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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Definitions and recent trends in circular cities

ITU-T L-series Recommendations – Supplement 46

ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

OPTICAL FIBRE CABLES	
Cable structure and characteristics	L.100–L.124
Cable evaluation	L.125–L.149
Guidance and installation technique	L.150–L.199
OPTICAL INFRASTRUCTURES	
Infrastructure including node elements (except cables)	L.200–L.249
General aspects and network design	L.250–L.299
MAINTENANCE AND OPERATION	
Optical fibre cable maintenance	L.300–L.329
Infrastructure maintenance	L.330–L.349
Operation support and infrastructure management	L.350–L.379
Disaster management	L.380–L.399
PASSIVE OPTICAL DEVICES	L.400–L.429
MARINIZED TERRESTRIAL CABLES	L.430–L.449
E-WASTE AND CIRCULAR ECONOMY	L.1000–L.1199
POWER FEEDING AND ENERGY STORAGE	L.1200–L.1299
ENERGY EFFICIENCY, SMART ENERGY AND GREEN DATA CENTRES	L.1300–L.1399
ASSESSMENT METHODOLOGIES OF ICTS AND CO2 TRAJECTORIES	L.1400–L.1499
ADAPTATION TO CLIMATE CHANGE	L.1500–L.1599
LOW COST SUSTAINABLE INFRASTRUCTURE	L.1700–L.1799

For further details, please refer to the list of ITU-T Recommendations.

Supplement 46 to ITU-T L-series Recommendations

Definitions and recent trends in circular cities

Summary

Supplement 46 to the ITU-T L-series Recommendations aims to provide the definition and conceptualization of the circular city, identify the terminology that deals with circular city, define these terms and uncover the recent trends of circular cities, based on the systematic literature review and bibliometric analysis. Circularity in cities appear to be more than the sum of the multiplication of urban circular economies and has increasingly become the subject of policy innovations, urban strategies, and research and development agendas. However, the concept of circular city and the terminology that deals with it remains unclear, regardless of the emerging scientific and political attention that it gains.

The main elements examined in this Supplement are:

– The definition of circular cities;

– The determination of a conceptual architecture of circular cities;

– The identification of recent trends in a circular city.

History

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Table of Contents

Introduction

This Supplement 46 to the ITU-T L-series Recommendations aims to uncover the terminology that is created together with the circular city, which is a matter of research trends and industrial growth. However, since this definition must be associated with a vocabulary of terms that clarify the term. In this regard, this Supplement performs a bibliometric analysis in scientific repositories and collects the keywords, their timeline emergence and the association between the terms, and also provides the definitions of these terms.

Although there is no clear definition for circular cities, circularity in cities appears to be more than the sum of multiplication of urban circular economies and it is increasingly the subject of policy innovations, urban strategies, and research and development agendas. According to existing approaches, a circular city is meant to increase the efficiency and effectiveness of its assets and products by extending either its own or its constituents/components utilization and life span. This approach grounds the circular city as the city that utilizes its assets (infrastructure, resources, goods, and services) as inputs for circular action (sharing, recycling, refurbishing, reusing, replacing, and digitizing) and generates corresponding circular outputs (i.e., purified, and reused water) ecosystem, which associates the city assets with circular activities and generated outputs and in this respect, the circular city is defined in this Supplement as *the city that utilizes its assets (infrastructure, resources, goods, and services) as inputs for circular action (sharing, recycling, refurbishing, reusing, replacing, and digitizing) and generates corresponding circular outputs (i.e., purified, and reused water).*

Supplement 46 to ITU-T L-series Recommendations

Definitions and recent trends in circular cities

1 Scope

This Supplement defines circular cities and determines the terminologies that deal with it. It provides clear definitions and conceptualizations of circular cities and the definitions of the corresponding keywords/entities/topics that are associated with circularity in cities.

A recent bibliometric analysis uncovered some of this terminology:

Circular city; circular economy; modelling; spatial competition; commuting costs; land use; agglomeration; spatial differentiation; location choice; etc.

Moreover, a recent bibliometric analysis showed some of the recent trends that must be confirmed and analysed deeper. Urban heat mitigation, spatial competition agglomeration, circular city horizontal product differentiation, cultural heritage and local interactions are only some of these trends that can help industry and policy makers define their strategies to align to the ones that relate with their cases. Trends are highlighted with literature review and bibliometric analysis on scientific repositories (i.e., Web of Science and Scopus).

This Supplement is expected to help cities identify the context of circularity and the trends for improving sustainability and achieving the Sustainable Development Goal 11 and the related targets.

The main elements examined in this Supplement are:

1) The definition of circular cities
2) The determination of a conceptual architecture of circular cities
3) The identification of recent trends in circular cities.

2 References

[ITU-T L.1020] Recommendation ITU-L.1020 (2018), *Circular economy: Guide for operators and suppliers on approaches to migrate towards circular ICT goods and networks*.

[ITU-T L.1022] Recommendation ITU-L.1022 (2019), *Circular economy: Definitions and concepts for material efficiency for information and communication technology*.

[ITU-T L.1023] Recommendation ITU-L.1023 (2020), *Assessment method for circular scoring*.

[ITU-T Y.4900] Recommendation ITU-T Y.4900/L.1600 (2016), *Overview of key performance indicators in smart sustainable cities*.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 circular economy [ITU-T L.1023]: An economy closing the loop between different life cycles through design and corporate actions/practices that enable recycling and reuse in order to use raw materials, goods, and waste in a more efficient way. The circular economy concept distinguishes between technical and biological cycles; the circular economy is a continuous, positive development

cycle. It preserves and enhances natural capital, optimises resource yields, and minimizes system risks by managing finite stocks and renewable flows, while reducing waste streams.

NOTE – Definition adapted from [ITU-T L.1023], [ITU-T L.1022] and [ITU-T L.1020].

3.1.2 circular economy in cities [b-U4SSC]: Circular economy in cities aims to create a sustainable system that allows for the optimal use of city assets and products through re-using, refurbishing, remanufacturing, and recycling and other circular actions.

3.1.3 smart sustainable cities [ITU-T Y.4900]: A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, the efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects.

3.2 Terms defined in this Supplement

This Supplement defines the following terms:

3.2.1 agglomeration: Principle of deontic logic, if one ought to do A and ought to do B, then one ought to do both A and B.

3.2.2 circular city: A city that utilizes its assets (infrastructure, resources, goods, and services) as inputs for circular action (sharing, recycling, refurbishing, re-using, replacing, and digitizing) and generates corresponding circular outputs (i.e., purified and reused water).

3.2.3 commuting costs: Travel costs for a trip between home and work. Cost for periodically recurring travel between one's place of residence and place of work or study, where the traveler leaves the boundary of their home community.

NOTE – Definition derived from [b-DictionaryCom].

3.2.4 economic planning: Economic planning is a resource allocation mechanism based on a computational procedure for solving a constrained maximization problem with an iterative process for obtaining its solution. The plan sets out quantitative targets for industries, but without either inducement or direction. The point of such a plan is to preconcert economic activity.

NOTE – Definition derived from [b-Vohra 2008], [b-McCain 1985].

3.2.5 horizontal product differentiation: Markets where a large number of product versions are available, and sellers' marginal costs and buyers' valuations are uncorrelated.

NOTE – Definition derived from [b-Momsen 2021].

3.2.6 land use: Alternative uses of land. They can be classified into clusters like grasslands, shrublands, olive groves, agricultural, residential, riverine, outcrops.

NOTE – Definition derived from [b-Kazaklis 1993].

3.2.7 location choice: Residential location choice is a fundamental process determining real-estate dynamics, regional development, and spatiotemporal traffic flows.

NOTE – Definition derived from [b-Bekhor 2021].

3.2.8 local interactions: On traditional markets, customers usually communicate their purchase experience to their neighborhood. Moore neighborhood is usually applied to structure this neighborhood in cellular automata, which is defined on a two-dimensional square lattice and is composed of a central cell and the eight cells that surround it.

NOTE – Definition derived from [b-Leloup 2003].

3.2.9 pollution problem: The action or process of making land, water, air, etc., dirty and not safe or suitable to use; the action of polluting especially by environmental contamination with man-made waste.

NOTE – Definition derived from [b-Webster 2021]

3.2.10 spatial competition: Spatial competition arises from the fact that nearby firms in the same industry are generally competing against each other more than against distant ones; consumer preference for particular locations (adopted from location or spatial model definition).

NOTE – Definition derived from [b-Hunold 2019], [b-Hotelling 1929]

3.2.11 travel distance: The distance that must be covered by a subject with the use of alternative transportation options. It is calculated with alternative indexes (i.e., walking access index, cycling accessibility index, public transportation accessibility index (PTAI).

NOTE – Definition derived from [b-Saghapour 2019].

3.2.12 urban agglomeration: Urban clusters or the formation of a truly evolved and integrated new urban spatial organization.

NOTE – Definition derived from [b-Fang 2017].

3.2.13 urban heat island: An urban heat island (UHI) is an area of the surface that is relatively warm; most associated with areas of human disturbance such as towns and cities [b-Meteorology 2020]; it is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities.

NOTE – Definition derived from [b-Li 2012], [b-Santamouris 2014].

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

BA Bibliometric Analysis

MCA Multiple Correspondence Analysis

PTAI Public Transportation Accessibility Index

UHI Urban Heat Island

5 Conventions

None.

6 Circular city

There is no clear definition for a circular city. According to [b-U4SSC], which attempts to identify a list of city assets and products that would broaden the circularity concept beyond the economy to include different aspects of city management. Hence the term 'circular' cities, a "circular city" is meant to increase the efficiency and effectiveness of its assets and products by extending either their own or their constituents'/components' utilization and life span.

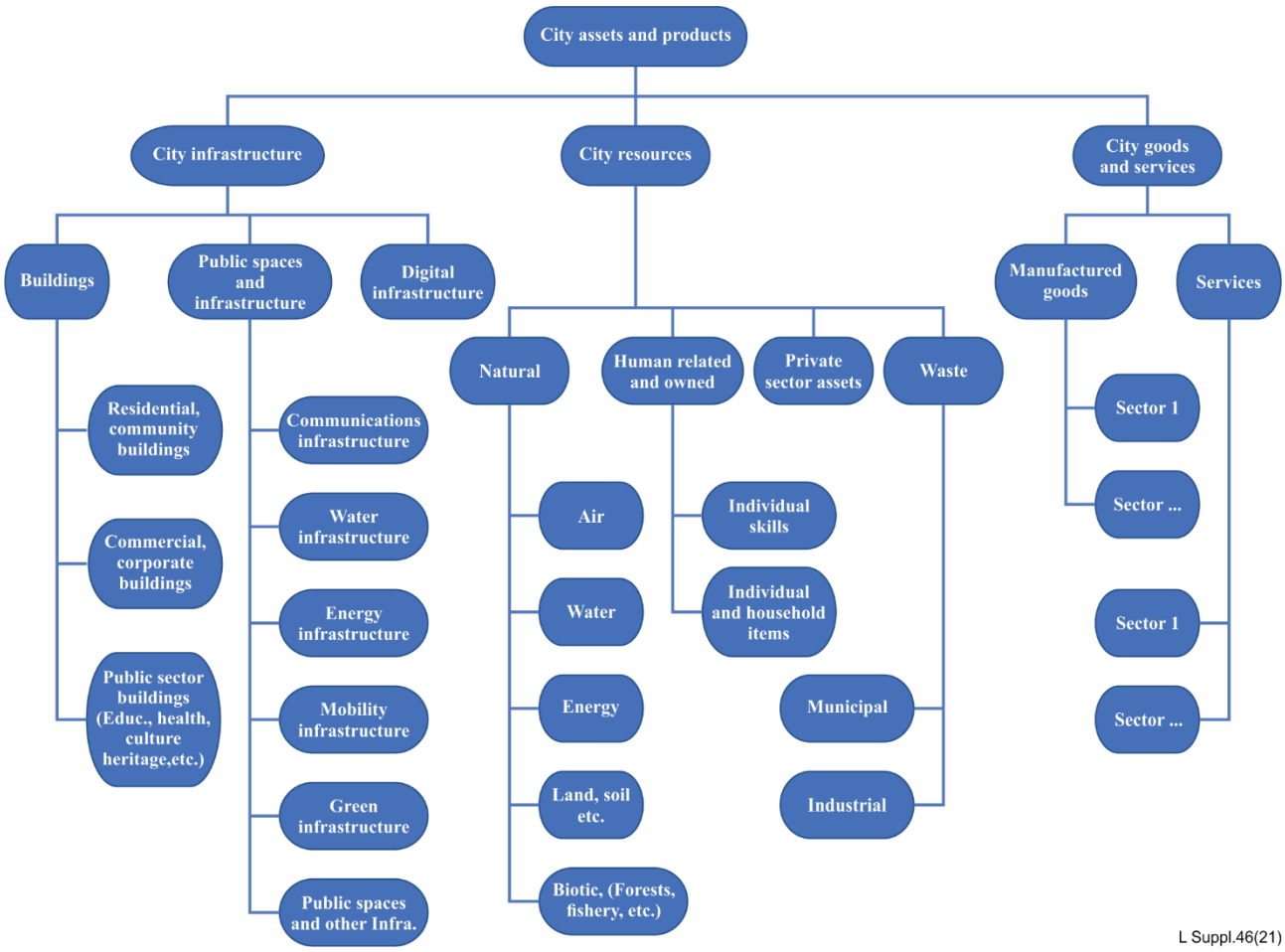

Figure 1 – City assets and products [b-U4SSC]

In Figure 1, buildings, public spaces and infrastructure, and digital infrastructure can be seen as *city assets*, while environmental, human related and owned resources, private sector assets and its waste can be considered as city resources. Moreover, *city goods* are seen being manufactured by the city resources and infrastructure, and *city services* are being offered by the same resources and its infrastructure. Lastly, sharing, recycling, refurbishing, re-using, replacing, and digitising activities that transform the production of city goods and services from linear to circular processes come under *city circular actions*. In this respect, this Supplement defines a circular city as *the city that utilizes its assets (infrastructure, resources, goods, and services) as inputs for circular action (sharing, recycling, refurbishing, re-using, replacing, and digitizing) and generates corresponding circular outputs (i.e., purified, and reused water).*

Today, an interrelation between a circular city and a smart city appears to be growing [b-D'Amico 2022], since the integration of digital technologies in mobility, waste, water and wastewater management, energy efficiency, safety, and so on, represents a crucial aspect for cities involved in the circularity of their urban metabolism. Moreover, digital infrastructures such as real-time monitoring stations, GPS tracking sensors, augmented reality, virtual sharing platforms, social media dashboards, smart grids, and the like in the development and strengthening of the quality and efficiency of the circularity of resources [b-D'Amico 2022]. Under these lenses a conceptual architecture of a circular city can consist of the following components, see Figure 2:

1) City assets (infrastructure, open spaces, private infrastructure)
2) City smart assets
3) City resources
4) City goods

5) City services

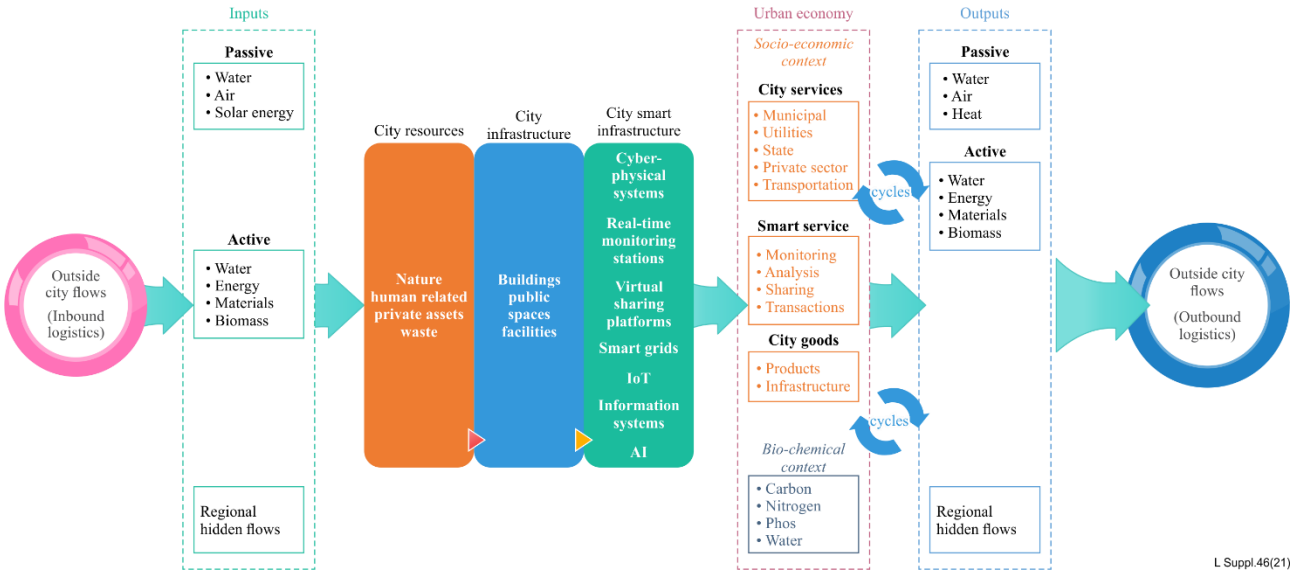

Figure 2 – Circular city conceptual architecture

The circular city conceptual architecture has been based on and has combined features from both the urban metabolism (UM) framework [b-European Commission 2020] and the circular city's concept [b-U4SSC]. It aims to combine circular and smart features in order to minimize / eliminate produced waste (transforms them into goods and materials) and to maximize efficiency.

The above analysis shows that a circular city goes beyond the sum of circular economic activities within the city. It can be seen as a city that promotes the transition from a linear to a circular economy in an integrated way across all its functions in collaboration with citizens, businesses and the research community.

Thus, a circular city is highly related to the circular economy whose definition has been given by [ITU-T L.1023] as *the economy closing the loop between different life cycles through design and corporate actions/practices that enable recycling and reuse in order to use raw materials, goods and waste in a more efficient way. The circular economy concept distinguishes between technical and biological cycles, and it is a continuous, positive development cycle. It preserves and enhances natural capital, optimises resource yields, and minimizes system risks by managing finite stocks and renewable flows, while reducing waste streams.*

Some corresponding definitions were collected by [b-U4SSC] as follows:

– A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extracting the maximum value from them whilst in use, then recovering and reusing products and materials.

– Circular economy is 'an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals which impairs re-use and aims for the elimination of waste through the superior design of materials, products, systems and within their business models. The overall objective is to 'enable effective flows of materials, energy, labour and information so that natural and social capital can be rebuilt'.

– The circular economy is an economy 'where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimised'.

7 Circular city trends

To give a definition to a circular city the above approach highlighted a connection with the circular economy. Nevertheless, it is important to justify the definition in depth whether this connection is valid to uncover interrelations with other terms and concepts. Moreover, it is important to also uncover associated trends of a circular city. The following clauses attempts to provide answers to these concerns.

7.1 Methodology

This Supplement uses the bibliometric analysis (BA) methodology. BA focuses on the statistical analysis of scientific literature published in a specific subject area and classifies information into specific variables such as scientific journals, academic institutions, authors, and countries. BA is an important tool for the quantitative evaluation and analysis of published scientific literature. It is useful for classifying and providing an overview of the literature, through the visualization and quantification of the evolution of specific thematic areas [b-Anthopoulos 2021].

A scientific topic grows through science and its findings and research is seen in several academic publications. When the number of these academic publications emerges, it is hard to keep track of them. This prevents the accumulation of knowledge and the collection of data from previous research work. Therefore, literature reviews play a crucial role of synthesizing previous research findings to effectively use the existing knowledge base and promote new research. Researchers use qualitative and quantitative literature review approaches to understand and organize previous findings. Among these approaches, BA introduces a systematic, transparent, and reproducible process based on statistical analysis of science, scientists, or the scientific activity of a particular field. Unlike other methodologies, BA provides more objective and reliable analyses. It enables a structured analysis of a large body of information, identifies trends over time, topics researched and the most productive scholars and institutions and presents the big picture of the existing research. To facilitate BA, the bibliometrix R-tool is used, which is an open-source tool for quantitative research and includes all the main bibliometric methods of analysis. The analysis is conducted in R Studio using the R language [b-Anthopoulos 2021].

7.2 Results

To find the main bibliography of the research fields, many trial searches have been performed on Scopus, and Web of Science (WoS). The keywords that were used are:

"Circular city"

The collection of data about corresponding publications was performed in May 2021, and provided the following record:

– Scopus: 165 results
– Web of Science: 106 results

To filter results, inclusion and exclusion criteria are applied to the literature collections of both databases.

Inclusion criteria:

– Articles in scientific journals (articles)
– Conference papers
– Reviews
– Book chapters

Exclusion criteria:

– Conference reviews

– Documents not written in English

The raw data are extracted from Scopus and WoS as BibTeX files, which are suitable for bibliographic analysis as they include all the basic information, such as title, author names, summary, keywords, and references.

The BibTeX files collected from each literature are loaded to the R Studio with the bibliometrix R-tool. Two bibliographic data-frames for each literature collection are created with document records and bibliographic metadata, such as author names, titles, keywords, and other information. The two data-frames are merged and the duplicate documents in both databases are removed from the results [b-Anthopoulos 2021].

To summarize the main results, a table with the most important information is created including details such as the annual scientific production, the most important articles by the number of citations, the most productive authors, the most productive countries, the number of citations per country, the most relevant sources, and the most relevant keywords. In addition, various co-authorship indicators also appear. The author collaboration index is calculated as the total number of articles per the total number of authors' ratio. The co-authors per document index is calculated as the average number of co-authors per article. The collaboration index is calculated as the ratio of the total number of authors of multiple articles and the total number of articles of multiple authors [b-Anthopoulos 2021].

The primary outcome of this analysis shows the top keywords which can demonstrate the background terminology and the emerging trends of the examined domain (circular city). The word cloud given in Figure 3 shows that a circular city indeed emerges quite at the same level of circular economy, and it is highly associated with "economic planning". While "operations research", "calculus of variations" and "modelling" are more likely to concern research methods.

However, some interesting concepts appear together with circular city: "spatial competition", "agglomeration", "travel distance", "pollution problem" and "local interactions" are some examples while "location choice", "horizontal product differentiation", "land use", "commuting costs", "local interactions" appear to grow. The rest of the words are more likely to concern research methods (i.e., excess entry theorem).

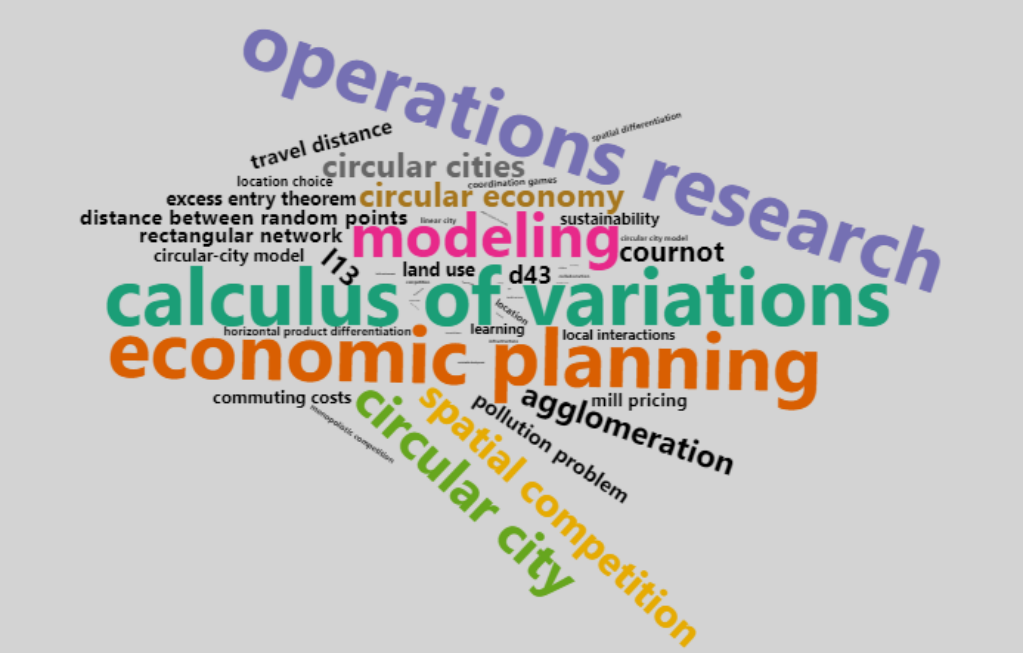

Figure 3 – Top keywords uncovered from the examined pool of articles

To define the terms, a literature review was performed, and the following definitions were collected:

– Economic planning: Economic planning is a resource allocation mechanism based on a computational procedure for solving a constrained maximization problem with an iterative process for obtaining its solution [b-Vohra 2008]. The plan sets out quantitative targets for industries, but without either inducement or direction. The point of such a plan is to preconcert economic activity [b-McCain 1985].

– Agglomeration: Principle of deontic logic, if one ought to do A and ought to do B, then one ought to do both A and B.

– Urban agglomeration: Urban clusters or the formation of a truly evolved and integrated new urban spatial organization [b-Fang 2017].

– Spatial competition: Spatial competition arises from the fact that nearby firms in the same industry are generally competing against each other more than against distant ones [b-Hunold 2019], consumer preference for particular locations (adopted from location or spatial model definition [b-Hotelling 1929]).

– Travel distance: The distance that must be covered by a subject with the use of alternative transportation options. It is calculated with alternative indexes (i.e., walking access index, cycling accessibility index, public transportation accessibility index (PTAI) [b-Saghapour 2019].

– Pollution problem: The action or process of making land, water, air, etc., dirty and not safe or suitable to use; the action of polluting especially by environmental contamination with man-made waste [b-Webster 2021].

– Local interactions: In traditional markets, customers usually communicate their purchase experience to their neighbourhood. 'Moore neighborhood' is usually applied to structure this neighbourhood in cellular automata, which is defined on a two-dimensional square lattice and is composed of a central cell and the eight cells that surround it [b-Leloup 2003].

– Location choice: Residential location choice is a fundamental process determining real-estate dynamics, regional development, and spatiotemporal traffic flows [b-Bekhor 2021].

– Horizontal product differentiation: Markets where a large number of product versions are available and sellers' marginal costs and buyers' valuations are uncorrelated. [b-Momsen 2021].

– Land use: Alternative uses of land. They can be classified into clusters like grasslands, shrublands, olive groves, agricultural, residential, riverine, outcrops [b-Kazaklis 1993].

– Commuting costs: Travel costs for a trip between home and work. Cost for periodically recurring travel between one's place of residence and place of work or study, where the traveler leaves the boundary of their home community [b-DictionaryCom].

– Urban heat island: An urban heat island (UHI) an area of the surface that is relatively warm; mostly associated with areas of human disturbance such as towns and cities [b-Meteorology 2020]; it is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities [b-Li 2012, b-Santamouris 2014].

7.2.1 Bibliographic networks

One of the most important techniques of BA is the network analysis. Various approaches have been developed using different methods, such as co-word analysis which uses the most important words or keywords in articles to study the conceptual structure of a research field. This method uses the actual content of the articles to create a measure of similarity. Co-word analysis produces semantic maps of a research field that facilitate its understanding [b-Anthopoulos 2021].

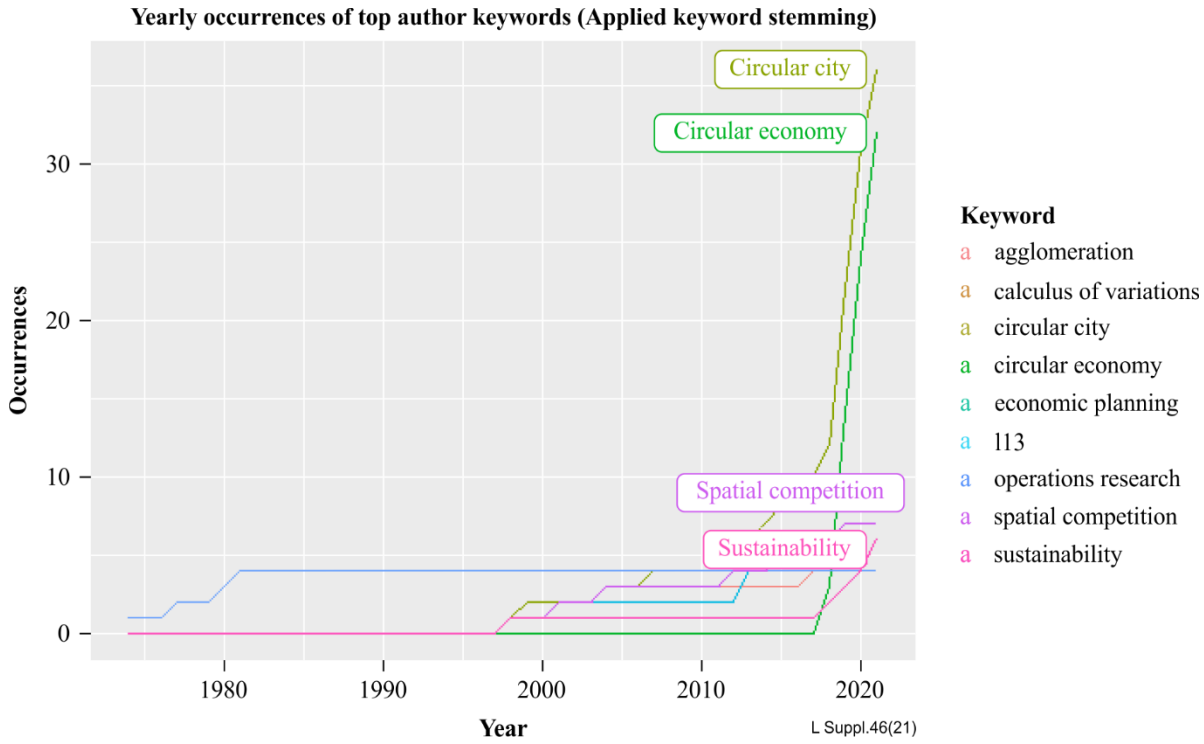

Figure 4 – Cumulative occurrences of top author keywords

To create networks, the properties of an article are linked together (e.g., author to journal, keywords to publication date). These links can be represented by a document × attribute matrix. An attribute of an article is the information associated with the article (e.g., authors, journal, keywords, citations). The connections of characteristics create a bipartite document × attribute networks that can be represented as two-dimensional networks. Various matrices can be computed such as document × citation, document × author, document × country, document × authors' keyword [b-Anthopoulos 2021].

The evidence shown in Figure 4 shows that the term "sustainability" is used frequently since the beginning of the collection, while the term "spatial competition" appears in 2000 and has been consistently frequent since then. It is noteworthy that in the literature, the terms "circular city" and "circular economy" appeared together approximately in 1995 and emerged together since then, a fact that describes the interaction of these knowledge areas.

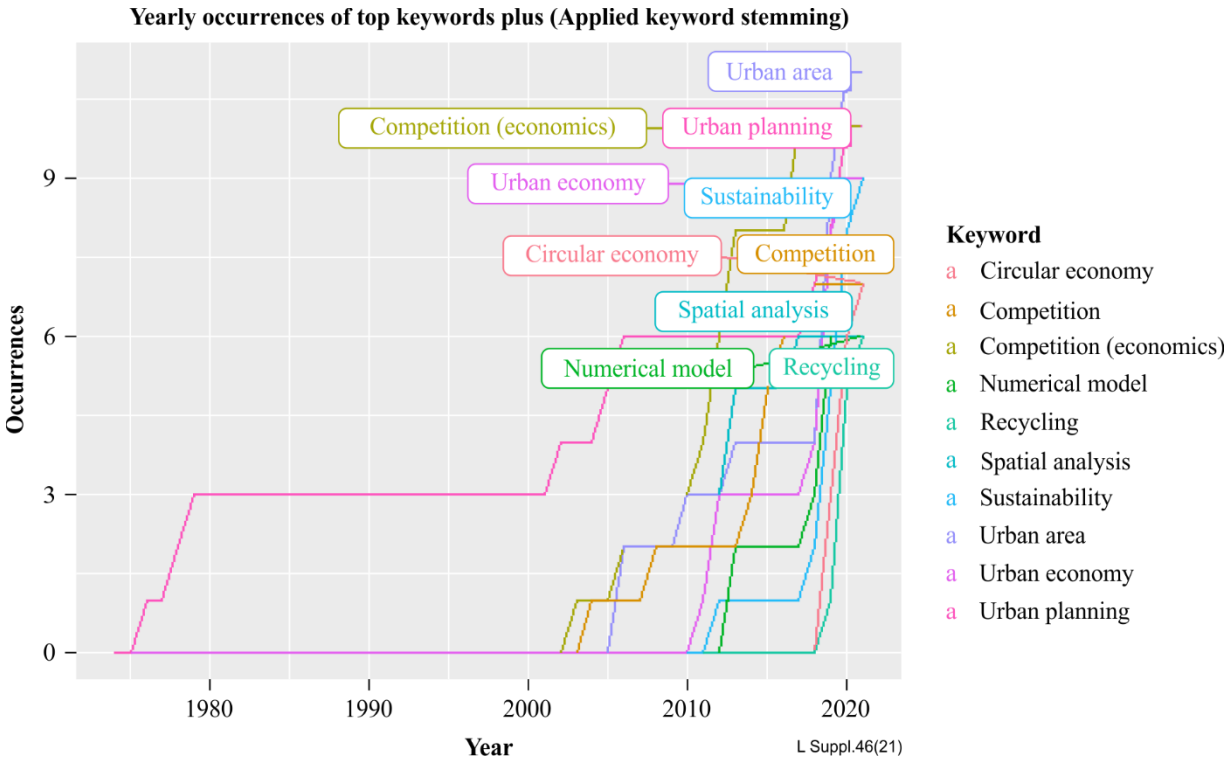

Figure 5 – Cumulative occurrences of top keywords

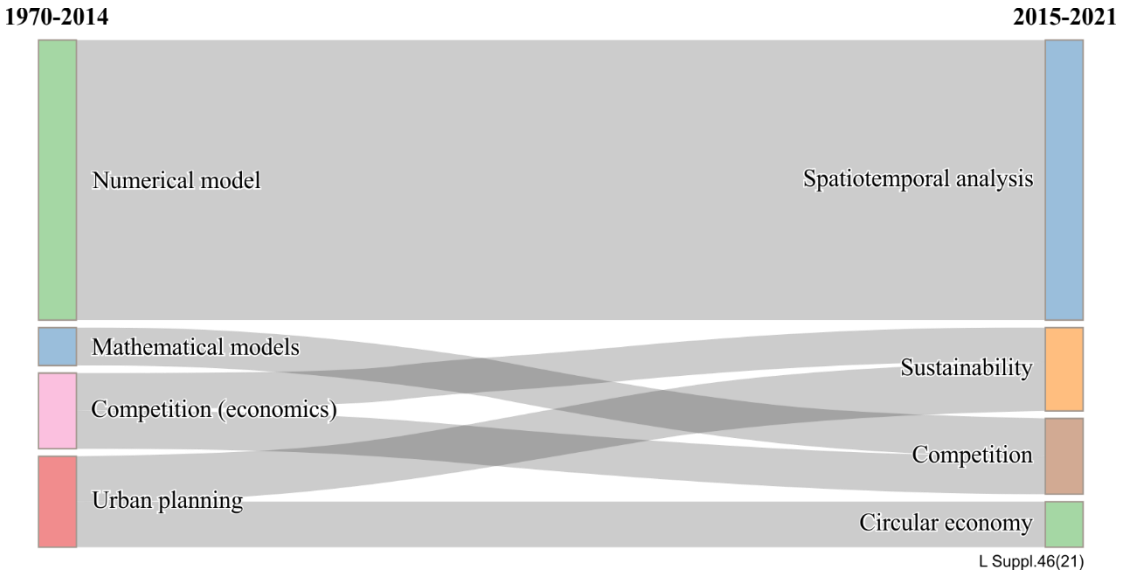

Figure 6 – How top keywords cumulative occurrence emerged in time

The evidence in Figure 5 shows a pool of terms that are associated with circular economy. Some of these terms ("urban planning" and "urban economy") started appearing from the beginning of the existence of this collection (before 1980). However, associated terms like "recycling" and "spatial analysis" are quite recent (appeared after 2010) together with the term "sustainability". A deeper analysis of this terminology evolution is depicted in Figure 6, which shows that "urban planning" emerged with topics related to "sustainability" and "circular economy", while the rest of the keywords are more likely to concern research methodologies that are applied on the investigated domains.

7.2.2 Thematic map

Co-word analysis creates keyword clusters, which are considered as themes. It is performed using a word co-occurrence network to map and cluster terms extracted from keywords. The network can be

obtained from a document × keyword matrix. Each cluster is considered as a theme with two parameters, density and centrality. The clusters can be used to classify topics and maps them into a two-dimensional diagram named a strategic diagram, where the x-axis denotes the centrality and the y-axis is the density. The themes are classified as: motor themes in the upper-right quadrant, highly developed and isolated themes in the upper-left quadrant, emerging or declining themes in the lower-left quadrant, and basic or transversal themes in the lower-right quadrant [b-Anthopoulos 2021].

The factorial analysis creates the conceptual map of a scientific field by performing multiple correspondence analysis and clustering of words or a summary of the articles included in a bibliographic collection. The bibliometrix R-tool performs multiple correspondence analysis (MCA) to draw a conceptual structure of the field and K-means clustering to identify clusters of documents that express common concepts. In co-word analysis, MCA is applied to a document × keyword matrix and the keywords are plotted on a two-dimensional map. The results are interpreted based on the relative positions of the points [b-Anthopoulos 2021].

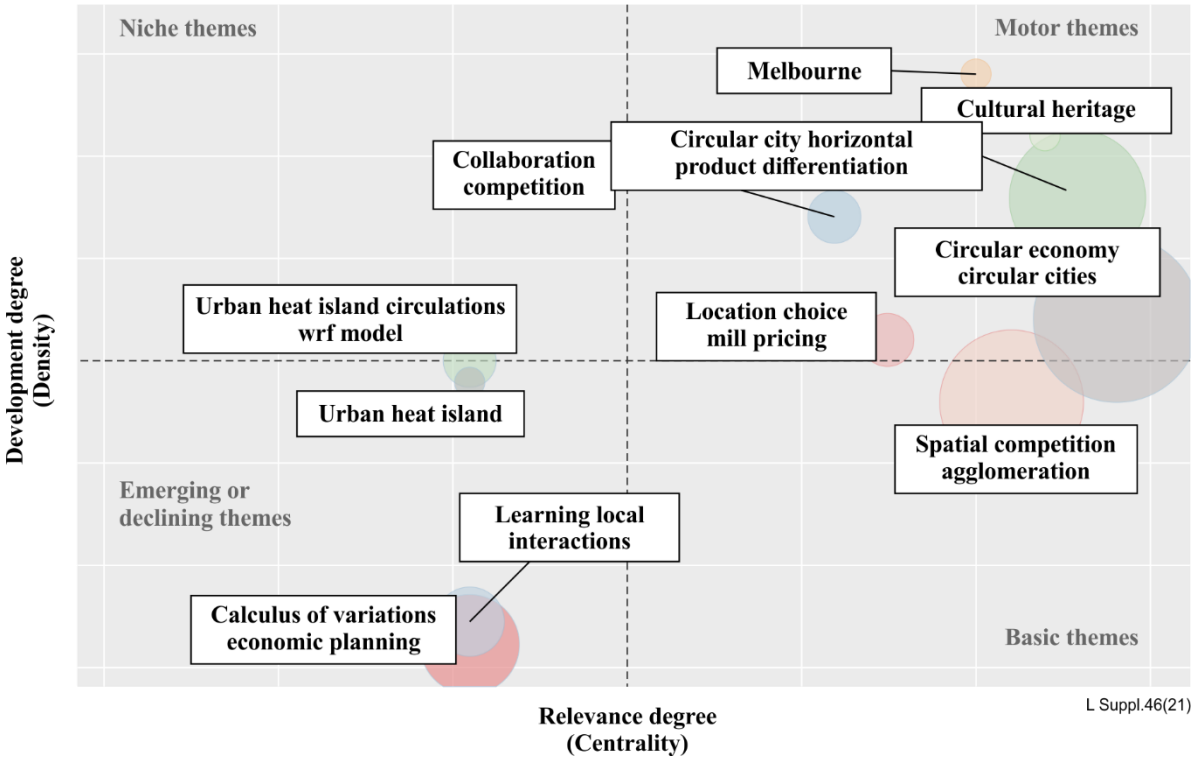

Figure 7 – Thematic map of a literature collection

The co-word analysis creates a thematic map given in Figure 7, which reveals that the largest clusters are in the areas of "circular economy, circular cities", "spatial competition agglomeration" and "circular city horizontal product differentiation", which are in the upper right and lower-right quadrant of the basic themes. The upper-right quadrant also includes the cluster with the areas "cultural heritage" and "location choice mill pricing" as well.

The rest of the findings are presented in the Appendix I, and they mostly concern demographics (i.e., top articles, top authors, etc.), which can be used in future studies.

Appendix I

Second level bibliometric outcomes

The second level biometric outcomes are depicted in Tables I.1 to I.5 and Figures I.1 to I.6.

Table I.1 – Collection analysis

DESCRIPTION	RESULTS
MAIN INFORMATION ABOUT DATA	
TIMESPAN	1970: 2021
SOURCES (JOURNALS, BOOKS, ETC.)	102
DOCUMENTS	164
AVERAGE YEARS FROM PUBLICATION	12.5
AVERAGE CITATIONS PER DOCUMENT	10.46
AVERAGE CITATIONS PER YEAR / PER DOC	1.23
REFERENCES	5356
DOCUMENT TYPES	
ARTICLES	134
BOOK CHAPTERS	5
CONFERENCE PAPERS	14
CONFERENCE REVIEWS	1
EDITORIALS	1
ERRATA	2
NOTES	1
REVIEWS	6
DOCUMENT CONTENTS	
KEYWORDS PLUS (ID)	603
AUTHOR'S KEYWORDS (DE)	462
AUTHORS	286
AUTHOR APPEARANCES	389
AUTHORS OF SINGLE-AUTHORED DOCUMENTS	45
AUTHORS OF MULTI-AUTHORED DOCUMENTS	241
AUTHORS COLLABORATION	
SINGLE-AUTHORED DOCUMENTS	53
DOCUMENTS PER AUTHOR	0.573
AUTHORS PER DOCUMENT	1.74
CO-AUTHORS PER DOCUMENTS	2.37
COLLABORATION INDEX	2.17

Table I.2 – Collection sources

SOURCES	ARTICLES
SUSTAINABILITY (SWITZERLAND)	11
ECONOMICS BULLETIN	8
ECONOMICS LETTERS	6
ANNALS OF REGIONAL SCIENCE	5
JOURNAL OF URBAN ECONOMICS	5
SUSTAINABILITY	5
INTERNATIONAL JOURNAL OF INDUSTRIAL ORGANIZATION	4
REGIONAL SCIENCE AND URBAN ECONOMICS	4
BUILDING AND ENVIRONMENT	3
JOURNAL OF ECONOMIC THEORY	3
JOURNAL OF OPTIMIZATION THEORY AND APPLICATIONS	3
PAPERS IN REGIONAL SCIENCE	3
SUSTAINABLE CITIES AND SOCIETY	3
TRANSPORTATION RESEARCH	3
AESTIMUM	2
B.E. JOURNAL OF ECONOMIC ANALYSIS AND POLICY	2
ENVIRONMETRICS	2
GEOGRAPHICAL ANALYSIS	2
JOURNAL OF ECONOMICS / ZEITSCHRIFT FÜR NATIONALÖKONOMIE	2
JOURNAL OF REGIONAL SCIENCE	2

Table I.3 – Top cited articles

Author	Year	Title	DOI
PAL, D.	1998	DOES COURNOT COMPETITION YIELD SPATIAL AGGLOMERATION?	10.1016/s0165-1765(98)00074-3
MATSUSHIMA, N.	2001	COURNOT COMPETITION AND SPATIAL AGGLOMERATION REVISITED	10.1016/S0165-1765(01)00481-5
GRAVAGNUOLO, A., ANGRISANO, M., GIRARD, L.	2019	CIRCULAR ECONOMY STRATEGIES IN EIGHT HISTORIC PORT CITIES: CRITERIA AND INDICATORS	10.3390/su11133512

Table I.3 – Top cited articles

Author	Year	Title	DOI
		TOWARDS A CIRCULAR CITY ASSESSMENT FRAMEWORK	
WILLIAMS, J.	2019	CIRCULAR CITIES: CHALLENGES TO IMPLEMENTING LOOPING ACTIONS	10.3390/su11020423
MARIN, J., MEULDER, B. D.	2018	INTERPRETING CIRCULARITY: CIRCULAR CITY REPRESENTATIONS CONCEALING TRANSITION DRIVERS	10.3390/su10051310
CERRETA, M., MUCCIO, E., POLI, G., REGALBUTO, S., ROMANO, F.	2020	A MULTIDIMENSIONAL EVALUATION FOR REGENERATIVE STRATEGIES: TOWARDS A CIRCULAR CITY-PORT MODEL IMPLEMENTATION	10.1007/978-3-030-48279-4_100
CERRETA, M., GIRASOLE, E. G. D., POLI, G., REGALBUTO, S.	2020	OPERATIONALIZING THE CIRCULAR CITY MODEL FOR NAPLES' CITY-PORT: A HYBRID DEVELOPMENT STRATEGY	10.3390/su12072927
FAN, Y., LI, Y., YIN S.	2018	NON-UNIFORM GROUND-LEVEL WIND PATTERNS IN A HEAT DOME OVER A UNIFORMLY HEATED NON-CIRCULAR CITY	10.1016/j.ijheatmasstransfer.2018.03.069
JIANG, G., WEIDENHOLZER, S.	2017	LOCAL INTERACTIONS UNDER SWITCHING COSTS	10.1007/s00199-016-1002-3
AGO, T., HAMOUDI, H., LEFOUILI, Y.	2017	FIRM LOCATION AND MONOPOLISTIC COMPETITION	10.1111/pirs.12173
HIROSE, K., MATSUMURA, T.	2016	PAYOFF INTERDEPENDENCE AND THE MULTISTORE PARADOX	10.1080/16081625.2016.1188447
MATSUMURA, T., MATSUSHIMA, N.	2012	SPATIAL COURNOT COMPETITION AND TRANSPORTATION	10.1007/s00168-010-0399-z

Table I.3 – Top cited articles

Author	Year	Title	DOI
		COSTS IN A CIRCULAR CITY	
EBINA, T., MATSUMURA, T., SHIMIZU, D.	2011	SPATIAL COURNOT EQUILIBRIA IN A QUASI-LINEAR CITY	10.1111/j.1435-5957.2010.00333.x
EBINA, T., MATSUMURA, T., SHIMIZU, D.	2009	MIXED OLIGOPOLY AND SPATIAL AGGLOMERATION IN QUASI-LINEAR CITY	NA
SCALERA, D., ZAZZARO, A.	2008	OBSERVABLE MANAGERIAL INCENTIVES AND SPATIAL COMPETITION	10.1111/j.1467-999X.2007.00287.x
SCALERA, D., ZAZZARO, A.	2007	THE UNPLEASANT EFFECTS OF PRICE DEREGULATION IN THE EUROPEAN THIRD-PARTY MOTOR INSURANCE MARKET: A THEORETICAL FRAMEWORK	10.2202/1935-1682.1764
MATSUSHIMA, N., MATSUMURA, T.	2006	MIXED OLIGOPOLY, FOREIGN FIRMS, AND LOCATION CHOICE	10.1016/j.regsciurbeco.2006.03.005
SCALERA, D., ZAZZARO, A.	2006	COST REDUCING INVESTMENTS AND SPATIAL COMPETITION	NA
GUPTA, B., LAI, F., PAL, D., SARKAR, J., YU, C.	2004	WHERE TO LOCATE IN A CIRCULAR CITY?	10.1016/j.ijindorg.2004.03.002
MATSUSHIMA, N., MATSUMURA, T.	2004	MIXED OLIGOPOLY AND SPATIAL AGGLOMERATION	10.1111/1540-5982.00004
ZITRON, N.	1981	A CRITICAL CONDITION FOR THE COST DENSITY IN THE CIRCULAR CITY MODEL	10.1007/BF00935254
MIYAO, T.	1980	AN APPLICATION OF THE LECHATELIER PRINCIPLE IN LOCATION THEORY	10.1016/0094-1190(80)90013-3
BRAKKE, K., ZITRON, N.	1977	FURTHER OPTIMAL COST ROUTES IN THE CIRCULAR CITY MODEL	10.1007/BF00933097

Table I.3 – Top cited articles

Author	Year	Title	DOI
MIYAO, T.	1977	THE GOLDEN RULE OF URBAN TRANSPORTATION INVESTMENT	10.1016/0094-1190(77)90005-5
MIYAO, T.	1975	DYNAMICS AND COMPARATIVE STATICS IN THE THEORY OF RESIDENTIAL LOCATION	10.1016/0022-0531(75)90044-7
ZITRON, N.	1974	A CONTINUOUS MODEL OF OPTIMAL-COST ROUTES IN A CIRCULAR CITY	10.1007/BF00932612
BRAKKE, K., ZITRON, N.	1980	SOME GENERALIZATIONS OF THE CIRCULAR CITY MODEL	10.1016/0270-0255(80)90035-4
LUCAS, J. R., ROSSI-HANSBERG, E.	2003	ON THE INTERNAL STRUCTURE OF CITIES	10.1111/1468-0262.00338
THEEUWES, N., SOLCEROVÁ, G., STEENEVELD, G.	2013	MODELING THE INFLUENCE OF OPEN WATER SURFACES ON THE SUMMERTIME TEMPERATURE AND THERMAL COMFORT IN THE CITY	10.1002/jgrd.50704
PRENDEVILLE, S., CHERIM, E., BOCKEN, N.	2018	CIRCULAR CITIES: MAPPING SIX CITIES IN TRANSITION	10.1016/j.eist.2017.03.002
ROSSI-HANSBERG, E.	2004	OPTIMAL URBAN LAND USE AND ZONING	10.1016/S1094-2025(03)00056-5
LIVESEY, D.	1973	OPTIMUM CITY SIZE: A MINIMUM CONGESTION COST APPROACH	10.1016/0022-0531(73)90031-8
FOSTER, G., SALEH, R.	2021	THE ADAPTIVE REUSE OF CULTURAL HERITAGE IN EUROPEAN CIRCULAR CITY PLANS: A SYSTEMATIC REVIEW	10.3390/su13052889
PAIHO, S., WESSBERG, N., PIPPURI-MÄKELÄINEN, J., MÄKI, E., SOKKA, L.,	2021	CREATING A CIRCULAR CITY – AN ANALYSIS OF POTENTIAL TRANSPORTATION,	10.1016/j.scs.2020.102529

Table I.3 – Top cited articles

Author	Year	Title	DOI
PARVIAINEN, T., NIKINMAA, M., PAAVOLA, M., ANTIKAINEN, M., HEIKKILÄ, J., HAJDUK, P., LAURIKKO, J.		ENERGY AND FOOD SOLUTIONS IN A CASE DISTRICT	
CHEN, C-W.	2021	CLARIFYING REBOUND EFFECTS OF THE CIRCULAR ECONOMY IN THE CONTEXT OF SUSTAINABLE CITIES	10.1016/j.scs.2020.102622
WILLIAMS, J.	2019	CIRCULAR CITIES	10.1177/0042098018806133
PAIHO, S., MÄKI, E., WESSBERG, N., PAAVOLA, M., TUOMINEN, P., ANTIKAINEN, M., HEIKKILÄ, J., ROZADO, C., JUNG, N.	2020	TOWARDS CIRCULAR CITIES – CONCEPTUALIZING CORE ASPECTS	10.1016/j.scs.2020.102143

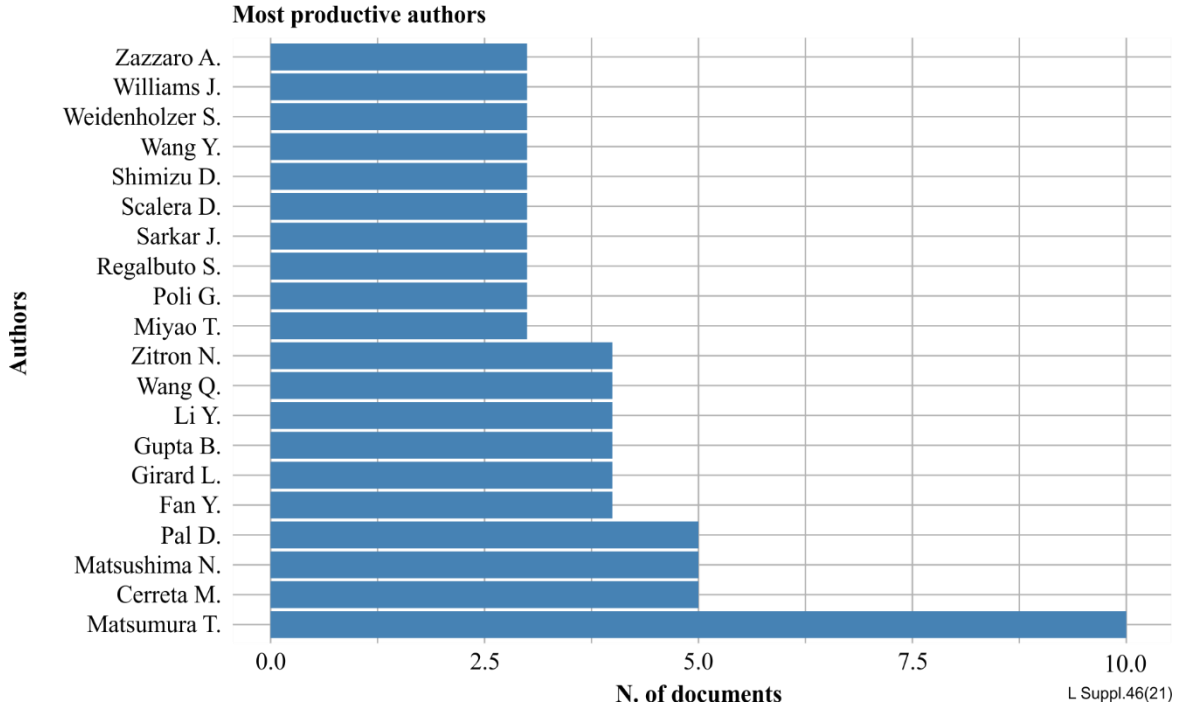

Figure I.1 – Authors with the most produced articles

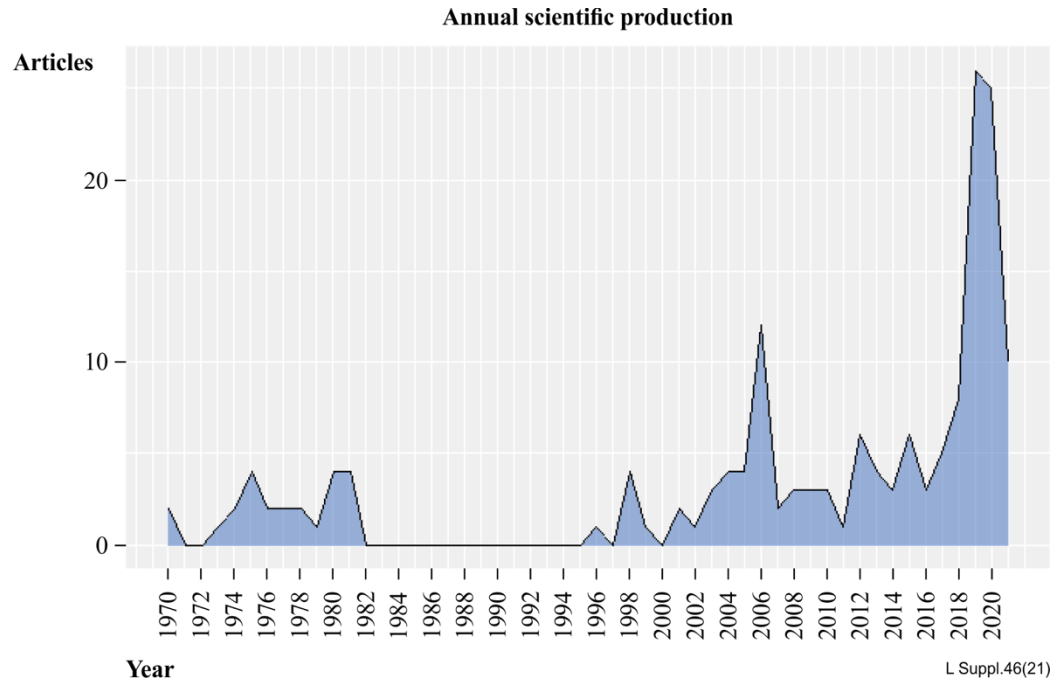

Figure I.2 – Time period of the emerging articles

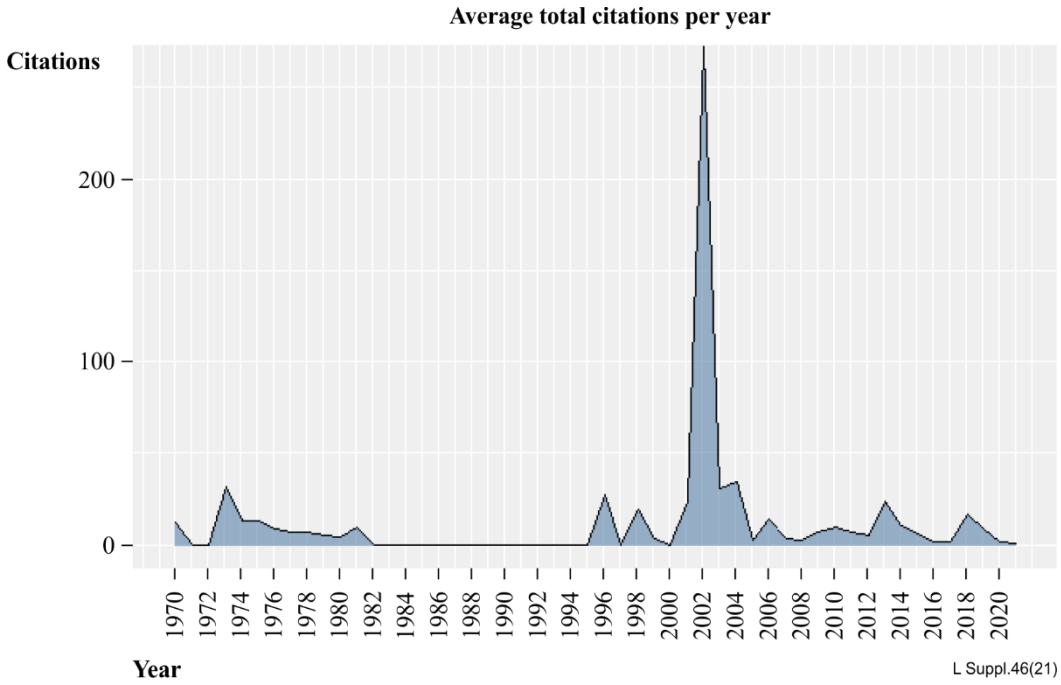

Figure I.3 – Scientific interest's emergence in time, expressed with a citation number

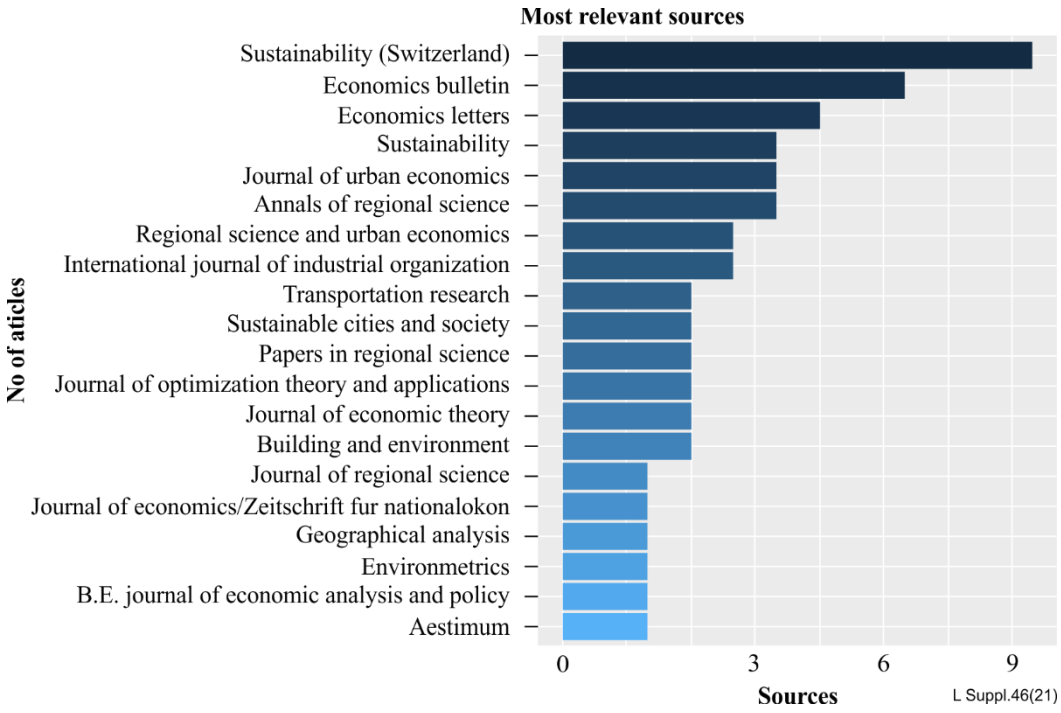

Figure I.4 – Scientific resource performance in terms of articles publication

Table I.4 – An analysis of the scientific resources

Element	h_index	g_index	m_index	TC	NP	PY_start
SUSTAINABILITY (SWITZERLAND)	6	8	1.5000000	121	8	2018
ECONOMICS LETTERS	4	6	0.1666667	160	6	1998
ANNALS OF REGIONAL SCIENCE	3	4	0.2500000	31	4	2010
BUILDING AND ENVIRONMENT	3	3	1.0000000	21	3	2019
ECONOMICS BULLETIN	3	5	0.1578947	31	7	2003
INTERNATIONAL JOURNAL OF INDUSTRIAL ORGANIZATION	3	4	0.1250000	116	4	1998
JOURNAL OF ECONOMIC THEORY	3	3	0.0612245	69	3	1973
JOURNAL OF URBAN ECONOMICS	3	5	0.0638298	40	5	1975
REGIONAL SCIENCE AND URBAN ECONOMICS	3	3	0.1153846	95	3	1996
B.E. JOURNAL OF ECONOMIC ANALYSIS AND POLICY	2	2	0.1333333	7	2	2007
ENVIRONMETRICS	2	2	0.0833333	6	2	1998

Table I.4 – An analysis of the scientific resources

Element	h_index	g_index	m_index	TC	NP	PY_start
PAPERS IN REGIONAL SCIENCE	2	3	0.1818182	11	3	2011
SUSTAINABLE CITIES AND SOCIETY	2	3	1.0000000	12	3	2020
AESTIMUM	1	1	0.3333333	7	1	2019
GEOGRAPHICAL ANALYSIS	1	1	0.0212766	3	1	1975
JOURNAL OF ECONOMICS/ ZEITSCHRIFT FÜR NATIONALÖKONOMIE	1	1	0.0625000	7	1	2006
JOURNAL OF OPTIMIZATION THEORY AND APPLICATIONS	1	2	0.0208333	15	2	1974
JOURNAL OF REGIONAL SCIENCE	1	1	0.0625000	6	1	2006
SUSTAINABILITY	1	1	0.5000000	3	2	2020
TRANSPORTATION RESEARCH	1	1	0.0217391	17	1	1976

Table I.5 – Most cited authors

Author	No of citations
MATSUMURA	49
ANDERSON	47
SALOP	40
GUPTA	36
HOTELLING	31
FUSCO GIRARD	30
PAL	30
MATSUSHIMA	27
HAMILTON	25
WILLIAMS	24
EUROPEAN COMMISSION	21
EATON	20
NORMAN	20
SMEED	20
FAN	18
PRENDEVILLE	18

Table I.5 – Most cited authors

Author	No of citations
WANG	18
FUJITA	17
KIRCHHERR	16

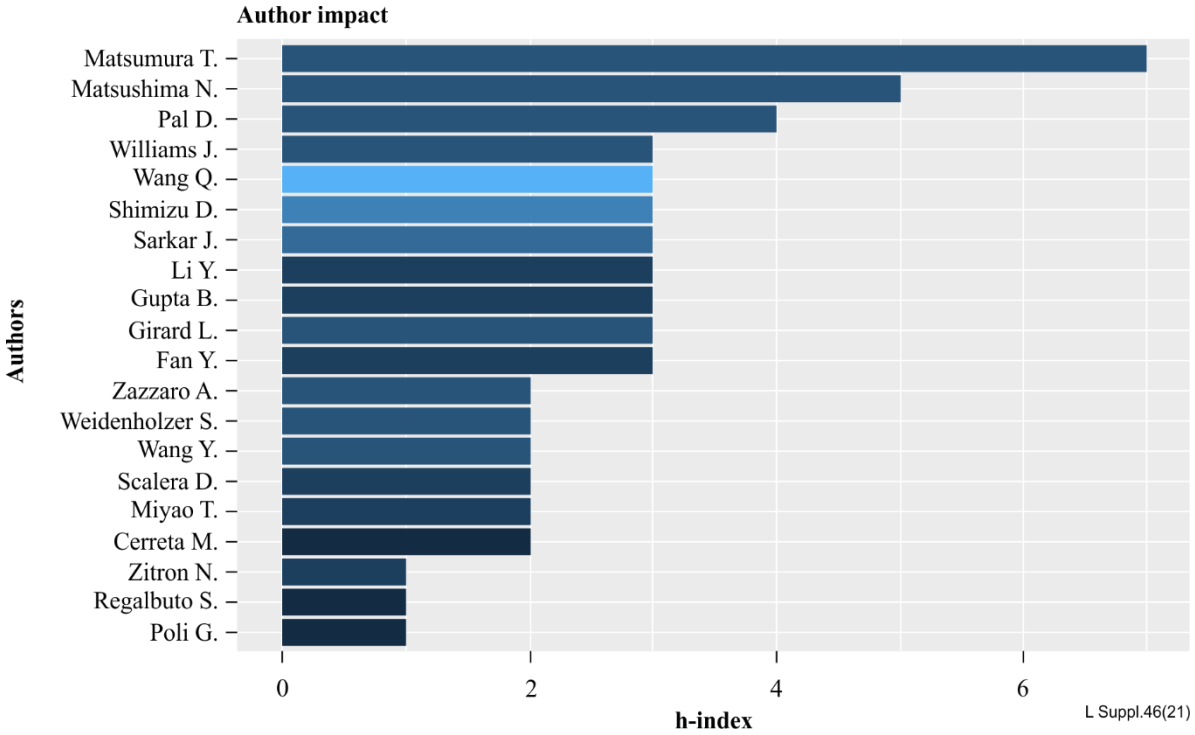

Figure I.5 – Author impact in terms of citations to their work (h-index)

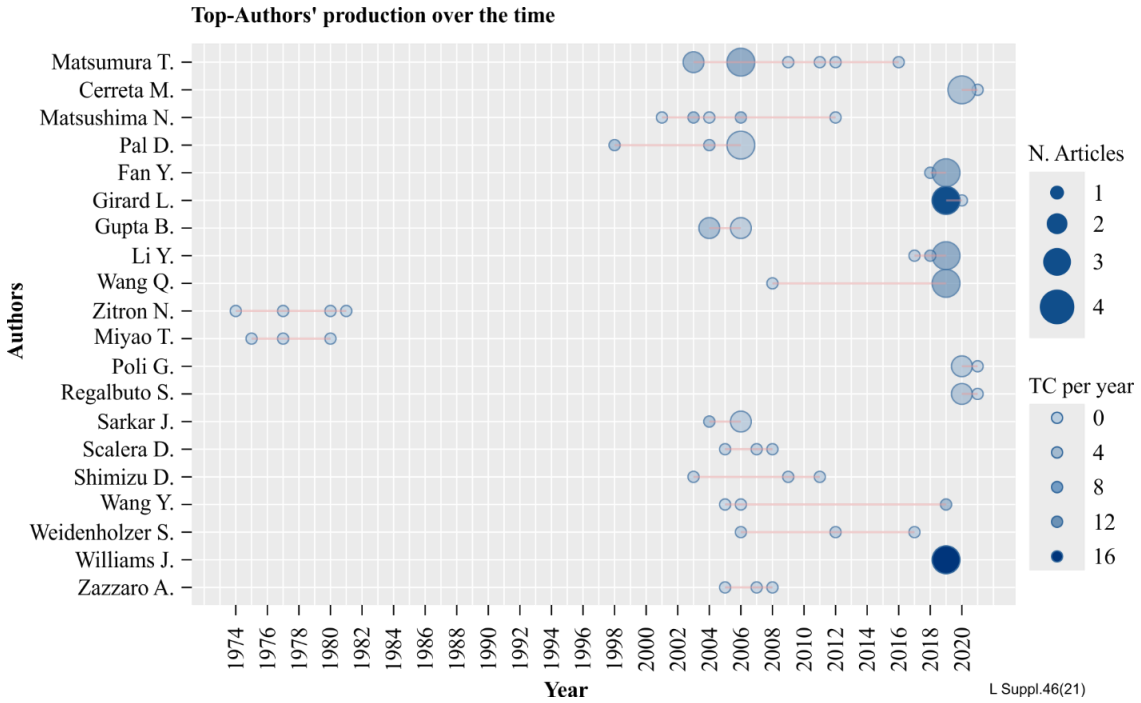

Figure I.6 – Top authors' production emergence

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