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# Cities and quality of life. Quantitative modeling of the emergence of the happiness field in urban studies

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ABSTRACT

Where we live affects all aspects of our life and thus our happiness. In recent years, and now for more than half of the population of the Earth, our place of residence or activity has been increasingly transformed into an urban one. However, while the impact of happiness studies has grown in importance during the last twenty years, we note that happiness-related concepts find it difficult to penetrate the planning and design of cities, and affect the field of urban studies. In this paper, we map the temporal evolution of the fields of happiness and urban studies into dynamic networks obtained by paper keywords co-occurrence analysis. We identify the main concepts of the "urban happiness" field and their capacity to agglomerate into coherent thematic clusters. We find that while *quality of life* and *well-being* are highly interconnected with some well-defined urban categories, other happiness-related concepts, as *subjective well-being* or *happiness* itself, are located in peripheral positions where their influence is minimised. We present a one-parameter spatial network model in order to reproduce the changes in the topology of these networks. Results explain the evolution and the level of interpenetration of these two fields as a function of "conceptual" distances, mapped into Euclidean ones. In addition to other approaches (i.e., co-frequency matrix of bibliometric analysis), complex networks science appears as a valid alternative and opens the way for the systematic study of other academic fields in terms of complex evolving networks.

## 1. Introduction

Sustainability science is considered an emerging field of research.[1] It actually occupies a central position in the social, economic and political agenda of many Western democracies. However, a genuine transition towards sustainability has not yet begun (Helne & Hirvilammi, 2015), given the multiple significances of the word (Brown, 2016), many times seen as an empty signifier (Laclau, 2005) and a plastic word (Poerksen, 1995). Approaches such as sustainable development or green economy seem to have failed to deliver a halt in the worsening of planetary health and the eradication of poverty and inequality (Kothari, Demaria, & Acosta, 2014). Main reasons include the recent phase of accelerated expansion of capitalism (Harvey, 2014), the complexities encountered when economy is embedded in a wider social and biophysical system (Dodds, 1997), and the difficulties associated with defining and measuring the global condition of an individual or a group (e.g., happiness, subjective well-being, life satisfaction and positive affect, to name a few of the existing close-related terms in the literature). Such definitions must include social, economic, psychological, spiritual or medical states (Kullenberg & Nelhans, 2015). It is thus necessary to enrich the understanding of concepts (like the ones previously mentioned) on the basis of a relational paradigm, internalising human well-being and the health of the ecosystems (Helne & Hirvilammi, 2015).

In recent years, and now for more than half of the earth's population (United Nations Population Division, 2014), this ecosystem has been increasingly transformed into an urban one. Although urban contexts and cities are considered engines of human innovation (Glaeser, 2011), they are also characterised by important problems which have become central political issues (Davis, 2006; El Araby, 2002; Liu, Dijst, & Geertman, 2015; Wissink, Schwanen, & van Kempen, 2016): segregation, neighbourhood degradation, socio-economic deprivation and inequities in health, well-being and health-care accessibility. Cities form "the biggest, non-genetic influence on how healthy" we are (Buettner, 2008) and the influence of their environmental and built factors in the quality of life and aging of their inhabitants has been widely demonstrated (Steptoe, Deaton, & Stone, 2015). Green open cities that allow sport activity positively affect the brain and cognition (Hillman, Erickson, & Kramer, 2008; Sofi et al., 2011; Zhu et al., 2014) relaxing

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environments that promote social activity, increase both emotional health (Morrow-Howell, Hinterlong, Rozario, & Tang, 2003) and life span (Epel et al., 2004), and diminish cerebral infarcts (Yu et al., 2015).

Where we live affects all aspects of our life and thus our happiness (Florida, 2009): who we know, the "affective markets" in which we participate and the jobs, social networks and careers we have access to. According to J. A. Marina, promoter of the project "*Ciudades con talento*" (en., *cities with talent*),[2] the subjective happiness of the citizens consists of the harmonious satisfaction of three great needs or aspirations: (1) to live comfortably and safely, (2) to maintain pleasant social relations and (3) to feel that the vital possibilities increase. Thus, a city is considered "talented" if able to help meet those expectations by offering quality public services, favouring successful ways of coexistence and solving conflicts, and offering more options to expand their intellectual, emotional, cultural or economic possibilities (Marina, 2016). How well a society takes care of its new generations is also a measure of its health (Benson, 2006). But the options that our built environment gives in order to consider this perspective are increasingly limited (Jacobs, 1961). For example, among the twenty fundamental external resources detected to foster and build developmental assets for adolescents,[3] 40% of them depend, directly or indirectly, on the built environment. These include caring neighbourhood, caring school climate, safety (at home, school, and in the neighbourhood), school and neighbourhood boundaries, creative activities, youth programs (i.e., sports, clubs, or school and/or community organisations) and time at home, to name a few.

Concepts such as liveability, living quality, living environment, quality of place, residential perception and satisfaction, have been introduced and transformed into indicators to evaluate the residential and living environment (Van Kamp, Leidelmeijer, & Marsman, 2003). These different but closely connected concepts originate with the various research and policymaking traditions of health and safety. Terms such as quality of life and sustainability, which have been in the development discourse for some time now, do overlap and are often used as synonyms of well-being, residential satisfaction or urban physical environment. This overlapping makes it clear that measuring happiness and other related concepts in cities and the urban environment is difficult and the relation to each other is still unclear.

In the last years, an increasing number of researchers have approached the conceptual analysis of the happiness field by means of concepts such as quality of life (see Marans, 2012; Veenhoven, 2000), happiness (see Di Tella & MacCulloch, 2006; Easterlin, 2003; Layard, 2005; Veenhoven, 1997), (subjective) well-being (see (Diener, 1994; Diener, Suh, Lucas, & Smith, 1999; Dolan, Layard, & Robert, 2011; Layard, 2010; Veenhoven, 2007)) and life satisfaction (Cummins, 1996; Diener, Inglehart, & Tay, 2013). Although there have been numerous attempts to measure and analyze the factors that affect quality of life in cities and regions (Ballas, 2013), and even construct alternative, non-monetary indices of social and economic well-being in urban planning (Khalil, 2012), how happiness concepts have penetrated urban planning, at which pace, and how they have been included in the urban studies field has not yet been assessed in the literature.

This paper aims at answering these last questions with the use of complex networks science based on paper keywords co-occurrence analysis (Newman, 2010). We examine the temporal evolution and penetration process of the fields of happiness and urban studies into dynamic networks with the final objective to identify the main concepts of the "urban happiness" field and characterise their areas of conceptual influence. Secondly, we present a one-parameter spatial network model in order to reproduce and better understand the changes in the topology of these networks. The paper is organised as follows. In the Materials and Methods section, we explain our database and methodology. In the Results section, we present firstly an analysis of the keywords of papers related with happiness studies with the objective of quantitatively assess the evolution of the structural features of this network. Secondly, we perform an analysis of the keywords of papers related with urban studies that include particularly central keywords from the first network with the objective of explaining and modeling the emergence of happiness in urban planning. In the Discussion section, and in order to suggest an explanation to our results, we present a simple spatial network model that reproduces significantly well this penetration process as a function of a "conceptual" distance that the model turns into a Euclidean one. We finish with the Conclusions section, where we recap and define some possible further work.

## 2. Materials and methods

Since the still relevant, and also criticised, account of the rise of new science by Thomas Kuhn (Kuhn, 1962), many attempts have been made in recent decades to characterise the advent, structure and evolution of both new and well established scientific fields. With the advent of the indexing and availability of scholarly documents and literature, we have begun to quantitatively understand the process by which scientific fields, and even science itself, emerge (Bettencourt & Kaiser, 2015; Börner, 2010, 2015). These quantitative methods commonly include one or a mixture of the following ones:

1. Population contagion dynamical models for the spread of ideas and the emergence and development of scientific fields (Bettencourt, Cintrón-Arias, Kaiser, & Castillo-Chávez, 2006; Bettencourt, Kaiser, Kaur, Castillo-Chávez, & Wojick, 2008; Bettencourt & Kaur, 2011), where differential equations are numerically solved and calibrated to reproduce the temporal development of empirical data (i.e., authors, papers and dates of publication).
2. The structural analysis of networks of:
   a. Collaboration between scientists (Barabási et al., 2002; Luis M. A. Bettencourt & Kaiser, 2015; Bettencourt, Kaiser, & Kaur, 2009; Liu, Bollen, Nelson, & Van de Sompel, 2005; Newman, 2001), where two scientists are considered connected if they have co-authored one or more papers together.
   b. Connectivity between articles, in order to detect communities, fields or disciplines. In this case, articles can be connected with either of the following two ways:
      i. By means of the paper's references list:
         1. If they are cited in the same bibliographic list; a methodology known as co-citation analysis (Small, 1973).
         2. If they share common references; a methodology known as bibliographic coupling analysis (Kessler, 1963). While co-citation analysis aims at identifying the intellectual base of the research, bibliographic coupling analysis is more suitable to identify current and/or emergent research fronts (Persson, 1994). This methodology gives equal weight to all published papers (whether cited or not), can be applied to recent papers (which have not yet been cited) and establishes links on the basis of the author's own decisions rather than retrospectively from other scientists' citations (Grauwin et al., 2012).
      ii. By means of words (from the paper itself or its keywords); a methodology known as co-word analysis (Callon, Courtial, & Laville, 1991; Callon, Courtial, Turner, & Bauin, 1983). This methodology assumes that a paper's keywords constitute an adequate description of its content or, the links the paper established between problems (Ding, Chowdhury, & Foo, 2001).

In the structural analysis of these networks, communities are detected by modularity measures (Newman, 2002) and information about these communities is retrieved by means of qualifiers on the nodes.

[2] http://ciudadescontalento.com

[3] http://www.search-institute.org/content/40-developmental-assets-adolescents-ages-12-18

They can also be extended to generate different maps using co-occurrence of authors, keywords, institutions, etc. (Grauwin & Jensen, 2011).

The scientific research in human happiness has become an integrated line of inquiry throughout various disciplines. The impact of happiness studies has grown in importance during the last twenty years, but almost no attempts have been made yet to organise and map the scientific research contexts in which happiness studies either have penetrated pre-existing disciplines or become a core scientific activity. With the aim of analysing the historical development of the field itself and related journals, Kullenberg and Nelhans (2015) appears the only reference that uses bibliographic coupling to create clusters from a dataset of articles. The dataset included Web of Science topics searches based on four terms: happiness, subjective well-being, life satisfaction and positive affect, identified as core concepts in the field after a systematic literature review (Kullenberg & Nelhans, 2015). Results show that "happiness studies" have "emerged in many different disciplinary contexts and progressively been integrated and standardised" to become an "autonomous field of enquiry".

For this paper, we adopted co-word analysis for multiple reasons. Connectivity between articles by means of the paper's references list – be it co-citation or bibliographic coupling – has been long interpreted as an act of symbol usage (Latour, 1987; Small, 1978). As Small (1978) points out (p. 337), when a scientist cites, she creates a connection between a concept, procedure, or kind of data, and a document or documents. This process tends to generate recurring patterns of terminology for these documents, the outcome being the standardisation of usage and meaning. In the words of Kullenberg and Nelhans (2015), it implies that when an author cites an article, he or she "creates its meaning": the citation adopts "a symbolic dimension". Although this idea has resulted, for example, in the worldwide implementation and use of the science citation index (Garfield, 1955), it is a very strong assumption, since references lists rely on people openly citing papers rather than creating meanings. Besides, most citations are just copied from other papers, once a citation has reached a critical threshold, and they are not always read by the author who cites them (Newman, 2010).

A remarkable result coming from the quantification process of emerging scientific contexts shown in the literature is that a definite scientific field seems to emerge only once there exists a critical amount of commonly shared set of (a) research questions, (b) concepts, and (c) methods that allow multiple authors to cooperate and collaborate (Luis M. A. Bettencourt & Kaiser, 2015). Surprisingly enough, research questions, concepts and methods, which are normally coded into keywords and words in the papers, have been traditionally ignored in these studies. The co-word analysis is an important bibliometric approach based on co-occurrence analysis and has been widely applied to illustrate how concepts, ideas, and problems within a given scientific field interact and to explore the concept network within the relevant field (see (Yong Liu, Li, Goncalves, Kostakos, & Xiao, 2016) and references therein). It has been used in the literature for mapping conceptual networks of disciplines like consumer behaviour research (Muñoz-Leiva, Viedma-del-Jesús, Sánchez-Fernández, & López-Herrera, 2012), patent analysis (Chang, Wu, & Leu, 2010), urban sustainability concepts (Fu & Zhang, 2017), biology (An & Wu, 2011) and education (Ritzhaupt, Stewart, Smith, & Barron, 2010), to name a few.

Here we consider a network formed by keywords as nodes. Two keywords are connected if they appear in the same paper, and the weight of the link between them depends on their probability of co-occurrence across the various papers (Fig. 1). This weight is normalised by means of bibliographic coupling (Kessler, 1963):

$$w_{i,j} = \frac{|P_i \cap P_j|}{\sqrt{|P_i||P_j|}} \tag{1}$$

where $P_i$ and $P_j$ are the set of papers that contain keyword $i$ and $j$ correspondingly. By definition $w_{i,j} \in [0, 1]$, is equal to zero when $i$ and $j$ do not share any paper and equal to one when their sets of papers are identical. Thus constructed, the structural analysis of this network serves as a proxy for the conceptual structure of a specific discipline. It allows a time-series record of the changes that occurred in the conceptual space and it can reveal patterns and trends in a specific discipline by measuring the association weight of representative terms in relevant publications (Ding et al., 2001).

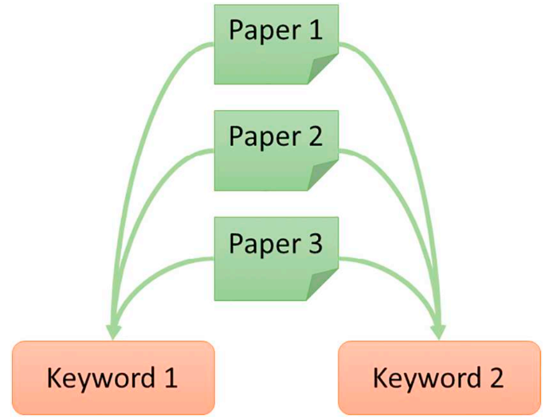


**Fig. 1.** Keywords are connected if they appear in the same paper. The weight of the connection depends on the probability of co-occurrence.

To create the "happiness studies" network, we have assembled author keywords from all papers of three ISI-JCR indexed journals that address the conceptualisation, measurement, explanation and evaluation of happiness, well-being, human satisfaction, human development, wellness and quality of life. These are the Journal of Happiness Studies (J HAPPINESS STUD), Journal of Positive Psychology (J POSIT PSYCHOL) and Applied Research in Quality of Life (APPL RES QUAL LIFE). All items in the collection are publications written in English between 2000 and 2016.[4] Although considering publications only in English is a limitation, it represents by far the largest component of the scholarly literature. It also ensures consistency of records and facilitates automatic text parsing. To measure the penetration of this field into the urban studies one, we conducted a second search, using the most connected keywords from the previous network. We adopted the Scopus database records as it provides more complete and easy downloadable data. We used indexed Journals of the Urban Studies Category of ISI Web of Science (see Appendix A for the complete list) for year 2015.

We quantified the evolution of the structural features of the networks using the following network metrics:

- **Average degree and degree distribution.** A key centrality measure of a node is its *degree*, $k_i$, representing the number of links node $i$ has to other nodes. In an undirected network with $N$ nodes (i.e., size of a network), the *average degree* is defined as:

$$\boldsymbol{k} = \frac{1}{\boldsymbol{N}} \sum_{\boldsymbol{i}=1}^{\boldsymbol{N}} \boldsymbol{k_i} = \frac{2\boldsymbol{L}}{\boldsymbol{N}} \tag{2}$$

where $L$ is the total number of links. The degree distribution $p_k$ is giving the probability that a randomly selected node in the network has $k$ links. Since $p_k$ is a probability, it must be normalised, i.e. $\sum_{k=1}^{\infty} p_k = 1$. For a fixed network of size $N$, the degree distribution is the normalised histogram $p_k = \frac{N_k}{N}$, where $N_k$ is the number of degree $k$ nodes, and its cumulative degree distribution $P_k$ is giving the probability that a randomly selected node in the network has $k$ or more links.

[4] J HAPPINESS STUD is the only Journal existing since 2000. J POSIT PSYCHOL and APPL RES QUAL LIFE made their appearance in 2006. Nevertheless, for abbreviation, we will mention that our period span is between 2000 and 2016.

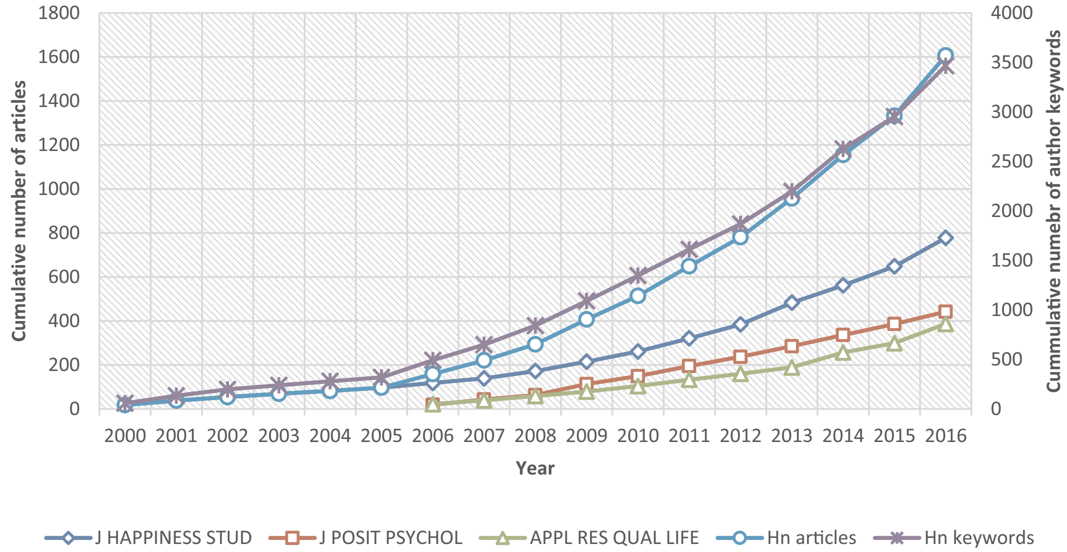


**Fig. 2.** Cumulative number of articles (per journal and in total) and unique author keywords, per year.

- **Weighted degree.** Also known as node strength, weighted degree is defined as the sum of weights attached to ties that belong to a node (Barrat, Barthélemy, Pastor-Satorras, & Vespignani, 2004). This measure is formalised as follows:

$$s_i = \sum_{j}^{N} w_{ij} \tag{3}$$

where $w_{ij}$ is > 0 if the node $i$ is connected to node $j$ and the value represents the weight of the tie (i.e., Eq. (1)).

- **Clustering coefficient.** The local clustering coefficient captures the degree to which the neighbours of a given node link to each other (Watts & Strogatz, 1998). For a node $i$ with degree $k_i$ the local clustering coefficient is defined as:

$$C_i = \frac{2L_i}{k_i(k_i - 1)} \tag{4}$$

where $L_i$ represents the number of links between the $k_i$ neighbours of node $i$. Here we use the average clustering coefficient of a network $\langle C \rangle$ as:

$$C = \frac{1}{N}\sum_{i=1}^{N} C_i \tag{5}$$

- **Average path length and diameter**. Most networks are built to ensure connectedness. In an undirected network two nodes $i$ and $j$ are connected if there is a path between them on the graph. A path is a route that runs along the links of the network, its length representing the number of links the path contains. The shortest path $d_{ij}$ between nodes $i$ and $j$, has the fewest number of links. The average path length, denoted $\langle d \rangle$, is the average shortest paths between all pairs of nodes in the network. The network diameter, denoted $D$, is the maximal shortest path in the network.

Complementarily, the structural features of the different modules found in the networks (section 3.2.4) were characterised by the following centrality measures:

- **Betweenness centrality.** For every pair of vertices in a connected graph, there exists at least one shortest path between the vertices such that either the number of edges that the path passes through (for unweighted graphs) or the sum of the weights of the edges (for weighted graphs) is minimised. The betweenness centrality for each vertex is the number of these shortest paths that pass through the vertex (Barrat et al., 2004). This measure is formalised as follows:

$$b_i = \sum_{s \neq i \neq t} \frac{d_{st(i)}}{d_{st}} \tag{6}$$

where $d_{st}$ is the total number of shortest paths from node $s$ to node $t$, and $d_{st(i)}$ is the number of those paths that pass through vertex $i$.

- **Closeness centrality.** Calculated as the sum of the length of the shortest paths between the node and all other nodes in the graph. Thus the more central a node is, the closer it is to all other nodes (Bavelas, 1950). This measure is formalised as follows:

$$c_i = \frac{N - 1}{\sum_j d_{ij}} \tag{7}$$

where all variables have been already introduced.

## 3. Results

### 3.1. “Happiness” network (Hn)

#### 3.1.1. Database

Up until year 2016, our “happiness studies” dataset contains 1607 records: 778 (48%), 442 (28%) and 387 (24%) from J HAPPINESS STUD, J POSIT PSYCHOL and APPL RES QUAL LIFE, respectively (Fig. 2). We observe an increase in the cumulative number of published articles per year that follows an exponential function of the form $y \sim \exp(\alpha t)$ – where $t$ represents time, with an exponential parameter $\alpha = 0.27 (R^2 = 0.97)$ – in accordance to other several cases of emergence of new scientific fields (Luis M. A. Bettencourt & Kaiser, 2015). The cumulative number of author keywords for the “happiness” network (Hn) reaches a value of 3491 for year 2016, and follows a similar growth exponential trend – with $\alpha = 0.23$ ($R^2 = 0.98$).

#### 3.1.2. Network metrics

In Fig. 3, panel (i) we show the evolution of the topology of Hn in terms of four commonly used network centrality indices (i.e., degree, diameter, average path length and average clustering coefficient) and the percentage of nodes in the connected component (i.e., the subgraph in which any two vertices are connected to each other by paths). A giant connected component, which contains between 88% and 95% of the nodes (i.e., keywords) through the years, constantly dominates its

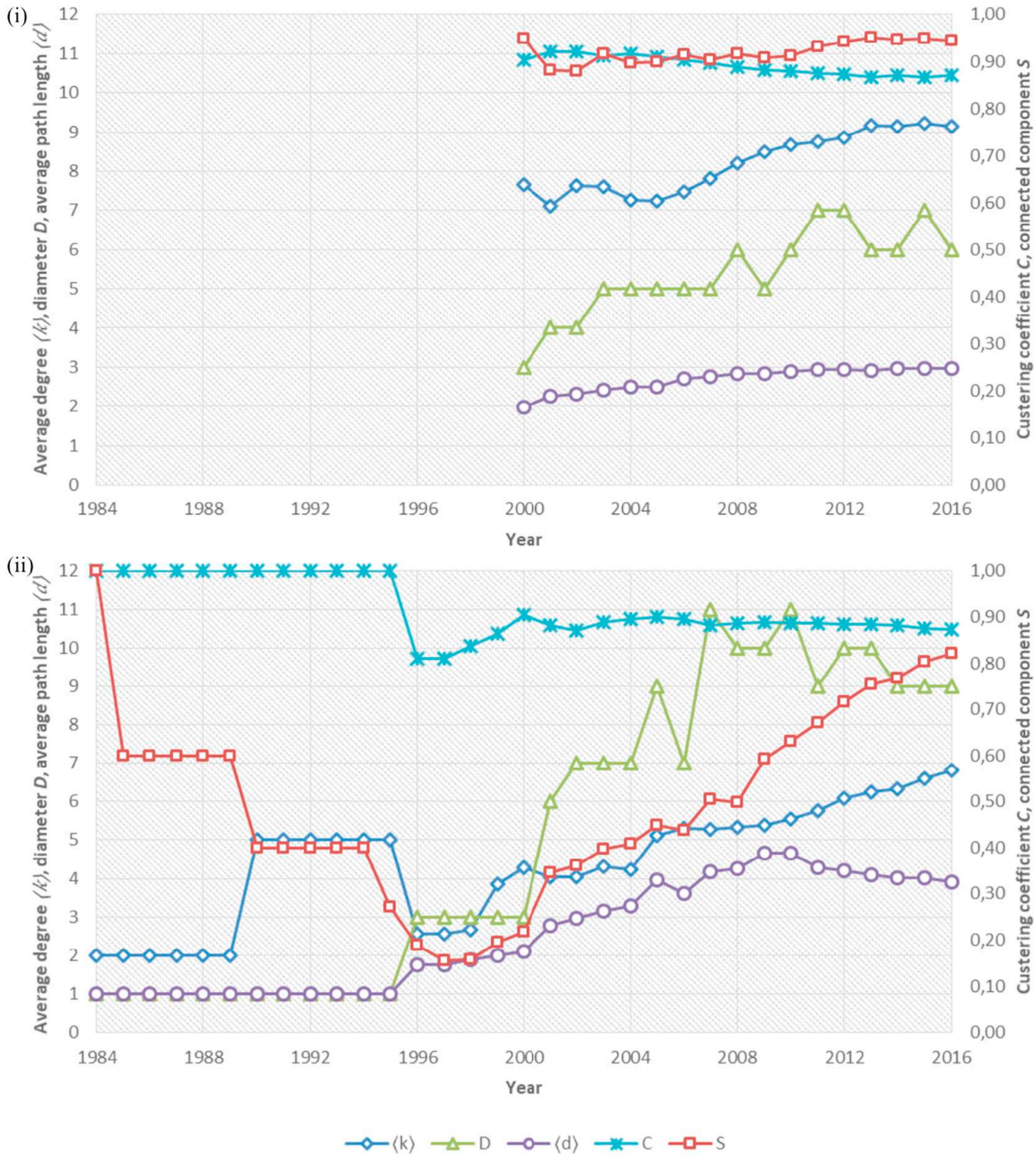


**Fig. 3.** Emergence of Hn (i) and UHn (ii) in terms of average degree ⟨***k***⟩, percentage of nodes in giant connected component ***S***, diameter ***D***, average path length ⟨***d***⟩ and average clustering coefficient ⟨***C***⟩.

topology. Average degree ⟨*k*⟩ increases from ⟨*k*⟩ = 7.66 in year 2000 to ⟨*k*⟩ = 9.14 in year 2016. Diameter *D* and average path length ⟨*d*⟩ increases as well over time with the number of new nodes added, but they seem to stabilise from year 2011 onwards. Clustering coefficient *C* decreases slightly, from 0.904 in year 2000 to 0.867 in year 2013, with a constant value up to 2016.

At year 2016, the Hn degree cumulative probability distribution appears fat-tailed, with the most connected nodes being happiness (H), life-satisfaction (LS), subjective well-being (SWB), well-being (WB), quality of life (QoL) and positive psychology (PP) (see Fig. 4 and Table 1). Hn shows a slightly negative nearest neighbour degree correlation (results not shown in the text), implying a disassortative behaviour where hubs tend to avoid each other, linking mainly to small-degree nodes, and making communities of similar keywords difficult to appear (Barabási, 2016).

Finally, we are interested in detecting possible pairwise correlations among keywords using weighted degree. As shown in Fig. 5, node degree and node strength are not correlated, and nodes with extremely high degree values (Table 1, column Hn) are characterised by relatively low strengths. The variability in the weighted degree is marginal for the most connected nodes: in descending order, H ($k$ = 652), LS, SWB, WB, QoL and PP ($k$ = 244). Special mention deserves WB, with $k$ = 336 but $s$ = 0.1 (red triangle in the graph), which indicates a very low connectivity in terms of co-occurrence with the rest of the keywords. The probability distribution of edge weights (Fig. 5, inset) – which fits an exponential function – shows that the connectivity is not dominated by especially strong links between keywords.

### 3.2. “Urban-happiness” network (UHn)

#### 3.2.1. Database

For the “urban-happiness” network (UHn), we conducted a search in Scopus database using the keywords with maximum degree in Hn (Table 1, column Hn).[5] Our data include 793 published (or pre-published online) articles from the 39 journals indexed in Urban Studies category of ISI Web of Knowledge (see Appendix A) between years 1971

[5] Positive psychology gave no search results in the bibliographic search of the Urban Studies category.

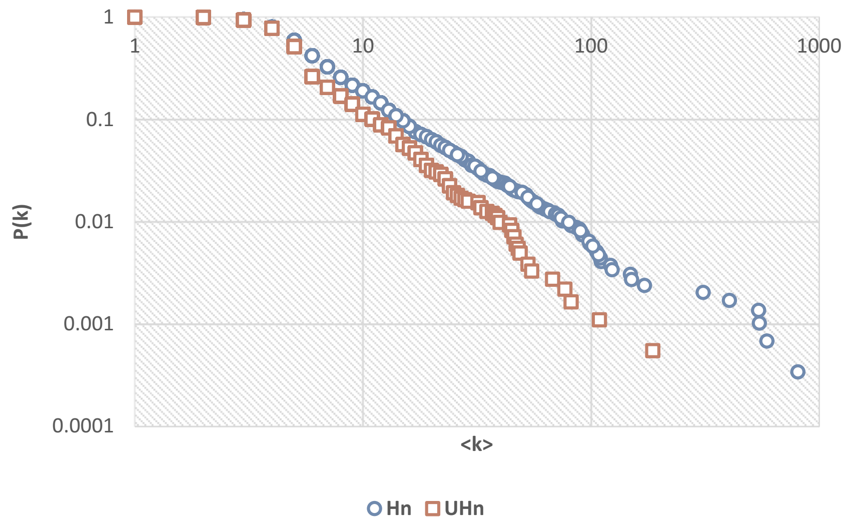


**Fig. 4.** Cumulated degree probability distribution $P_k$ for Hn (blue dots) and UHn (red squares) in log-log plot. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

**Table 1**
Most connected keywords in J HAPPINESS STUD, J POSIT PSYCHOL, APPL RES QUAL LIFE, Hn and UHn, in year 2016 (cumulated data from 2000 and 1984 respectively). Degree shown in parenthesis.

| APPL RES QUAL LIFE | J HAPPINESS STUD | J POSIT PSYCHOL | Hn | UHn |
|---|---|---|---|---|
| Quality of life (224) | Happiness (535) | Positive psychology (178) | Happiness (652) | Quality of life (194) |
| Life satisfaction (102) | Life satisfaction (324) | Well-being (167) | Life satisfaction (463) | Well-being (154) |
| Subjective well-being (69) | Subjective well-being (319) | Happiness (123) | Subjective well-being (429) | Health (81) |
| Happiness (66) | Well-being (228) | Life satisfaction (111) | Well-being (401) | Ecosystem services (77) |
| Well-being (61) | Quality of life (91) | Subjective well-being (96) | Quality of life (309) | Urban planning (68) |
| Health-related quality of life (61) | Positive affect (90) | Meaning/positive emotions (87) | Positive psychology (244) | Sustainability (65) |

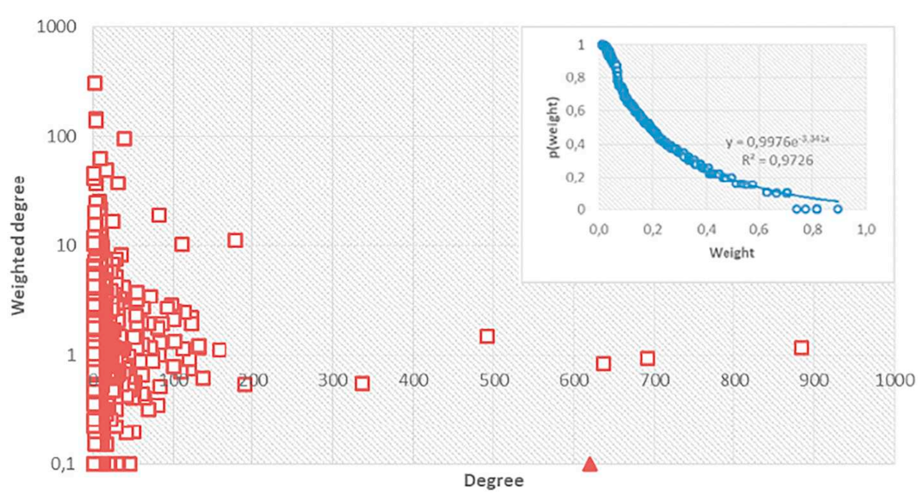


**Fig. 5.** Topological degree vs. weighted degree and cumulated probability distribution of weights (inset) for the Hn.

and 2016.[6] For the network analysis, we considered only articles with author keywords, resulting in a list of 1826 unique keywords associated with both happiness and urban studies categories, and a network of 5737 edges, as shown in Fig. 6.[7] We created the graph using Gephi software (Bastian & Heymann, 2009). For the layout we used ForceAtlas 2 algorithm (Jacomy, Venturini, Heymann, & Bastian, 2014). The size of a node is proportional to its degree and colours represent clusters (also known as modules) according to Blondel et al.'s modularity algorithm (Blondel, Guillaume, Lambiotte, & Lefebvre, 2008).

[6] The first article of our database with author keywords appeared in 1984.
[7] An interactive web widget to explore Fig. 6 can be found at https://summlabbd.upc.edu/papachristou-et-al. Widget created and designed in Gephi (https://gephi.org) and for Mozilla Firefox (https://www.mozilla.org) web browsers.

#### 3.2.2. Network metrics

The evolution of the topology of UHn in terms of the same centrality indices used for the Hn case (i.e., degree, diameter, average path length and clustering coefficient) and the percentage of nodes in the connected component is shown in Fig. 3, panel (ii). In this case, a primitive

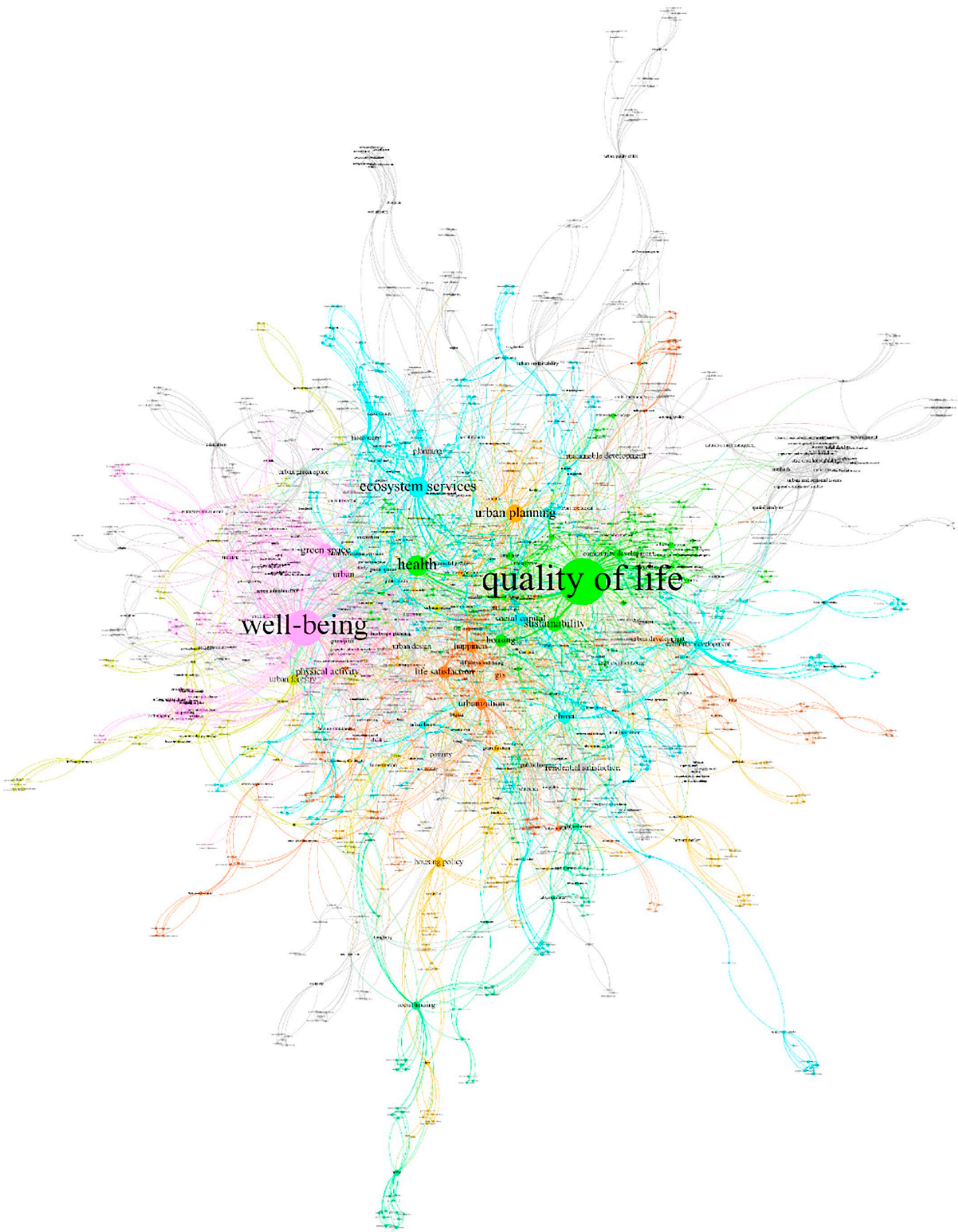


**Fig. 6.** Overall aspect of the UH network. The size of a node is proportional to its degree and the colours represent the different clusters. Created in Gephi (https://gephi.org).

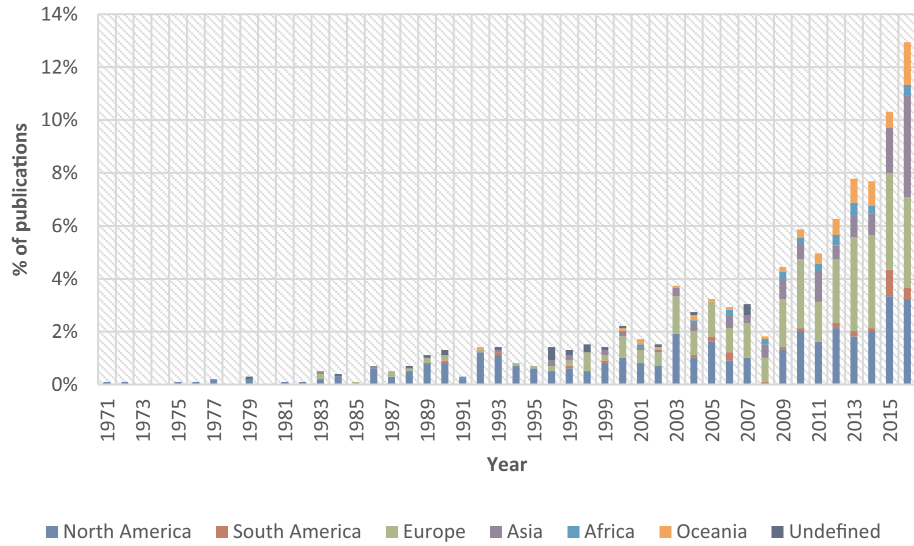


**Fig. 7.** Percentage of articles related with the happiness field and within the urban studies category per year and continent.

connected component appears in 1984, but the percentage of nodes in the giant connected component *S* begins to increase in 1998, including 15% of the total network, and reaches 80% of the nodes in 2016. Average degree $\langle k \rangle$ increases from $\langle k \rangle = 2.667$ in year 1998 to $\langle k \rangle = 6.828$ in year 2016. Here, diameter *D* and average path length $\langle d \rangle$ increase more steeply than in the Hn case, but unlike the later, they do not display a stable behaviour over time. The clustering coefficient *C* decreases slightly, from 1.0 (where keywords appear as cliques in each paper) to 0.872 in 2016. Similarly to Hn, at year 2016, the degree cumulative probability distribution appears fat-tailed, with most connected nodes being QoL (194) and WB (154) and followed by "health", "ecosystem services", "urban planning" and "sustainability" (Table 1, column UHn). UHn shows no nearest neighbour degree correlation and uncorrelated strength and degree (results not shown in the text).

### 3.2.3. *Temporal evolution*

Although the first article of our database was published in 1971, the earliest one including author keywords appeared in 1984. To avoid bias, we firstly underwent a manual literature research within the initial database, based on the citations received by each article. We then focused on the results of the author keywords' network. Fig. 7 presents the percentage of articles according to their year of publication and continent of origin. We observe the clear dominance of Europe and North America and a noticeable upsurge in Asia during the last decade, mostly led by Chinese scholars.

QoL first appeared in the early 1970s in North America, connected with free time activities and urban planning law (Chapin, 1971). In fact, planning and measurement begin to dominate the narrative during this decade, including comprehensive urban planning of cities (Heskin, 1972), aspects related with policies and metropolitan areas (Mogulof, 1975) and optimum city size (Hoch, 1977), and interspatial and intertemporal measurement methods (Gillingham & Reece, 1979). WB first appearances were also connected with measurement, in relation with the potential role of remote sensing in human settlements (Hidalgo & Musa, 1976). Soon enough, though, the concept connected with outdoor physical activities (Nash, 1979) and urban green (Lewis & Sturgill, 1979). During the 1980's, the most-cited article regarding the subject states that "highly valued urban open spaces are those which enhance the positive qualities of urban life: variety of opportunities and physical settings, sociability and cultural diversity" (Burgess, Harrison, & Limb, 1988, p. 455). First publications in Europe turn the focus on "re-conquering" the cities to re-achieve quality of life (Papageorgiou-Venetas, 1983) and, for the first time, computer modeling for the urban settlement is considered to achieve efficiency, stimulate employment and sustain a good quality of life for all inhabitants (Juppenlatz, 1983). In Asia, the initial paper in this field mentions "the need for public intervention to reduce urban congestion, ecological damage and protect QoL" (Plaut, 1983, p. 353), thus connecting QoL with pollution and environmental protection. The 1990's saw the appearance of the most-cited article in our database. Following the blossoming of land use and land cover computational techniques (i.e., GIS) and theories as means to understand environmental changes, Chester L. Arnold and C. James Gibbons first connected the quality of life of a community with water resources and impervious land cover in 1996 (Arnold & Gibbons, 1996). Other complementary and also important topics of the period include how the use of public space by adults affects the well-being of children (Valentine, 1996), how homeownership benefits both renters' and owners' life satisfaction (Rossi & Weber, 1996) and how nature affects the well-being of workforce (Kaplan, 1993). The appearance of South America, Africa and Oceania in the debate turn the focus on more concrete social urban problems like the participation of popular movements in the fight for improvements and the process of democratising the local power (Bava, 1990), spatial inequality (Chokor, 1991) and housing stress (Kearns, Smith, & Abbott, 1992), to name just a few. The introduction of H is made through a criticism on Victor Gruen's view of a good urban form (Hill, 1992) but its presence is minimum until year 2004, when it appears mostly related with socio-economic issues (Andersson, 2004; Priemus, 2004).

With the turn of the century, we observe an important increase in the number of publications (see Fig. 7), possibly affected by the appearance of the "happiness" journals (see Fig. 2) rather than the appearance of new journals in the urban studies category.[8] The focus on urban ecosystems and green is obvious. Urban parks and the sustainable city (Chiesura, 2004), ecosystem and human health in urban areas using green infrastructure (Tzoulas et al., 2007), biodiversity concepts and urban ecosystems (Savard, Clergeau, & Mennechez, 2000) and the effects of urban patterns on ecosystem function (Alberti, 2005) are some of the most important subjects associated with QoL and WB that concern scholars and scientists. The link between ecosystem services and well-being derives from the global scholarly discussion that the Millennium Ecosystem Assessment[9] stimulated during the first decade of this century, with the objective to put at the front of the scientific

[8] 95% of urban journals appeared before the new millennium (see Appendix A).

[9] Reports spanning years 2000–2005 (http://millenniumassessment.org/).

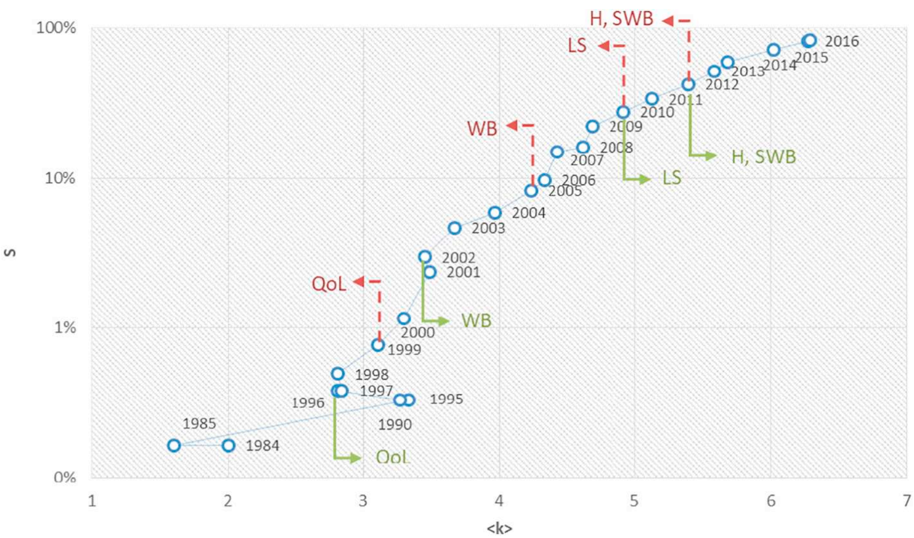


**Fig. 8.** Percentage of nodes (cumulative) in the giant components as a function of $\langle k \rangle$ in linear-log plot. Green continuous arrows show the year of appearance of the most connected keywords of Hn in UHn and red dashed arrows the year of connection of these keywords to the UHn's giant component. Keywords appear directly connected to the giant component as the graph increases its size (i.e., number of keywords) over time. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

debate the consequences of ecosystem change for human well-being.

During the current decade we still observe a focus on urban green, environmental justice (Wolch, Byrne, & Newell, 2014) and its positive effect on stress and WB (Ward Thompson et al., 2012). But we also clearly detect a new upcoming subject associated with the "smart" concept, like smart city initiatives and their potential on enhancing QoL (Neirotti, De Marco, Cagliano, Mangano, & Scorrano, 2014). Last but not least SWB makes its appearance as a society's measure of success during this decade (Leyden, Goldberg, & Michelbach, 2011).

The analysis of the temporal evolution of UHn offers the possibility to observe the coalescence of several urban fields around concepts related with happiness (Fig. 8). We observe the predominance of QoL and WB and the late entrance of SWB and H, in years 2004 and 2011 respectively. Regarding the rest of UHn's most connected keywords (Table 1, last column), *health* entered the graph in 2003, *ecosystem services* in 2009, *urban planning* in 2000 and *sustainability* in 2006.

### 3.2.4. Cluster analysis

We use cluster (or modularity) analysis to recognise communities (also called modules, groups or clusters). Networks with high modularity have dense connections between the nodes within modules but sparse connections between nodes in different modules. We run a modularity algorithm (Blondel et al., 2008) over the giant connected component of UHn (Fig. 6), which segregates the network into 27 clusters, with 40.4% of all keywords included in the first eight of them (sorted by decreasing size). Remarkably, with the exception of *positive psychology*, all Hn keywords in Table 1 are included in the first three clusters. Clusters 1, 2 and 3 are shown in Fig. 9 (ii), (iii) and (iv) respectively, where keywords are plotted according to their closeness $c_i$, betweenness $b_i$ and degree $k_i$ (size of the bubble) centrality measures. All three measures are positively correlated. Cluster 2 (Fig. 9 (iii) in red) shows a more significant dispersion in terms of $b_i$. For the keywords in this cluster, this trend suggests a more distributed capacity to act as separated connectors (i.e., to be in the shortest paths) between other words. That is, a cluster with truly differentiated words and meanings. On the contrary, cluster 1 (Fig. 9 (ii) in blue) shows a higher concentration of words in the range $10^3 < b_i < 10^5$ and with little variance in $k_i$, which implies a more densely connected community with stronger connections between concepts and words. This kind of connectivity suggests a cluster with undifferentiated words, maybe with similar meanings, and a lower capacity for them to act as distinctive connectors. Cluster 3 (Fig. 9 (iv) in green) shows similarities with cluster 1 in terms of $b_i$ and with cluster 3 in terms of $k_i$. In a more precise way:

- Cluster 1 (253 keywords) is dominated by ecosystem services and urban design and planning. *Social capital*, *urban green*, and *biodiversity*, including tools such as *geographical information systems* (GIS) are also part of this cluster. Although H, SWB and LS appear in the cluster, they are not central elements of the system, with intermediate values of $c_i$, $b_i$ and $k_i$ (Fig. 9(ii)). LS enters the graph in 2009 and directly connects to the giant component (Fig. 8). It makes an entrance in its cluster externally, directly depending on *urbanisation* and indirectly from the central concept of *urban planning*. In 2011 LS is still peripheral in the cluster that contains it. SWB and H join both the graph and the giant component in 2011. They both form part of the cluster dominated by *urban design*. H has a higher centrality than SWB. In the period between 1984 and the end of 2016, the biggest cluster changes from that of QoL to that of LS, SWB and H. The three keywords are still not central but connected to the rest of the graph through *urbanisation*, *social capital* and *urban design*.
- Cluster 2 (245 keywords) is clearly dominated by QoL and includes economic development (with *income* and *low-income housing*) and *health* related aspects of *urbanisation* (Fig. 9(iii)). *QoL* appears in 1996 and connects to the giant component in 1999 (Fig. 8). At this point of time, it belongs to the biggest cluster and shares a triangle with *urban environment* and *information technology*. It also connects to *public housing*, *housing policy* and *urban transport*. In 2005, the module containing QoL evolves into a more hierarchical structure, while it continues forming the larger cluster of the giant component. In 2011, QoL module has a similar, although more expanded, form in comparison to the previous period, agglomerating a greater quantity of nodes. *Sustainability*, *urban planning* and *urbanisation* are some of the concepts connected to it. At the end of 2016, this module shows a clear hierarchical form. High degree and centrality keywords such as *health*, *housing*, *sustainability*, *community development* and *economic development* are connecting QoL to the notions that define the concept itself.
- Cluster 3 (191 keywords) is clearly dominated by WB and includes words more related to the human dimension, like *psychological benefits*, *attitude*, *culture* and *deprivation*. *WB* appears in the graph in 2002 (Fig. 8) and connects to the giant component in 2005. Two keywords dominate the graph during this period: WB and *elderly*. In the 2009 snapshot, WB has a dominant centrality shared with *landscape planning* and *recreation*, and it is connected to *leisure activities* and *healing environments*. In 2011, we also observe a triangle of three central elements where WB maintains its predominant centrality, and *health* and *physical activity* form the new poles. At the end of 2016, WB appears associated with the environment and *green space*.

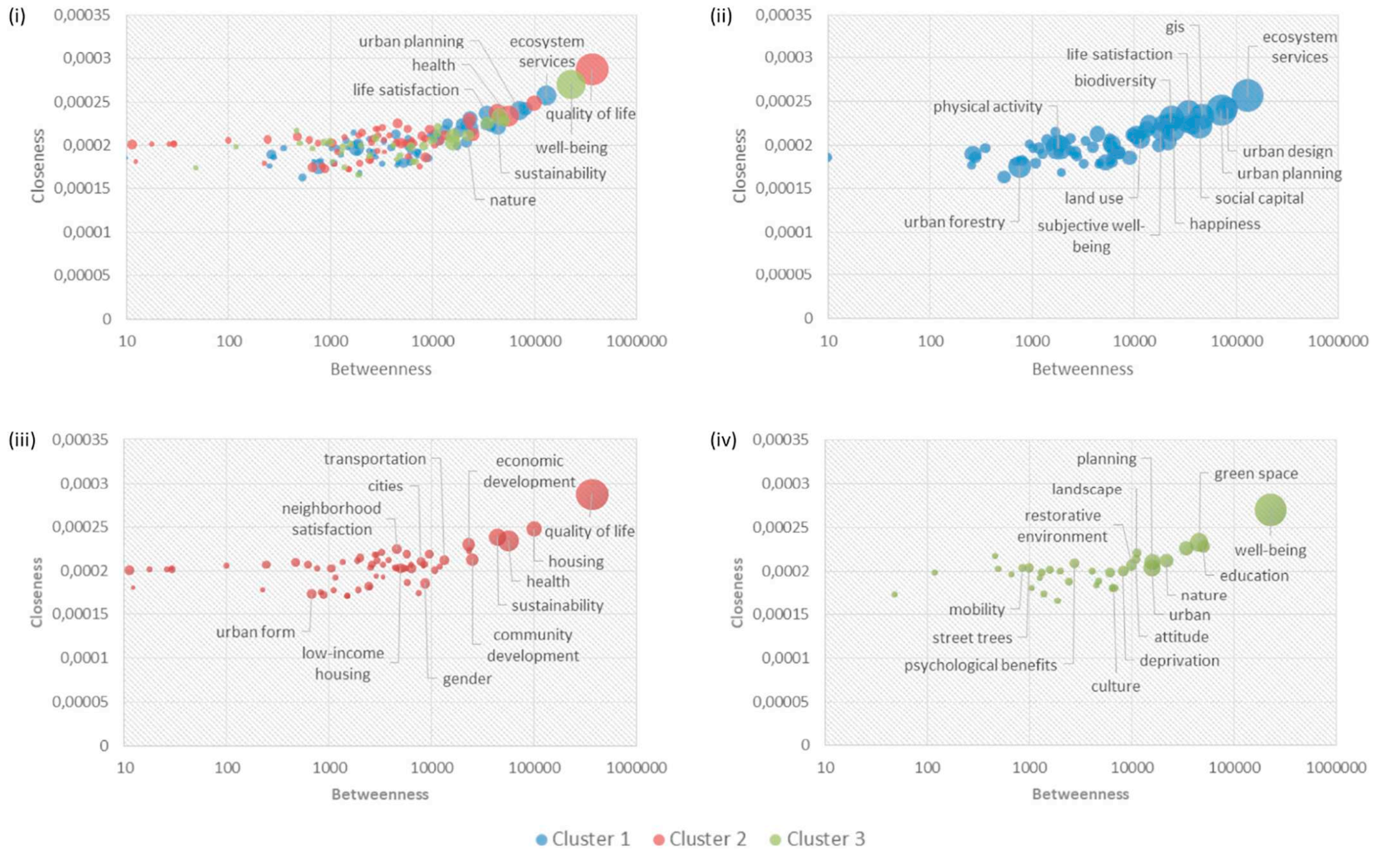


**Fig. 9.** The first three most important clusters in terms of size, and their keywords plotted according to closeness and betweenness centrality measures. Bubble sizes represent the degree of each keyword. (i) The three clusters together. (ii, iii and iv) Cluster 1, 2 and 3 respectively.

The remaining clusters (not shown in the text) include keywords interconnected in very specific areas of study. For example, cluster 4 (140 keywords) is certainly dominated by housing-related concepts (i.e., *housing policy*, *poverty*, *social housing*, *housing conditions*, *home-ownership*, *housing affordability*, etc.) while cluster 5 (135 keywords) is dominated by *China* and Chinese urban issues, an evidence of the previously mentioned increase in papers coming from the Asian continent, and mostly led by Chinese scholars. Cluster 6 (118 keywords) refers to *sustainable development* regarding *environmental quality*, *sanitation* and *waste* in *developing countries*, while clusters 7 (74 keywords) and 8 (58 keywords) are associated with the *sociological aspects of urbanisation*, and *landscape perceptions* and *environmental psychology*, respectively.

### 3.2.5. Ego-network analysis

Finally, we complete our analysis studying the ego-networks of the most connected keywords. An ego-network consists of a focal node (ego), a set of alters who have ties to ego, and measurements on the ties from ego to alters and on the ties between alters (Wasserman & Faust, 1994). Ego-networks allow taking a closer look at the neighbour characteristics, so we can describe the variation across elements in the way they are embedded in “local” network structures. Fig. 10 shows ego-networks related to the five main Hn keywords: QoL, WB, LS, SWB and H. Subgraphs were created in NodeXL[10] and took place in five temporal snapshots, corresponding with the connection of each of the keywords to the giant component of the graph (Fig. 8). The snapshots of Fig. 10 focus on the neighbours and the neighbours of neighbours of the keywords and the connections between them. We observe a star-like structure repeated each time a keyword enters the connected component and characterised by cliques (i.e., keywords in one particular paper) randomly distributed around hubs (i.e., most connected nodes).

The temporal evolution of network indices for the ego-networks related with keywords QoL, WB, LS, SWB and H, show a striking similarity (Fig. 11). For our keywords, the rate of increase of $\langle k \rangle$ (Fig. 11, i) and $d$ (Fig. 10, ii) is similar, the only difference being the point in time when that a particular keyword makes its entrance in the field. The average increase in $\langle k \rangle$ per year is $\Delta\langle k \rangle = 0.300$, while for the diameter is $\Delta d = 0.793$. The evolution over time of the average path length $\langle d \rangle$ for QoL and WB (Fig. 11, iv) reaches a common value in logarithmic form, while the clustering coefficient $\langle C \rangle$ shows more variability, since it depends on how first neighbour keywords of keywords are linked to each other.

Finally, and in order to detect how the connectivity of the network ends up dominated by hubs, we plot the evolution over time (years 1999, 2005, 2009, 2011 and 2016) between average clustering coefficient $\langle C \rangle$ and degree $\langle k \rangle$ for the ego-networks related with keywords QoL, WB, LS, SWB and H (Fig. 12). It shows a non-linear power law correlation of the form $\langle C \rangle \sim \langle k \rangle^{-\alpha}$, where $\alpha = 1.035$ ($R^2 = 0.89$), with clustering and degree decreasing and increasing in time respectively.

## 4. Discussion

The use of complex networks science (Newman, 2010) and, particularly, the evolution of network centrality measures instead of the more classical co-frequency matrix of bibliometric analysis in this study, opens a path to a complementary and valid alternative for the study of academic fields. The particularity of our method lies in the ‘field inside field’ where we use co-word analysis to draw attention to non-obvious keywords (Kirby, 2012). During the initial analysis of the Hn we noted that the exponential increase in the cumulative number of articles and keywords (Fig. 2) follows a trend similar to those of emerging new scientific fields (Luis M. A. Bettencourt & Kaiser, 2015;

[10] http://nodexl.codeplex.com/

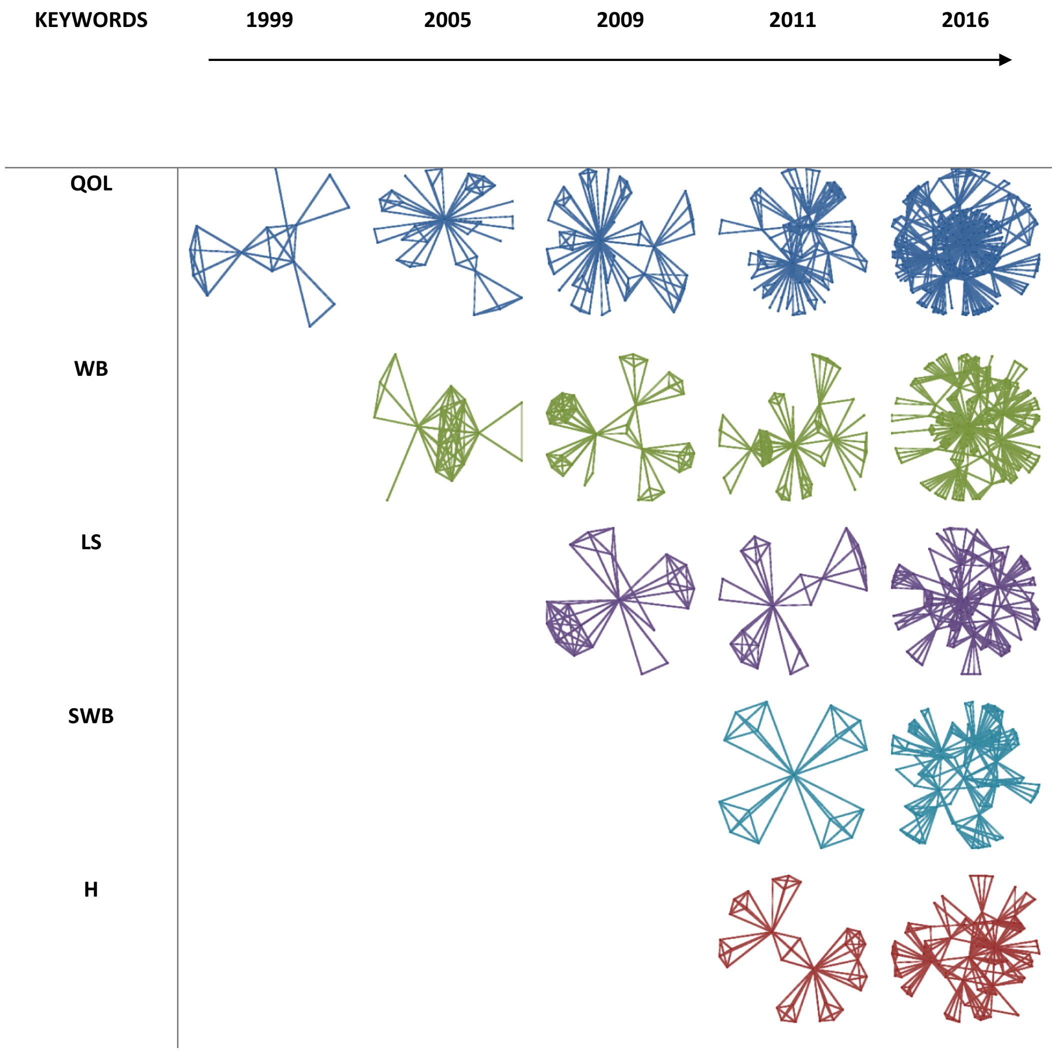


**Fig. 10.** Evolution of the UHn ego-networks of the most connected keywords of Hn. Network snapshots created in NodeXL using Harel-Koren Fast Multiscale layout (Harel & Koren, 2000).

Luis M. A. Bettencourt et al., 2009; Luís M A Bettencourt & Kaur, 2011). Both the graph diameter and the average path length grow, and eventually stabilise from year 2010 onwards (Fig. 3). The increase in $\langle k \rangle$ over time indicates that a densification process is at play. Although in other study cases the network diameter $d$ tends to decrease as a graph grows (Leskovec, Kleinberg, & Faloutsos, 2007) implying a more tightly woven connected component, in this case, Hn shows an initial fast growth in its diameter that tends to stabilise at $d \sim 6-7$. We observe the same behaviour in collaboration graphs for scientific and technological fields (Luis M. A. Bettencourt et al., 2009). Thus, even when the keyword graph densifies, it stays globally connected in a way that does not affect the diameter of its largest component. This process comes essentially from linear connections between keywords, rather than local increase in connectivity. The decreasing trend over time in $\langle C \rangle$ and the disassortative behaviour of the network supports also this feature. This behaviour deviates from other examples where the establishment of central conceptual or experimental techniques are primordial. In our case, new concepts do not need to be closely related to others to appear in the Hn graph. The homogeneity in link weights (Fig. 5, inset) imply that weighted degree and degree do not correlate: keywords connect to other keywords, but this connectivity implies no co-occurrence. In other words, the most connected keywords in Hn are used indistinctly to categorise many different parts of the field, but not univocally: these are used as plastic words with interchangeable meanings (Poerksen, 1995). Given this particular character, the capacity of keywords such as H, QoL, SWB, etc., to penetrate other fields should be significant, as it happens in general with words able to be twisted to fit various circumstances, or those with disputed definitions (Nature, 2008). This behaviour is not observed, for example, in social networks, where degree and strength (and even their probability distributions) can be highly correlated (Panzarasa, Opsahl, & Carley, 2009).

Regarding now the UHn, we observe an ever-growing network, with irregular evolution but constant increase in its structural measures (Fig. 3, ii). The network as a whole undergoes a transition in year 1998, when it reaches a minimum value for $S$ and begins to increase again in an incipient connected component. The current giant component is still growing, and it includes slightly over 80% of the nodes. This fact reveals that the field is still emerging. The increase in $\langle k \rangle$ over time indicates that a densification process is also at play. Its diameter $D$ is far from stabilising and it grows faster than its average path length $\langle d \rangle$, suggesting that as the UHn graph densifies, the distance between concepts increases further, in a process that comes essentially from linear connections between keywords, and not from an increase in local (i.e., neighbourhood) connectivity. It is the typical process of transition (also undergone by the urban studies field) from a still single discipline to a multidisciplinary one with the inter- and transdisciplinary transitions yet to come (Ramadier, 2004).

In the "urban happiness" sphere, we observe that H, LS and SWB do

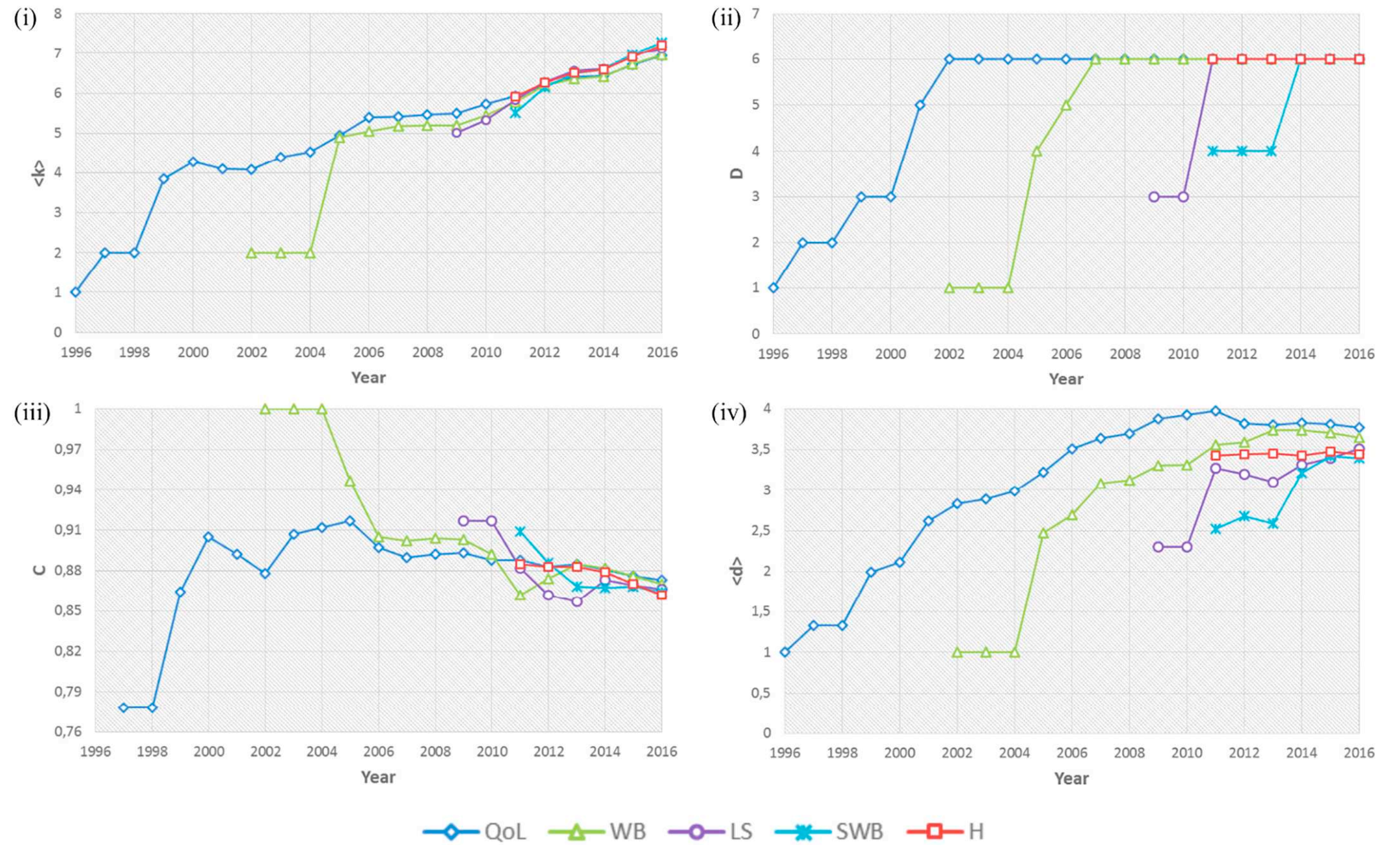


**Fig. 11.** Temporal evolution of four global network indices (i.e., average degree, diameter, average clustering coefficient and average path length) of the ego-networks related with keywords QoL, WB, LS, SWB and H.

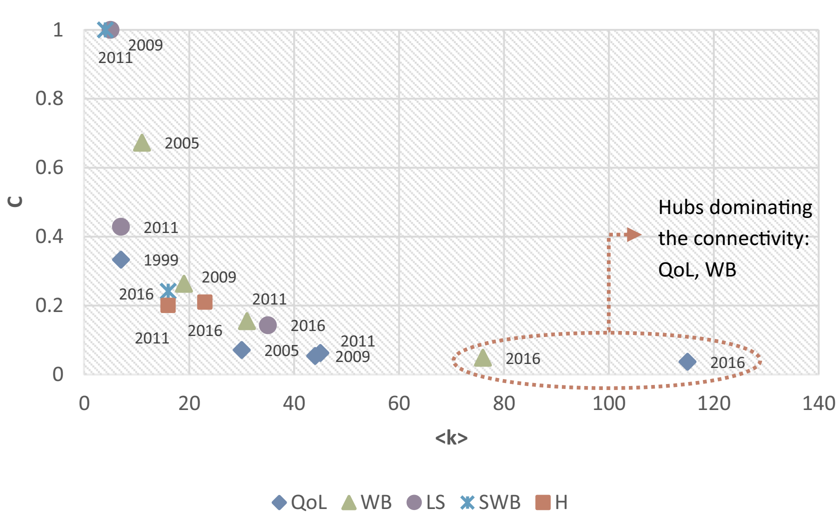


**Fig. 12.** Evolution and correlation over time between average clustering coefficient and average degree, for keywords QoL, WB, LS, SWB and H. The two most connected elements (hubs) which dominate the graph's connectivity for 2016 are QoL and WB.

not rank high. These three particular words are peripheral in the urban literature, with low connectivity and centrality measures. Given their malleable and combinable character, they might have not been yet properly defined inside the field. On the contrary, scholars prefer the use of QoL and WB keywords instead, with QoL clearly related to housing, economic development and health, and WB more related to psychosocial urban issues (Fig. 9). From the overall view of the UHn topology (Fig. 6), QoL and WB are well defined in the urban field, with ecosystem services as the in-between connecting cluster, and their common ground being environmental issues. Complementary results coming from a case by case literature review based on first publications per continent and most cited papers per decade, show that it is after year 2000 that this common ground is clarified and a distinction is made between these two concepts, with QoL associated with urban green and urban parks, and WB connected with biodiversity and eco-systems. It is also during this decade when sustainability (year 2006) and ecosystem services (year 2009) keywords enter UHn. This focus on environmental research, especially associated with ecosystem services and sustainability, comes in contrast to previous findings regarding the urban studies field (Kamalski & Kirby, 2012), where sustainability appears still as a very low ranking keyword.

Co-word analysis draws attention to non-obvious keywords for the narrower "urban happiness" studies literature (Kirby, 2012): along with expected keywords as QoL, WB and urban planning, others as health, ecosystem services, and sustainability appear also as high ranked keywords (i.e., most connected elements of Table 1) of our 'field inside field' context. Thus, we suggest the utilization of these concepts in policy debates and assessments, instead of other words with ambiguous meaning in the urban studies field as life satisfaction, subjective well-being or happiness itself.

Other new appearing keywords in the current urban debate such as urban resilience (Zhang & Li, 2018) or smart city (Fu & Zhang, 2017) are rather non-existent or with low connectivity. We assume that this fact will change in the following years, mainly because of the upcoming publications in Asia (Fig. 7) – predominantly in China – that are already showing a great interest in these subjects.

It is important to stress that the descriptive capacity of a keyword to reflect the current content of an article depends not only on the authors' free will but also on the review and publishing processes. Original keywords are sometimes modified and new ones can be added at various stages in the manuscript submission phase and until it is published.[11] One possible approach to address this issue would be to correlate the percentage of keywords created by authors against those chosen from standardized lists and/or suggested/entered by editors after the submission is accepted. The rationale behind this procedure is that a significant difference between the amount of keywords used to reflect the actual content of an article (i.e., those coming from authors) and keywords used to categorise its content into already well-stablished research spheres (i.e., those coming editors/lists) suggests which conceptual framework should be used to analyze results (i.e., a truly descriptive one or a more categorizing one). Unfortunately, on the one hand, our data structure made it impossible to obtain this information at a meaningful statistical level; on the other hand, we have not found any reference in the literature assessing this issue either.

To explain the structural evolution of the UHn, we present a simple model of a spatial network that maps spatial Euclidean distances onto categorical (i.e., conceptual) ones.[12] Spatial networks have nodes and edges that are constrained by some geometry and are usually embedded in a two- or three-dimensional space (Barthélemy, 2011). Although most research in this field has been focused in searching optimal topologies (Barrat et al., 2004; Luo, Pagani, & Rosas-Casals, 2016; Marza, Dehghan, & Akbari, 2015), our model aims at reproducing the connectivity pattern of keywords in papers, as a function of the Euclidean spatial distance that acts as the separation (i.e, virtual distance) between academic/scientific fields. The model starts with a node (known as *keyword* 0) placed at the centre of a squared two-dimensional space, linked with other nodes that act as the keywords of the same paper. At every time step $t$ a new paper is located at a randomly chosen position governed by the parameter *paper-radius* (Fig. 13). This parameter models the virtual distance between academic fields in terms of Euclidean distance between papers. In this sense, the distance among the keywords of one same paper, *kw-radius*, is inversely proportional to *paper-radius*. The higher the value of this parameter, the longer the distance between keywords of two different papers and the shorter the distance between keywords of one particular paper. The connectivity between an existing and a new appearing keyword $n_t$ at time $t$ is established with decreasing exponential probability on the Euclidean distance $d$ that separates them:

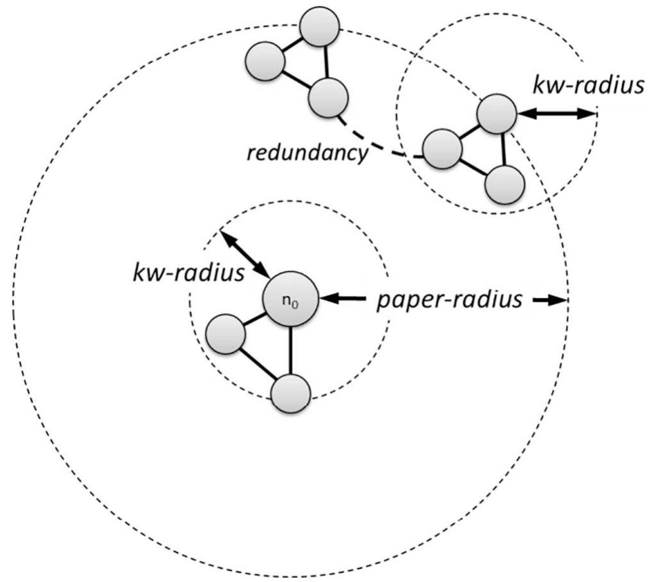


**Fig. 13.** Papers as networks of keywords. The model creates networks (i.e., papers) with nodes as keywords, and uses (a) *paper-radius* as a parameter to map a "conceptual" distance into a Euclidean one, and (b) *kw-radius* (inversely proportional to *paper-radius*) as a parameter to locate the keywords of a paper at a certain distance.

$$p(n_t, d) \sim exp(-d) \quad (8)$$

To model the fact that keywords located far-away from the central one could be more similar than expected, we introduce a second parameter known as *redundancy*: a random probability of connection between two nodes at a shorter distance than *kw-radius*.

The results of the model for two values of the parameter *paper-radius* and a *redundancy* value of 0.005 show qualitatively a transition between two kinds of networks (Fig. 14): (1) When *paper-radius* is low (*paper-radius* = 2), keywords appear in the same geographical zone, i.e., papers appear in very specific and closely related, academic fields. The average degree increases almost exponentially, while the diameter decreases over time (Fig. 14, i). (2) When *paper-radius* is high (*paper-radius* ≥ 10), keywords appear separated from each other, in different and distant geographical (i.e., conceptual) zones, i.e., papers emerge in very specific but unrelated, academic fields. The average degree is kept constant and the diameter increases over time (Fig. 13, ii). At a value of *radius-paper* = 10 (Fig. 14, ii) we obtain results that reproduce the particular evolution of the individual keywords presented in Fig. 11. We observe a linear increase in the average degree $\langle k \rangle$, and a decrease in the clustering coefficient $\langle C \rangle$. The average path length $\langle d \rangle$ approaches asymptotically a constant value, and the diameter $D$ increases suddenly and remains fixed for the rest of the experiment. Finally, with this particular combination of values, the model also reproduces the behaviour shown in Fig. 12, that is a non-linear power law correlation of the form $\langle C \rangle \sim \langle k \rangle^{-\alpha}$, where $\alpha = 1.2$ ($R^2 = 0.96$), with clustering and degree decreasing and increasing in time respectively (results not shown in the text, but replicable and shown in the model).

The robustness of the model is suggested by how well it reproduces the real temporal behaviour of the ego-network of the keyword "happiness", extracted from Hn (Fig. 15). The ego-network metrics of Fig. 15 are the same for the rest of the most connected keywords (QoL, WB, LS and SWB) of Hn, as all of them are closely connected to the giant component since the beginning of the history of the network. In this case, "happiness" appears in a field with similar concepts and short conceptual distances between keywords. We observe a trend similar to the initial states of Fig. 14 (i), where average degree, diameter and average path length slightly increase, while average clustering coefficient decreases. The differences observed between

[11] Authors are sometimes asked to choose keywords from a defined list of standardized terms, or/and keywords can also be entered by editors after the submission has been accepted.

[12] The model is implemented in NetLogo™ 6.0. The descriptive (ODD) information of the model can be found in the "Info" tab. It can be downloaded from http://tinyurl.com/ycdwpprp

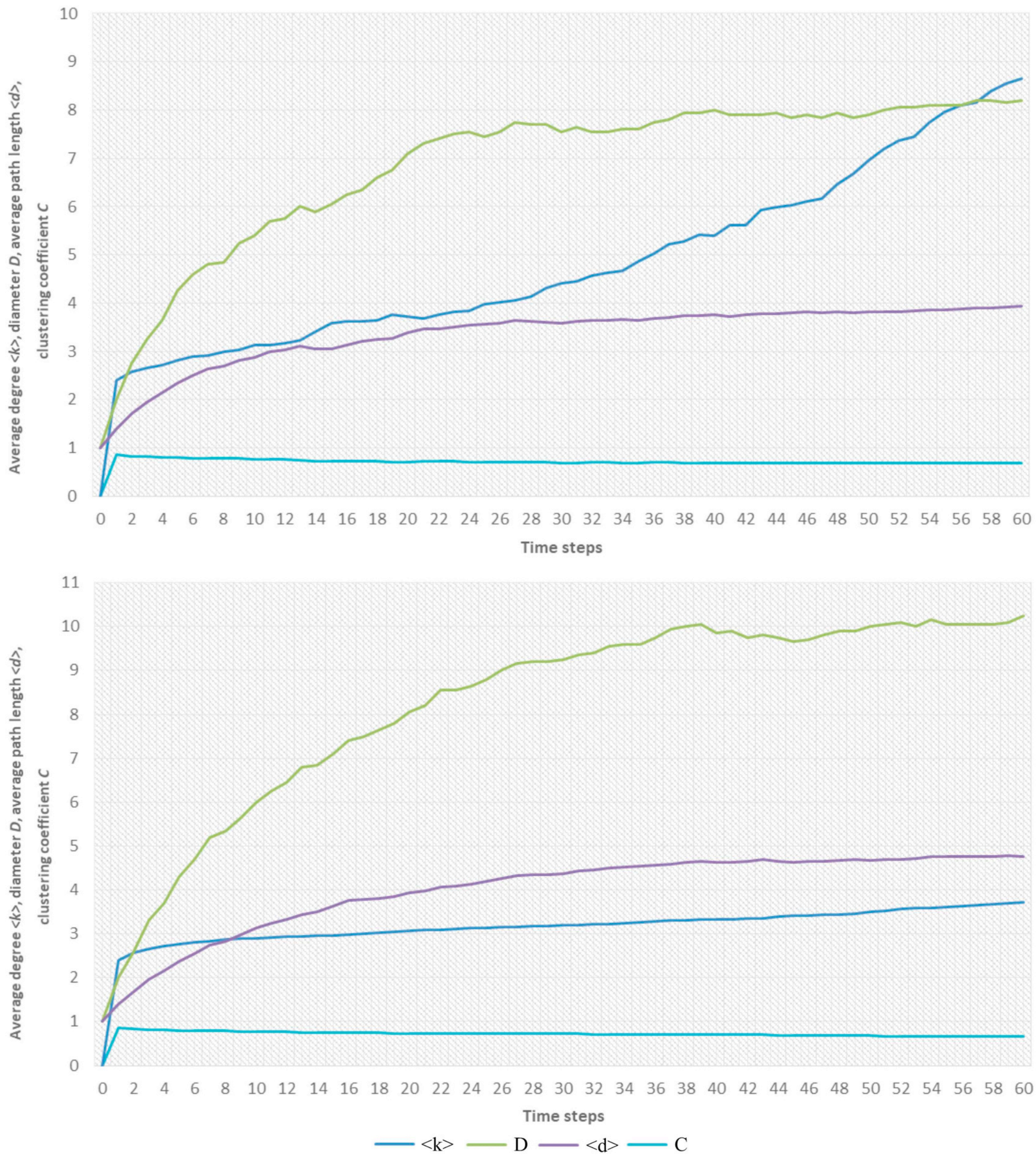


**Fig. 14.** Results for two values of the model parameter: (i) *paper-radius* = 2 and (ii) *paper-radius* = 10.

the model and the Hn are mainly concentrated in the first time steps of the model; the model starts with only one keyword (keyword 0) while the real network starts with much more keywords and connections. Some differences arise when the temporal scale of the model exceeds that of the real network: ⟨*C*⟩ is decreasing following a small pace, maintained close to 0.9 for both networks; ⟨*k*⟩ increases slowly over time after the initial quick increase in the model. *D* increases following a quicker pace than the rest of the metrics, stabilises and then slowly decreases. ⟨*d*⟩ increases slowly and starts decreasing after the 22nd step in the model.

## 5. Conclusions

Happiness field of studies has grown in importance during the past years, encompassing concepts such as quality of life, (subjective) well-being, life satisfaction and positive psychology. However, the level of penetration of this field into other fields of interest has not yet been studied. In this paper, we use co-word and complex networks analysis of scientific articles' keywords to map the temporal evolution of the fields of (i) happiness and (ii) happiness inside urban studies field. For the happiness field we show that its most connected words behave as plastic words with a global and adaptive significance: they are used indistinctly to categorise many different parts of the field. The plastic character of some of these words is reinforced in the urban field (UHn). The level of penetration of words like *life satisfaction*, *subjective well-being* and *happiness* to the urban studies field makes it difficult to connote them with a meaning in their current form. On the contrary, *quality of life* and *well-being* appear as precise words, not fitted for every context and clearly dominating significant clusters within the urban studies context.

Original keywords are usually modified and/or new ones can be added during the manuscript submission and publishing phases. Depending on this process, results from this type of analysis can be truly

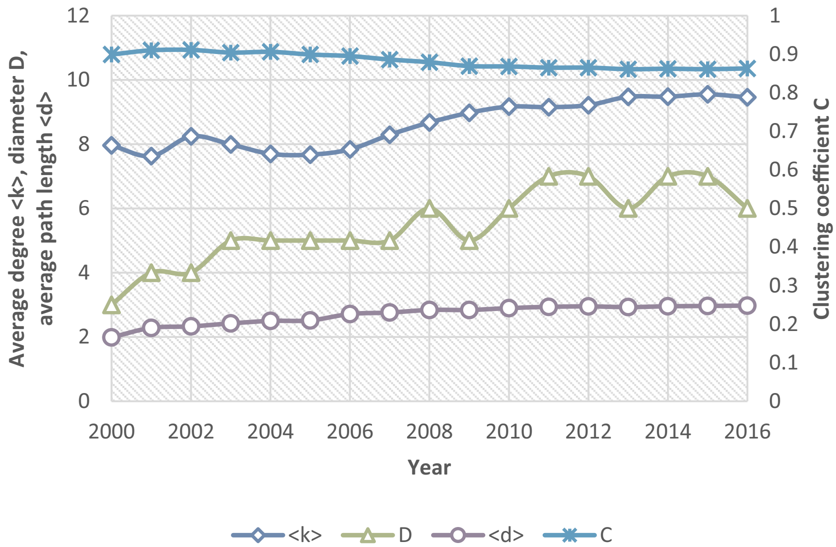


**Fig. 15.** Evolution of the H ego-network in terms of average degree ⟨k⟩, diameter D, average path length ⟨d⟩ and clustering coefficient C.

descriptive or merely categorizing ones. We suggest correlating the percentage of keywords created by authors against those chosen from standardized lists and/or suggested/entered by editors after the submission is accepted, to validate the analysis framework for the results.

In this paper, we also study the topology of the dynamic networks related with the aforementioned fields, transforming conceptual distances into Euclidean ones in a spatial network model. Despite its simplicity, the model reproduces remarkably well the growth of ego-networks and different levels of penetrations, depending on the "conceptual" distance. How in general an alien conceptual field penetrates another and, how in particular a field like happiness studies penetrates other fields as economics, ecology, etc., is a matter of future work and research.

We believe that our results and methodologies developed in the context of the happiness and urban studies keyword networks can be useful for a systematic discussion on both, the utilization and assumed meaning of these concepts, and the study of other complex evolving networks related with conceptual aspects of academic or other fields.

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## Appendix A. Journals in Urban Studies category according to 2015 classification

| Journal ID | Journal | First publication |
|---|---|---|
| 1 | Cities | 1983 |
| 2 | City and community | 2002 |
| 3 | Economic development quarterly | 1987 |
| 4 | Education and urban society | 1968 |
| 5 | Environment and urbanization | 1989 |
| 6 | EURE | 1960 |
| 7 | European planning studies | 1993 |
| 8 | European urban and regional studies | 1994 |
| 9 | Habitat international | 1976 |
| 10 | Housing policy debate | 1990 |
| 11 | Housing studies | 1986 |
| 12 | Housing theory and society | 1984 |
| 13 | International journal of urban and regional research | 1977 |
| 14 | International regional science review | 1975 |
| 15 | Journal of architectural and planning research | 1984 |
| 16 | Journal of contemporary ethnography | 1972 |
| 17 | Journal of housing and the built environment | 1986 |
| 18 | Journal of housing economics | 1991 |
| 19 | Journal of planning education and research | 1981 |
| 20 | Journal of planning literature | 1985 |
| 21 | Journal of real estate finance and economics | 1988 |
| 22 | Journal of the American planning association | 1935 |
| 23 | Journal of urban affairs | 1979 |

| | | |
|---|---|---|
| 24 | Journal of urban economics | 1974 |
| 25 | Journal of urban history | 1974 |
| 26 | Journal of urban planning and development | 1956 |
| 27 | Journal of urban technology | 1992 |
| 28 | Landscape and urban planning | 1974 |
| 29 | Open house international | 1976 |
| 30 | Real estate economics | 1973 |
| 31 | Regional science and urban economics | 1971 |
| 32 | Urban affairs review | 1965 |
| 33 | Urban design international | 1996 |
| 34 | Urban education | 1965 |
| 35 | Urban forestry and urban greening | 2002 |
| 36 | Urban geography | 1980 |
| 37 | Urban lawyer | 1969 |
| 38 | Urban policy and research | 1982 |
| 39 | Urban studies | 1964 |

## Appendix B

NetLogo* implementation of the model: http://tinyurl.com/ycdwpprp

(*) U. Wilensky, "NetLogo." Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL., 1999.

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