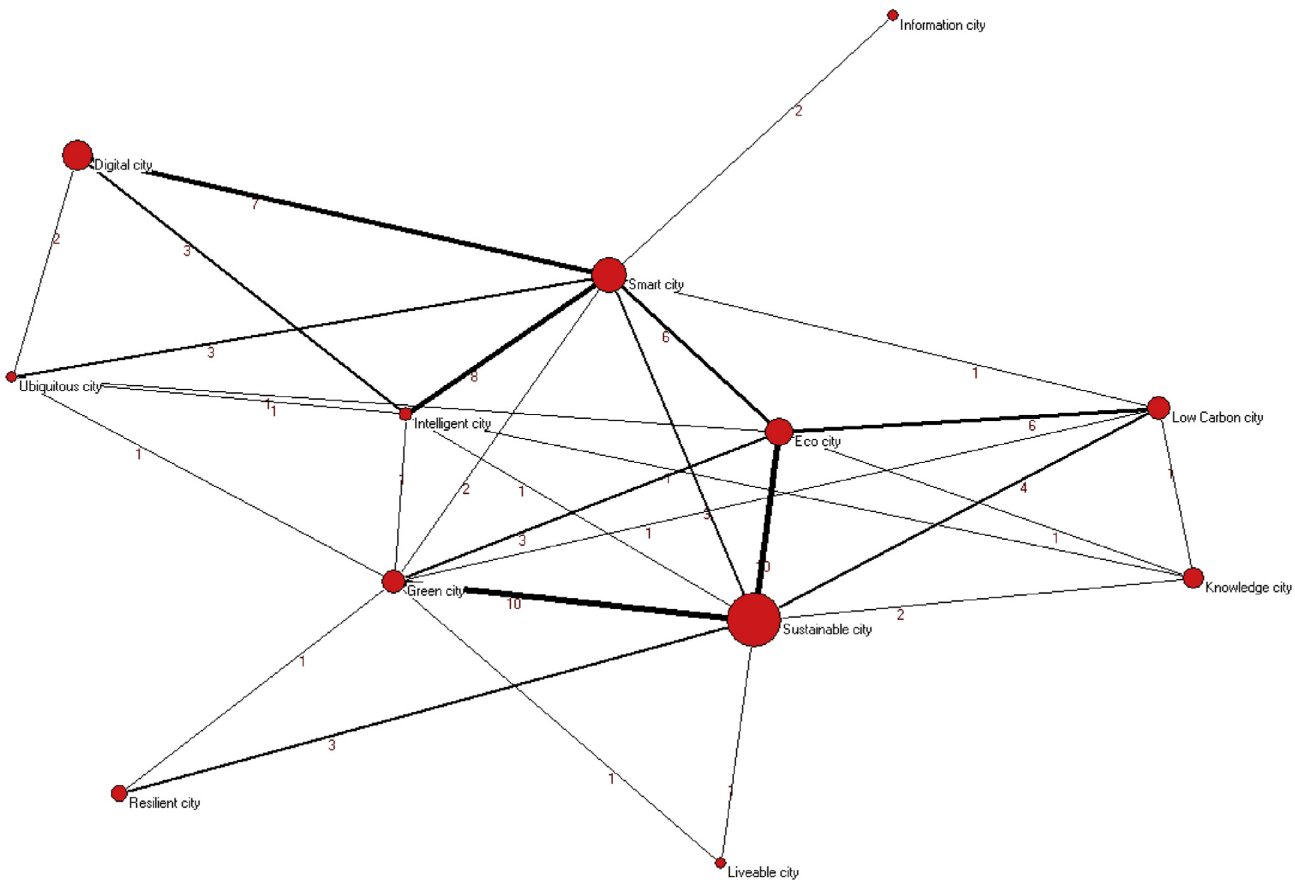


**Fig. 4.** Co-occurrence of twelve categories in titles, abstracts and key words.

author keywords. One can conclude, therefore, that academic authors rarely consider 'liveable city' and 'information city' concepts worth the status of keyword. 'Smart city', 'digital city', 'intelligent city' and 'ubiquitous city' can all be found closely linked together in a significant cluster of its own. Within this clustering, 'smart city' and 'digital city' are bifurcated, with 'digital city' mainly referring to terms such as web-services and the virtual city, while the range of topics for 'smart city' is more diverse including, among other associations, innovation, smart homes, smart government, smart grid and the Internet of Things. 'Intelligent city' and 'ubiquitous city' appear quite peripheral and minor, with the latter being linked with specific terms such as ubiquitous, Seoul (due to a related national policy programme in Korea) and urban infrastructure management. Equally interesting is the fact that the other categories: 'resilient city' (connections with emergency management and sustainability), 'knowledge city' (connections with knowledge based economy and knowledge based urban development) and 'low carbon city' (links with carbon emission reduction, urban upgrading and protective planning), all constitute clearly visible sub-clusters within the entire graph, with specific connotations and apparently different conceptions and underlying bodies of theory. From this, we can effectively conclude that, while 'liveable city' indeed seems of lesser importance in the entire conceptual field, the others have begun to establish their own independent conceptual worlds. Some of them, especially 'resilient city', are small and are not (yet) supported by a host of terms from well-established bodies of theory. 'Low carbon city' appears already quite significant, although being still relatively recent: in the case of 'knowledge city', there has been a more gradual process, but nevertheless with a distinct outcome. In contrast, this cannot be said of 'green city', which in Fig. 5 has become a relatively unimportant and indistinct satellite of 'sustainable city'; it fails to get more than one mention in the keywords section among all 1015 articles. Similarly, 'intelligent city' becomes an indistinct satellite of 'smart city'. The link from 'eco city' to 'sustainable city', and from 'sustainable city' to 'smart city' clearly constitutes the main axis of the figure, with 'sustainable city' appearing unmistakably in the center of the web. 'Eco city' is intensely connected with both 'sustainable city' and 'low carbon city' and shares many concepts with both of them. 'Eco city' does have distinctness in that a number of terms connected with it reveal its affinity with, on one hand, urban planning, urban design and technological urbanism and, on the other, green technology, good governance, techno-city and some Chinese and Korean cities. Finally, 'sustainable city' is so central in the whole graph that it is connected with the greatest variety of concepts, even including topics, such as resilience and poverty. Consequently, the conclusion to be drawn from this is that 'sustainable city' serves as a broad conceptual or 'umbrella' category, occupying a central place in the relational field of key categories analyzed here. In contrast, 'knowledge city', 'low carbon city', 'digital city' and 'smart city' are more tightly defined categories in relation to specific aspects of sustainable urban development and regeneration.

## 4. Genesis, evolution and theoretical underpinnings of city categories

In the sections above, we have explored and established: (i) the frequency of appearance of twelve city categories within the academic literature (journal articles); (ii) the interrelationship (in

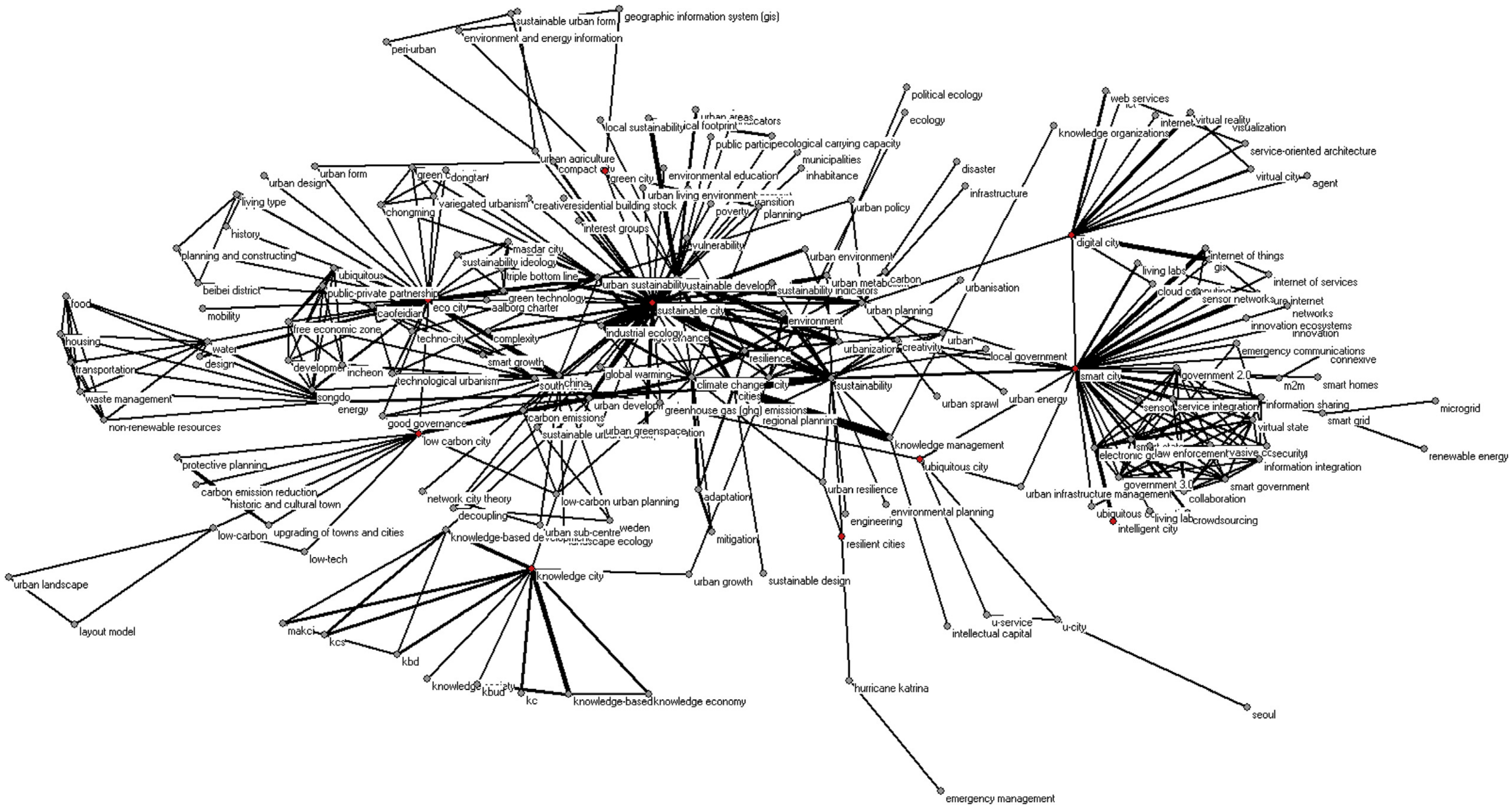


**Fig. 5.** Network structure of author keywords associated with twelve city categories (minimum of 2 co-occurrences).

terms of co-occurrence) among these categories; as well as (iii) the categories' associations with related theoretical and empirical concepts. We found that one category appears both with high frequency and in a central position, coupled with a broad overarching conceptual meaning ('sustainable city'); two categories are relatively frequent and yet conceptually more distinct ('smart city', 'eco city'); one is relatively frequent and conceptually distinct, but very peripheral ('digital city'); one is of average frequency, but with low distinction ('green city'); three are of average frequency, but with a distinct conceptual meaning ('low carbon city', 'resilient city' and 'knowledge city'); and, finally, four are of low frequency and low distinctness ('intelligent city', 'information city', 'ubiquitous city' and 'liveable city'). Table 3 (below) provides a summary of the twelve categories in terms of their respective prominence as found in the academic discourse. We have thus obtained a better perspective on the relative positions of each of these city categories within the broader academic discourses on sustainable development, ecological modernization and regenerative development. In order to further interpret these findings, we have examined (a) the historical genesis and evolution of the most important categories and (b) the theoretical interests driving them. To keep this discussion manageable, we have selected what we believe are the key categories in terms of frequency AND conceptual distinctiveness ('sustainable city', 'eco city', 'low carbon city', 'smart city', 'knowledge city', 'resilient city'), while referring to the others in passing and where relevant under the categories they are mostly connected with ('green city' and 'liveable city' under 'sustainable city'; 'digital city', 'intelligent city', 'ubiquitous city' and 'information city' under 'smart city').

### 4.1. *Sustainable city*

Whereas the concept of sustainable development can be traced back to 18th century forestry management in Germany (Grober, 2012), the Brundtland Commission is to be credited for the present day use of sustainable development as a policy term. In the report 'Our Common Future', the concept was defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland Commission, 1987). The 'sustainable city' is an almost automatic derivative from this relating to urban development. It was subsequently fleshed out in the Aalborg Charter (1994) by more than 700 cities worldwide, and the Melbourne Principles in Local Agenda 21 (UNEP, 2002). The sustainable city as a concept grew especially popular in the 1990s (Roy, 2009) and in practice became strongly intertwined with, and operationalized by, the conception of the 'triple bottom line' (or 'three pillars'), denoting a close interrelationship between economic, social and environmental sustainability with a combination of indicators to measure each of them. Rogers (1998) conceptualizes the sustainable city as a place where a higher quality of life is realized in tandem with policies which effectively reduce the demand on resources (energy, materials etc.) drawn from the city's hinterland. As such, the sustainable city becomes a more self-sufficient economic, social and environmental system. Although the triple bottom line has by far become the most common view of the sustainable city, there are exceptions. Meadows (1999) and Brugmann (1999) approach the term from a more environmental angle and propose that it should include indicators for pollution and carbon emission, energy and water consumption, water quality, energy mix, waste volumes and recycling rates, green-space ratios, primary forests, and agricultural land loss. Rode and Burdett (2011), however, adopt a more socio-economic interpretation, where social equity alongside a greener living environment should be considered for the development of sustainable cities. In addition, they point out that cities should offer proximity, density and variety which would engender productivity benefits for firms, and help stimulate innovation and new job creation through, for example, high-tech clusters in urban regions, such as Silicon Valley. Since 'sustainable city' advocates often adopt the triple bottom line view, they tend to frame it in broader terms than either the 'eco city' or the 'low carbon city'. Ecological sustainability is then seen as less in conflict with social and economic considerations: this is especially so in combination with argumentation for the replacement of a manufacturing-based economy associated with high emission levels with a 'cleaner' service-oriented economy, which allows economic growth and social stability to occur alongside ecological preservation by generating higher eco-efficiency in the economic value chain. This trend is often caught under the heading 'ecological modernization' (Hajer, 1996).

**Table 3**
Prominence of city categories in academic discourse.

| Level of distinctness | Frequency > 100 | Frequency < 100 |
|---|---|---|
| High distinctness (high visibility in Fig. 4) | Sustainable city (quite central)<br>Smart city<br>Digital city (quite peripheral)<br>Eco city | Low carbon city<br>Resilient city<br>Knowledge city |
| Low distinctness (low visibility in Fig. 4) | Green city | Intelligent city<br>Information city<br>Ubiquitous city<br>Liveable city |

The broad conceptualization of 'sustainable city' is reflected in the findings of our quantitative analysis: this category features with the highest frequency and the most central position among the group of twelve; the central positioning arises from the high co-association with the other categories (as shown in Fig. 4) as well as from the diverse conceptual key word associations (as shown in Fig. 5). The 'liveable city' category constitutes a small satellite of the 'sustainable city', with largely similar interpretations (see Figs. 4 and 5). In contrast, the 'green city' obtains more notable ecological overtones. Showing a strong connection with both the 'sustainable city' and the 'eco city', it has a more explicit focus on the environment. For example, Dekay and O' Brien (2001), argue that a 'green city' is built on three interrelated mental models: living systems, landscape experience and native context. The integration of the three models generates a set of five patterns: hydrologic city, productive city, bioclimatic city, transit city and habitat city, which need to be addressed cohesively for the green city to emerge. More recently, Lehmann (2010) used the term 'green urbanism' to denote a conceptual model for zero-emission and zero-waste urban design, promoting compact energy-efficient urban development, and seeking to transform and re-engineer existing city districts and regenerate the post-industrial city center. However, in our own analysis, in Fig. 5, the 'green city' does not appear nearly as distinct and significant as the 'sustainable city', the 'eco city' and the 'low carbon city'. The fact that 'green city' is rarely chosen as keyword and, hence, seems to be quite interchangeable is perhaps reflected in the two definitions of it given above: the first definition could equally apply to 'eco city', the second equally to 'low carbon city', while both could equally apply to the 'sustainable city'.

### 4.2. *Eco city*

The idea of building an 'eco city' (ecological city) leads back to the mid-1970s when the Urban Ecology group was set up with the aim of (re)constructing cities in balance with nature. Richard

Register, co-founder of Urban Ecology and author of the seminal *Ecocity Berkeley*: *Building Cities for a Healthy Future* (1973), defined the eco city as one built according to the principles of living within the means of the environment; that is, with its population and the artifacts produced and used remaining within the ecological carrying capacity of the city's bioregion. Register himself has credited the architect Paolo Soleri as an important source of inspiration for his thinking. Originally the eco city category was rooted concurrently in the environmental (natural) sciences and in the (humanities oriented) deep ecology movement, proclaiming a return to a life-style in harmony with nature. However, over time the term has been embraced by a growing number of academic and policy specialists, with the attempt to translate the general definition into workable principles for construction, production and consumption. However, no commonly agreed definition has emerged to date. The category's range of application is as wide as for instance: completely carbon-neutral and renewable energy supply; a well-planned city layout and public transportation system; resource conservation; water and waste recycling; green roofs; restoring environmentally damaged urban areas; local urban agriculture; decent and affordable housing for all socio-economic and ethnic groups; improved job opportunities for disadvantaged groups; and voluntary simplicity in lifestyle choices (Roseland, 1997; Harvey, 2011). While Newman and Jennings (2008) adopt an eco-systems perspective and liken the eco city with an eco-system, deriving principles from that analogy for recipes of eco city development, Suzuki et al. in their World Bank (2010) publication have given it a more pragmatic twist: they consider the ecologically sustainable city viable only if it is also an economically vibrant one, which they represent as 'eco$^2$ city' ('ecological cities as economic cities'). This interpretation, then, shifts the eco city closer to that of the sustainable city. On their part, White (2002) and Lehmann (2010) emphasize eco city planning as combining urban planning concepts with the provision of a next generation of infrastructures and environmental friendly buildings. Elsewhere, Joss (2011) has made an attempt to map the variety of eco cities around the world and come up with a typology (new-build, extension and retrofitting) and a variety of motives adduced by policy-makers to promote and legitimize large-scale eco city projects.

Over time, the 'eco city' has, thus, acquired a variety of conceptual meanings and interpretations of which the ecological may be the main, but certainly not the only, one. The growing connection of the concept with real-life urban building and development processes, the adoption of it by mainstream policy and economic organization, and the intensifying interweaving with wider economic and social issues, have arguably led to a softening of its environmental standards, or even its wholesale incorporation into mainstream real estate development projects. Consequently, the number of critical reviews of its actual policy intentions and implementation has grown significantly in recent years, especially with regard to its implementation in Asia (Cugurullo, 2013; Shiuh Shen, 2013; Chang and Shepherd, 2013; de Jong et al. 2013b; Joss and Molella, 2013; Shwayri, 2013; Caprotti, 2014; Rapoport, 2014). In its original conception, the 'eco city' category emphasized centrally ecological preservation, whereas the more recent dilution in meaning has rendered this aspect less emphatic. While it still holds potential as an attractive marketing term for large-scale urban development projects with attractive green surroundings and conspicuous devices to reduce consumption of non-renewable energy, the use of 'eco city' concepts in the academic literature has never surpassed the popularity of 'sustainable city'. Since 2010, as shown in Fig. 2, 'low carbon city' and 'smart city' have overtaken 'eco city' in frequency of occurrence in the academic debate; this is likely due to the latter representing more narrow, well defined concepts, which can more easily be made operational in urban development projects. Nevertheless, the 'eco city' category's relatively high frequency over time (as shown in Figs. 2 and 3) and central positioning (as shown in Fig. 4 and particularly Fig. 5) reflects the concept's long-ranging and broad-based treatment in the academic and policy debates.

### 4.3. Low carbon city

While the scope of the eco city is wide in theory, and perhaps even wider in practice, the 'low carbon city' — and its variants, 'zero carbon city', and even 'negative carbon city' — can be seen as a direct response to the more recent climate change debate and the related role of cities. The focus here is on minimizing the human-inflicted carbon footprint by reducing or even eliminating the use of non-renewable energy resources. In 2003, the UK government issued the 'UK Energy White Paper: Our Energy Future–Creating a Low Carbon Economy', which first proposed the low carbon economy concept (Liu et al., 2009). In the white paper, the low carbon economy is defined as one in which society creates higher standards of living and a better quality of life through improved economic output underpinned by advanced technological innovation and new business and job opportunities, while at the same time significantly reducing natural resource consumption and environmental pollution (DTI, 2003).

Since then, the low carbon economy has become a trend all over the world signifying the attempted transformation of the mode of economic production and consumption by making these less energy-intensive and enhancing the share of renewables. For example, in 2008, Japan published 'A Dozen Actions towards Low-Carbon Societies' proposing the application of three principles: reducing carbon emission in all departments; advocating frugality; and living in harmony with nature (GERF, 2008). Most scholars, especially when reasoning from an economics or engineering perspective, conceptualize the low carbon city using as their base reference the definition given by the UK government. Chen and Zhu (2009) explain the category's impact by pointing to the interrelationship between the macro level (necessity to change the economy such that energy consumption and $CO_2$ emissions will decrease) and micro level (reducing $CO_2$ by revising the entire material flow process from input to output phase). In recent years, growing numbers of more technical articles have emerged with a variety of proposals to flesh out the concept in a variety of cities around the world (Gossop, 2011; Guimaraes Castello, 2011; Storch and Downes, 2011; Premalatha et al., 2013). Although many policy-makers seem to see 'low carbon city' and 'eco city' as largely the same thing (see for instance the Wikipedia website on zero-carbon city), the focus in the academic literature concerning 'low carbon city' tends to be more on energy issues and shows more rapport with engineering and economic thought. While its origins are fairly recent, it has been growing in importance of late, beginning to generate a conceptual tradition of its own; this is evidenced in Fig. 5 by the category's distinct branching out and developing connections with terms, in contrast to the 'eco city' category. Its contribution to sustainable urban development can be substantial if and when the low carbon city is effectively carbon neutral, depending on where and how renewable energy is harvested, and to what extent the energy use per capita and per unit of GDP is effectively reduced. The analytical disadvantage of the 'low carbon city' may be that the concept does not comprise environmental and ecological issues other than energy, such as water, biodiversity, and natural resources. However, energy use touches on almost every aspect of society and the economy, and the 'low carbon city' category's potential to render ecological gains and losses explicit and measurable, appears to make it increasingly attractive to analysts.

### 4.4. Smart city

The concept of 'smart city' is also relatively new in origin, although it stems from, or can at least be seen as a more advanced successor to, the older 'information city', 'digital city' and the 'intelligent city' categories. In recent years, however the 'smart city' has completely eclipsed its associates and predecessors in popularity, even to the extent of surpassing the sustainable city in frequency of academic use in 2013 (see Fig. 3). A city can be defined as 'smart', according to Caragliu et al. (2011), when investment in human and social capital, coupled with investment in traditional (transport) and modern information and telecommunication infrastructure, generates sustainable economic development and a high quality of life while promoting prudent management of natural resources. In essence, elaborate and sophisticated ICT-facilities are provided across the urban territory, which allow companies to collaborate and innovate, to provide better services to citizens and, thereby, empowering citizens with access to information to the extent that they can debate, influence and even make policy (Lee et al., 2013). An early stage smart city can be conceptualized as one that provides combined services via the integration of the IT and construction industries (Korea Land Corporation, 2005), although it has been argued that the validity of any claim to be smart ought to be centered upon something more than the use of information and communication technologies (ICTs) alone (Hollands, 2008).

Based on a thorough review of the smart city literature, Caragliu et al. (2011) conceptualize the smart city by summing up six characteristic features: (1) improving administrative and economic efficiency and enabling the development of culture and society by utilizing networked infrastructures; (2) an underlying emphasis on business oriented urban development; (3) a strong focus on the goal of realizing the social inclusion of different kinds of urban residents in public services; (4) emphasizing the significant role of high-tech and creative industries in long-term growth; (5) paying close attention to the function of social and relational capital in city development; and (6) taking social and environmental sustainability as an important aspect of smart city development. Likewise, Giffinger and Gudrun (2010) and Lee et al. (2013) argue that the smart city consists of the following six ingredients – noting here the arguably rather tautological definition - namely: a smart economy, smart mobility, a smart environment, smart people, smart living and smart governance. In that sense, most recent academic literature emphasizes that smart(er) cities go significantly beyond 'information cities', 'digital cities' and 'intelligent cities' in that information technology is not considered on its own, but should effectively be contextualized and embedded in wider physical and social systems, thus allowing it to be at the service of people, business and government (Allwinkle and Cruickshank, 2011, Leydesdorff and Deakin, 2011, Deakin and Al Waer, 2012). In spite of its name, the 'ubiquitous eco city' is a characteristic and practical application of the 'smart city' concept specifically within South Korea, but nowadays also well-known outside it. Apart from the 'digital city', of which Fig. 5 shows that it has a distinct and separate sub-branch from the 'smart city' with more attention paid to internet related issues, the other related terms turn out to be relatively insignificant satellites of the smart city. The 'digital city' originates from an experiment in Amsterdam in 1994, with the aim of democratizing access to the Internet (Besselaar and Beckers, 1998; Besselaar et al., 2000). In this case, the 'digital city' serves as a space where relevant information on the city is collected and organized in digital form and where residents and visitors can interact. The more recent definitions are more comprehensive. The 'digital city' now refers to: a connected community that combines broadband communications infrastructure; flexible, service-oriented computing infrastructure based on open industry standards; and innovative services to meet the needs of governments and their employees, citizens and businesses (Civitium Wireless Broadband, 2010). Still, as the above description demonstrates, its meaning is far more restricted than that of the 'smart city' and less closely related to aspects of sustainable urban development. It is, therefore, no surprise that in Figs. 4 and 5 it ends up in the periphery.

The category 'smart city' has proven particularly popular not only among adopting cities, but also among large engineering firms, because it offers concrete innovation and investment opportunities for physical urban and infrastructure development. It promotes engineering system solutions to urban problems, and consequently has somewhat shifted attention away from environmental conceptions of the city to ones oriented towards infrastructure and information use. The terms 'eco' and 'green' are added mainly to indicate the inclusion of green spaces and parks for recreation. Consequently, its net contribution to the environmental cause remains disputed, according to some (Gargiulo Morelli et al., 2013; Viitanen and Kingston, 2014). In fact, the lack of particular emphasis on environmental sustainability, confirms the pattern observed in Fig. 5: the 'smart city' is relatively weakly related to the central 'sustainable city' category. At the same time its fast increase in frequency of occurrence suggests that a new, intensely linked node is in the making, which constitutes a new collection of keywords and related concepts, and which is distinctly different from the 'sustainable city'. While the present analysis pictures the 'smart city' as a satellite, it may well continue to grow in mass and, in time, move to the center stage of the academic debate on urban development.

### 4.5. Knowledge city

The category 'knowledge city' has an apparent resemblance with aspects of the 'smart city' in that what is seen to be the desirable direction for urban development is similar: information- and knowledge-intensive production without high environmental impact. However, its theoretical origins are quite different and associated more with the economics of innovation. It is effectively interchangeable with conceptions of 'knowledge-based urban development' (KBUD) (Arbonies and Moso, 2002; Yigitcanlar and Loennqvist, 2013). Yigitcanlar et al. (2008a) mention Knight (1995) as possibly being the first author officially to introduce the concept of KBUD, describing it as the conversion of knowledge ingredients into local development to offer a platform for the city to develop in a sustainable way, coupled with a social learning process to help citizens to realize urban change. More recently, 'knowledge cities' have been defined as integrated cities that physically and institutionally combine the functions of a science park with civic and residential functions (Yigitcanlar et al., 2008a). However, they lack the emphasis on the central role of ICTs in triggering this development. Hence, this category's conceptual evolution in the past decade has been separate from 'smart city'. Modern urban planning began to embrace KBUD because of the vital impact of knowledge cities on enhancing a region's competitiveness in globalization (OECD, 2006; del Rosario Ovalle et al., 2004). In its widest interpretation, the concept of 'knowledge city' not only focuses on the knowledge economy and industrial structure, but also stresses enriched human capital, a vibrant and diverse socio-cultural environment, conservation of the natural environment, a high-quality built environment, accessibility, tolerance and acceptance of multiculturalism, and social equity (Florida, 2005; Van Winden et al., 2007, Yigitcanlar et al. 2008b). Peer and Stoeglehner (2013) additionally argue that knowledge cities require a strong organizing capacity to establish such foundations, with essential partnership between public and private actors, the academic world and the wider community, in order to negotiate and determine jointly the knowledge demand, knowledge transfer and knowledge learning. Thus, the planning of a 'knowledge city' can foster the conditions for learning networks which help sustainable development at the regional level through a collective innovation process (Valkering et al., 2013). Fernandez-Maldonado and Romein (2010) hold the view that KBUD should balance economic quality, socio-spatial quality and organizational quality, in order to develop in a sustainable way. Taken together, the realization of 'knowledge cities' may have a positive impact on environmental sustainability, although it is essentially only instrumental for achieving other, economic innovation-related goals; as such, the 'knowledge city' does not centrally promote ecological sustainability or even regenerative development. Nevertheless, a much-praised city such as Melbourne has been winner of the Knowledge City Award in 2013, while equally priding itself in being 'green' as well as the home of the Melbourne Principles for sustainable city development, which essentially stress the community participation aspect of sustainable urban development. As shown in Fig. 3, the 'knowledge city' is a relatively long-standing conceptual category, but one which has not significantly grown across the time frame analyzed. It has a conceptually distinctive identity, quite separate from 'smart city', and paradoxically keyword associations suggest a closer interconnectedness with 'sustainable city', 'eco city' and 'low carbon city' than with the other categories, in spite of its largely economic innovation-oriented connotations.

### 4.6. Resilient city

Holling (1973: 17) may have been the first to use the term resilience. As he and Gunderson went on developing it, they did so from an ecological perspective as "the persistence of relationships within a system", "the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist" and "the capacity of a system to undergo disturbance and maintain its functions and controls" (Gunderson and Holling, 2001; quoted in Jabareen, 2013: 220). Since then, the concept has seen widespread application to a variety of other academic fields in addition to ecology, including economic geography, natural and man-made disaster management, terrorism, and flood control (Barnett, 2001; Polese 2010, Godschalk 2003; Davic and Welsh, 2004; Jabareen, 2013). The recent and most complete definition covering the application in the greater variety of academic disciplines was given by UNISDR (2010: 13): "resilience means the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including the preservation and restoration of its essential basic structures and functions".

According to recent literature, the study on the 'resilient city' illustrates the various perspectives implied in resilience research: (1) reacting to ecological problems; (2) handling hazards and disasters; (3) coping with shocks in the development of urban and regional economies; and (4) promoting resilience through urban governance and institutions (Leichenko, 2011). Some claim that researchers focusing on a small number of factors may draw inaccurate conclusions, because the 'resilient city' is a complex and multidisciplinary system requiring an integrated approach to allow analysts to deal with many uncertainties and vulnerabilities which are not always easy to predict (Folke et al. 2010; Little, 2004; Jabareen, 2013). Jabareen (2013) includes (1) adaptation, (2) spatial planning and (3) sustainable urban form (consisting of compactness, density, mixed land use, diversity, passive solar design, greening, and renewal and utilization) as the three interrelated components of uncertainty orientation which analysts have to deal with to build good predictive models of urban systems as a foundation for developing measures to promote the 'resilient city'. Academic use of the category 'resilient city' has seen a steady increase since 2008 and has by 2013 become significant. Figs. 4 and 5 demonstrate that the resilient city has established a theoretical branch of its own which has steadily been gaining in academic popularity since 2006. Its connections with hurricane Katrina (New Orleans, USA) and emergency management (reflective of its adaptation aspect) as well as with sustainability (reflective of its mitigation effect) seem significant. However, it remains to be seen whether related key words will evolve into substantial components of the 'resilient city' conceptual identity in the literature, assuming a further consolidation of this category in years to come. It also appears that although the 'resilient city' has been used in various academic disciplines, most recently it has become most conspicuous in safety science, environmental science and governance. This is apparent in Fig. 4 in that the 'resilient city' is only connected with the 'sustainable city' and no other categories. Whether this approach will eventually contribute positively to sustainable urban development will depend primarily on its interpretation as being at least partly about mitigation, in addition to adaptation, in relation to urban development. The effects of policy measures for the benefit of the 'resilient city' can only be assessed if unambiguous quantification approaches have been adopted. This does not appear to have happened to date, judging from the available literature.

## 5. Conclusions

The multitude of initiatives across the globe towards sustainable urban development and the plethora of terms introduced in the policy debate to characterize these initiatives are staggering. A variety of city categories is thrown in the mix, apparently all of them aiming to create the impression that social, economic and environmental sustainability (or even regeneration) can go hand in hand. 'Sustainable', 'smart', 'resilient', 'low carbon', 'eco', 'knowledge' and all the other city categories, do they really amount to virtually the same thing: 'better city, better life'? Are ecological modernization in the city and urban regenerative development safe in the hands of those who adopt any of these terms? Does it matter at all which one is chosen?

This article has sought to examine how the academic literature on the whole analyzes and interprets salient city categories related to sustainable urban development. The goal has been to establish whether there are distinct conceptual perspectives among the twelve most frequently encountered city categories. We have hypothesized that the academic literature would in fact reveal *conceptually distinctive identities* for the different city categories, possibly with some overlap and cross-fertilization between them. Besides identifying the key concepts embedded in the twelve categories, the analysis has also allowed us to trace their conceptual roots, revealing their underlying norms and perceptions. As such, the analysis shows where the theoretical concepts, and consequently their policy implications, converge or diverge.

The twelve categories of urban regenerative sustainability subjected to this bibliometric analysis are: 'eco city', 'sustainable city', 'smart city', 'low carbon city', 'knowledge city', 'intelligent city', 'digital city', 'ubiquitous city', 'resilient city', 'green city', 'information city', and 'liveable city'. The records analyzed involve the academic literature reposited in Scopus, from 1996 up to 2013.

First of all, the findings of our research overall support our hypothesis - namely, that *the selected city categories are not interchangeable*. Rather, the research findings robustly demonstrate important conceptual differences among them, although interrelationships among the twelve categories do exist. The genesis of new categories from older, more established categories in part explains the varying degrees of conceptual overlap between the categories. More specifically, we found six categories to be conceptually distinct enough to be seen as supported by a specific body of theories ('sustainable city', 'smart city', 'eco city', 'low carbon city', 'resilient city' and 'knowledge city').

Secondly, *'sustainable city' is the most frequently occurring category* and, in the maps of co-occurring keywords, the largest and most interconnected node, which is most intricately linked with 'eco city' and 'green city'. The keyword co-occurrence maps clearly show the power of 'sustainable city' as a comprehensive umbrella concept addressing the ecological, economic and social dimensions or pillars of sustainable development. In time, its comprehensiveness and the necessary trade-offs between ecological and social and economic sustainability arguably seem to have become its pitfall, as the more narrowly defined concepts of 'low carbon city' and especially 'smart city' are rapidly gaining in popularity, judging by their frequency of occurrence in academic journals.

Thirdly, whereas the 'low carbon city' essentially represents a subset of the 'sustainable city' category of concepts, the *'smart city' stands out as a new set of concepts*, in which social inclusion and the role of the internet for the creation of new businesses and jobs, for the provision of high quality services and for the empowerment of citizens with information, are prominent features; this positions the 'smart city' as a distinct category of urban modernization ambitions and initiatives. In fact, the 'smart city' family of concepts seems – at least at present – to be on its way to become leading as a driver of urban sustainability and regeneration initiatives. In 2012, the 'smart city' surpassed the 'sustainable city' in frequency of occurrence in academic discourse.

Next to the 'sustainable city' and 'smart city' families of concepts, the 'knowledge city' seems to represent another distinct category. Even though it shows significant overlap with the concepts underlying the 'sustainable city', it differs remarkably from the latter in its origins in innovation economics. The 'resilient city' may, in time, develop into a sufficiently significant, conceptually distinct category of its own, given the fact that it represents new keywords e.g. in the area of safety and emergency management. At this point in time, however, we can only speculate – its appearance in the academic literature to date has been modest.

Each of the city categories harbors a different view of what the city is and how it works, with respect to the role of citizens and the way they relate to the governance of the city, with respect to the interactions between the city and its natural environment, and with respect to the role of urban infrastructure systems and services in the city's economy and liveability. We should, therefore, stress the need for rigor in the use of these terms if one wishes to comprehend their policy implications and the explicit and implicit choices made among various public values in urban development.

These findings are of more than mere theoretical relevance. The distinctions found among the twelve city categories may well call into question the viability of key assumptions underlying the sustainable development, ecological modernization and regenerative development paradigms, at least in the urban context. These paradigms have as their main starting point that social, economic and ecological development can go hand in hand, that symbiosis between them is possible if not natural if the path of industrial transformation towards a services economy is chosen. That is, further economic expansion is assumed to be possible while keeping the ecological environment in a stationary state (sustainable development, ecological modernization) or even restoring and/or enhancing the natural environment (regenerative development). The social aspect also receives due attention in most of the twelve city categories, but turns out to be the hardest one to pinpoint and measure; in fact it seems to be interpreted differently in the various categories. In other words, however much we would like all public values, social, economic and ecological ones, to be winners in the process of urban restructuring, it *not safe* to assume that a win-win-win is always the logical outcome of modern urban transformation. The findings of our research suggests that the conception of the city chosen matters to the tradeoffs made among them and has an impact on what the future city will look like. If policy-makers want the natural environment not to lose ground (sustainable development, ecological modernization) or even to incur gains (regenerative development), some city categories may be more suitable than others.

Seen in this light, the mainstreaming of the 'eco city' over time as a no-nonsense approach to investments in sustainable urban infrastructures, the evolution of the 'low carbon city' from the 'eco city', the strong emphasis on climate adaptation (rather than mitigation) in the interpretation of the 'resilient city' concept and especially the rapid emergence of the 'smart city' and its satellites must give environmental analysts and activists some cause for concern. Increasingly fierce competition among cities for businesses and talented people, as well as growing dependency of their cash-stricken governments on private funds, have driven cities' self-promotion and investment programmes in the direction of stronger emphasis on economic feasibility and engineering systems solutions to realize their ambitions for desirable and viable urban development. The 'smart city' in particular seems to fit this picture of providing integrated building and technological fixes, and reflects the substantial capital needs involved in building new and/or maintaining existing urban infrastructure. But whether this type of smart growth can adequately cater for social equity is not certain; likewise, what environmental progress can be expected of large-scale development activities through technologically advanced, knowledge-intense buildings, infrastructure and services is not immediately obvious. Conducting more detailed fieldwork in a number of carefully selected cities in various regions of the world embracing the 'newer' categories of sustainable urban development, examining which players are the largest financial and intellectual contributors to the investment projects, studying the actual social, economic and environmental impacts of these investments, and monitoring the short and long term impacts, will all be needed to provide reliable answers to these questions. Interesting candidates for such case studies could be Grenoble, Melbourne and Guangzhou, which were referred to in the introduction as appealing to more than one of the city categories at the same time. Such research could bring us closer to an answer to the question whether they are underway to become a true 'city of harmony'.

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