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Research Paper

Spatial Structure and Inter-Urban Relations: A Scientometric Mapping Approach

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Abstract
Over the last two decades, the focus of studies on the spatial organization of urban systems has shifted noticeably from classical theories such as "the central place theory" to utilizing novel theories based on the network essence of intercity relations, such as "the central flow theory". This field of urban research, which has emerged under the term "external urban relations", has developed through integrating contributions from many disciplines. However, different methodological traditions and interdisciplinary contexts in which the research is conducted are leading to ambiguity in how we understand and measure intercity relations. This study systematically reviews and analyzes the body of this new literature. It does so by innovatively employing a scientometric mapping approach, which is a combination of bibliometric and citation network analysis methods. This review is based on a publication set of 145 papers published on the subject since 1995. The number of publications covered by the Web of Science (WoS) shows a significant increase in the most recent years. The current study identifies 20 papers as playing a pivotal role in the evolution of the literature on urban external relations. Furthermore, the results revealed five conceptualizations before the 1990s at the classical theories era, along with two renowned conceptualizations during the 1990s (the transition decade), which have had the most impact on changes in the metamorphosis of theoretical fundamentals. The present developments are influenced by a wide range of various concepts, methods, and empirical approaches. Two different subfields (schools) of thought known as "world/global cities", and "polycentricity" are identified by systemically integrating traditional top-down and bottom-up review methods. Their different aspects were also discussed.

Keywords: *Urban networks, External relations, Bibliometric analysis, Citation network, Scientometric.*

1. INTRODUCTION

The objective of this paper is to provide a review of how we study urban networks and their external relations, which is also referred to as 'urban systems' research. The focus of studies on the spatial organization of urban systems before the 1990s was on shortages and inefficiencies of classical and traditional theories, such as the central place theory and the spatial-hierarchical arrangement of urban places (Jacobs 1969, Bourne and Simmons 1978). In the 1990s, studies shifted noticeably to create and develop new viewpoints, which can reflect changes in the urban systems corresponding to social, economic, and environmental changes, as well as rapid technological developments (Batten 1995, Cattan 1995, Smith and Timberlake 1995, Van der Laan 1998). It is already claimed that the central place thinking is outdated (Taylor, Hoyler et al. 2010, Neal 2011), and researchers are now focusing on employing viewpoints of novel theories, such as the central flow theory (Derudder and Taylor 2018) and the network theory (Meijers 2007, Pflieger and Rozenblat 2010).

The current body of literature on urban networks shows distinct changes in the conceptual structure and views on the spatial organization of urban systems (Neal 2011), and the term "paradigm shift" is increasingly used by researchers willing to position themselves in opposition to the "classical" approaches (Peris, Meijers et al. 2018). These novel approaches mostly consider urban systems development within the framework of analyzing "network behavior", measuring intercity interchange "flows", and changing connectedness of cities (Devriendt, Derudder et al. 2010, Derudder, Cao et al. 2018). These studies gradually evolved as a separate stream under the term "the

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external relations between urban places" (Taylor, Hoyler et al. 2010).

However, it can be seen that over the past two decades, the achievements resulting from the growth in integrating contributions from various disciplines, such as economics, geography, sociology, and physics (Pflieger and Rozenblat 2010, Kamalski and Kirby 2012), along with the interdisciplinary development of complexity theories (Bretagnolle, Daudé et al. 2006, Wang, Mo et al. 2011, Dai, Derudder et al. 2018) have created a variety of diverse conceptualizations with different objectives in this research field. Furthermore, the direct influence of recent information and communication advances and the development in rapid and long-distance transportation have had a huge impact on intercity relations (Yang, Dobruszkes et al. 2018, Zhu, Zhang et al. 2018). Moreover, the methodology of this field has been described as limited, dispersed (Ducruet and Beauguitte 2014, Dai, Derudder et al. 2016), and highly heterogeneous (Cheng, Bertolini et al. 2013). This originates from the differences in their ontological and epistemological perspectives as well as the disciplinary background and sources of inspiration for the authors. These are leading to ambiguity about the basis of the spatial organization of urban systems in the new literature (Neal 2011).

According to recent studies, there is a need to move from multidisciplinarity to interdisciplinarity in urban systems research (Pflieger and Rozenblat 2010, Peris, Meijers et al. 2018). Therefore, it is necessary to review the status of the scientific backbone and analyze the interdisciplinary essence of ongoing research. By identifying intellectual structures and defining a new cognitive domain as well as borders, we aim to go one step further and capture how the external urban relational thinking evolved from an interdisciplinarity perspective.

To avoid certain bias in reviewing the literature, this study utilizes the scientometric mapping approach, which is a combination of bibliometric and citation network analysis methods, along with classical literature review to highlight its scientific backbone that helps to identify the sources of research influence for the researchers. It also examines the current research focuses and evaluates the pattern of interdisciplinary scientific cooperation.

One of the main advantages of the scientometric mapping approach is its ability to quantify and visualize the scientific discourses and clarify the literature evolution trajectory of the related research innovations. This approach has recently been applied to thematic content revealing of a publication set (Marx, Haunschild et al. 2017). It has also helped to create a hybrid citation-semantic network map of a body of literature (Peris, Meijers et al. 2018). Moreover, it was used to analyze confusion around the scientific status of smart-city research (Mora, Bolici et al. 2017, Mora, Deakin et al. 2019), and to detect the developmental landscape of transport geography research (Liu and Gui 2016).

Accordingly, two vital objectives of this literature review are as follows. The first objective involves recognizing the most influential research on forming discourse about the transition from the central place theory to the central flow theory, as well as the general acceptance of the paradigm shift event. The second objective involves exploring the typology of subfields (schools) of thought in studies on external urban relations as well as classifying their new practical approaches.

To this end, brief explanations about the source of data, the scientometric mapping approach, data processing, and main tools utilized in this study are provided in Section 2. In Section 3, the outcomes of the general analysis and the bibliometric analysis of the collected dataset and knowledge resources are discussed. This is followed by an in-depth description of the findings, which sheds some light on more recent years of research in the field of intercity relations research. Section 4 presents the conclusion of the study and some recommendations for guiding future research.

2. MATERIALS AND METHODS

This study tries to explain the evolution of the literature on urban external relations as a new field and a research area distinct from urban systems studies. The central place theory and its hierarchical visualization of urban networks have been the traditional bases for this field of study (Neal 2011). In current studies, a new focus has emerged on urban networks and external urban relations (Taylor, Hoyler et al. 2010).

Due to the interdisciplinary nature of this field and to overcome the diversity of the context (Pflieger and Rozenblat 2010, Peris, Meijers et al. 2018), we intend to use a hybrid approach combining bibliometric and citation network approaches (Van Eck and Waltman 2017) along with a systematic bottom-up literature review (Boland, Cherry et al. 2017).

This approach is inspired by the topic-guided/general systematic literature review. A general literature review provides an overview of a specific research topic in relatively general terms without the guidance of a research question (Frank and Hatak 2014). Systematic reviews typically focus on assessing what evidence exists for a specific topic (Haddaway, Woodcock et al. 2015). To avoid predefined categories and certain bias in reviewing the literature, we define the scientific field based on networks of citation relations retrieved from scientific literature in a chronological manner (Lucio-Arias and Leydesdorff 2008). This does not mean that our approach intends to historically reconstruct the scientific knowledge. Using bibliometric analysis and citation network visualization, it is possible to highlight the structural backbone in the development of an interdisciplinary scientific field (Van Raan 2005, Ji and Gan 2020).

Hence, this study was conducted in six different steps:

Dataset used: The first step in this study was to select a published set of papers dealing with the spatial structure and organization of urban systems based on the new network-based approach. These sources were all authentic papers which have been confirmed by the scientific processes of the citation databases. They can be searched in credible scholarly databases, such as Web of Science

(WoS), Scopus, or Google Scholar, which are accessible for free. All papers have been published from 1995 onward. Note that some scholarly databases, like Scopus, do not provide topic search with abstracts included before this date.

Primary keywords: Data collection started with creating a list of categories related to the subject matter. These categories were used as guidelines to choose suitable keywords for database searching. The prior experience of the researchers played a role in determining the main section of the study subject (Finfgeld 2003). We selected different categories and terms based on our knowledge. Some of these keywords include: central place/flow theory, spatial organization/configuration, spatial pattern/distribution, space of flows/places, urban/city network/system, network structure/configuration, urban/city relation/linkage, urban/city connectivity/interaction, and the like.

Search query: We applied a sophisticated search query to select papers specifically discussing urban networks and their external relations. This was done combining the selected terms, logical operations, and advanced search tools of the citation database (Kulkarni, Aziz et al. 2009) based on a super visible search method (Zitt 2015). Preliminary searches yield a large number of papers; however, not all of them are relevant. We iteratively refined the preliminary literature searches by excluding WoS research areas with incoherent records. This procedure resulted in a set of more than 300 papers.

Narrowing down: We perused the abstracts of the collected papers and narrowed them down to those papers specifically dealing with the conceptualization and operationalization of urban external relations using the network-based approach. It became clear that 145 out of 300 papers had focused on this subject matter.

Mapping knowledge structures: We used scientometric mapping tools in VOSviewer (Van Eck and Waltman 2011) and CitNetExplorer (Van Eck and Waltman 2014) to visualize and examine the current research. These software applications were developed at the Center for Science and Technology Studies of Leiden University, and they were freely available. In this study, two groups of analysis methods were applied as follows:

The first group was based on the concurrent occurrence (co-occurrence) and co-citation analysis of VOS viewer. The keyword co-occurrence analysis was used to reveal the intellectual bases and core context of the new literature. The author and journal co-citation analysis was used to uncover academic communities and their intellectual connections and changes by visualizing the network collaborations (González-Teruel, González-Alcaide et al. 2015, Liu, Yin et al. 2015).

The second group was based on the citation network analysis of CitNetExplorer. The citation network analysis was used to identify the historical sources and the most important documents within the scientific discourse. This analysis employs historiographical patterns to analyze co-cited relationships by reviewing all the papers that are internal citations. It extracts all references and identifies the main papers and their connections in a network timeline (Lucio-Arias 2010). Based on this map, we determined which landmark references have been most frequently cited by the papers in the dataset. The existence of comparatively highly-cited early landmark references was also examined.

Review and synthesize: Having finalized our set of citation and substantive analysis, we turned to the full review and summarization of individual studies. We categorized them based on their study focus, major concepts, methodology, and major findings to synthesize the results.

Note that in all of these processes, the insight of the scholar about the subject matter plays the main role in interpreting the results.

Therefore, in this paper, we have tried to systematically review recently produced literature on urban external relations. This allows us to answer the main question and identify different subfields of thought in this field of interdisciplinary research.

3. ANALYZING THE EXTERNAL URBAN RELATIONS LITERATURE

In this section, we applied the scientometric mapping approach within our publication set of papers regarding their specific role in the intellectual structures of studies on urban external relations. This analysis started by downloading the citation information of our set of papers from the Web of Science database and importing them into the specific above mentioned tools.

3.1. The Overall Picture of the Dataset

In general, as shown in Figure 1, the time-evolution of the publication rates evolves noticeably in the most recent years. Initially, this research field was very limited, with only 16 source documents published during the first 10 years. However, more than 75 percent of the collected papers have been published after 2010. This means that intercity relations literature has recently received an increasing amount of attention, which is reflected in a blooming phase. In terms of primary categories, Figure 1 also shows that the subject matter of selected papers has shifted from an economic and social focus to infrastructural theme of urban networks.

The majority of our set of selected papers have been published in urban studies journals (e.g., Urban Studies, Cities, and Regional Studies).Transport and planning science journals (e.g., Journal of Transport Geography, Journal of Air Transport Management) and geography journals (e.g., Journal of Transport Geography, and Acta Geographica Sinica) are second. This implies that transport geography has become a central theme in the study of urban external relations. Figure 2 illustrates the share of journals in our publication set of 145 selected papers, reflecting the ongoing research mainstreams in the field of urban external relations.

A keyword map of the new literature, created using content analysis in VOS viewer, is shown in Figure 3. As

this image of keyword co-occurrence analysis illustrates, our main search terms for searching the urban networks literature (i.e., urban network/system) are in the center of the map, as expected. They are surrounded by a set of signal words, related to conceptualization (e.g. world/global city, globalization, polycentricity, advanced producer services, air transport), operational indices of new ideas (e.g., connectivity, centrality, accessibility), or new network model items (e.g., community detection, complex network). These signal words reflect core contents of the new literature. It can be seen that more extensive attention has been paid to 'world city network' and 'advanced producer services', which are related to the literature on spatial organization of world cities, rather than the 'urban network/system'. This figure shows that the focus of external urban relations has been more intensively focused on the global scale rather than the local scale. In addition, the distance between keywords represents the rate of their concurrent occurrence in a paper, which reflects the connectivity between the signal worlds. In this vein, great attention is given to 'polycentricity' among the signal words surrounding the 'urban/city network'. This shows the importance of the conceptualization of polycentric development in this field of research. According to the highest-frequency signal terms, it is evident that 'world/global cities' and 'polycentricity' have become a leading subfield of research in the studies on urban external relations.

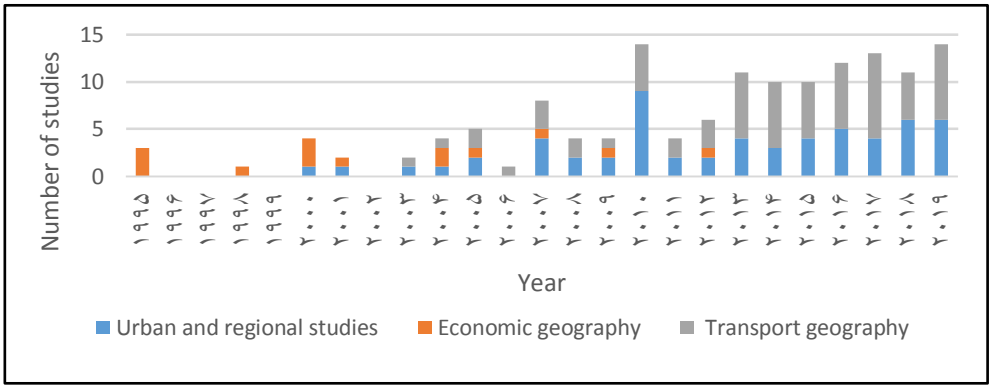

Fig 1. Frequency of studies in terms of their subject matters and publication date

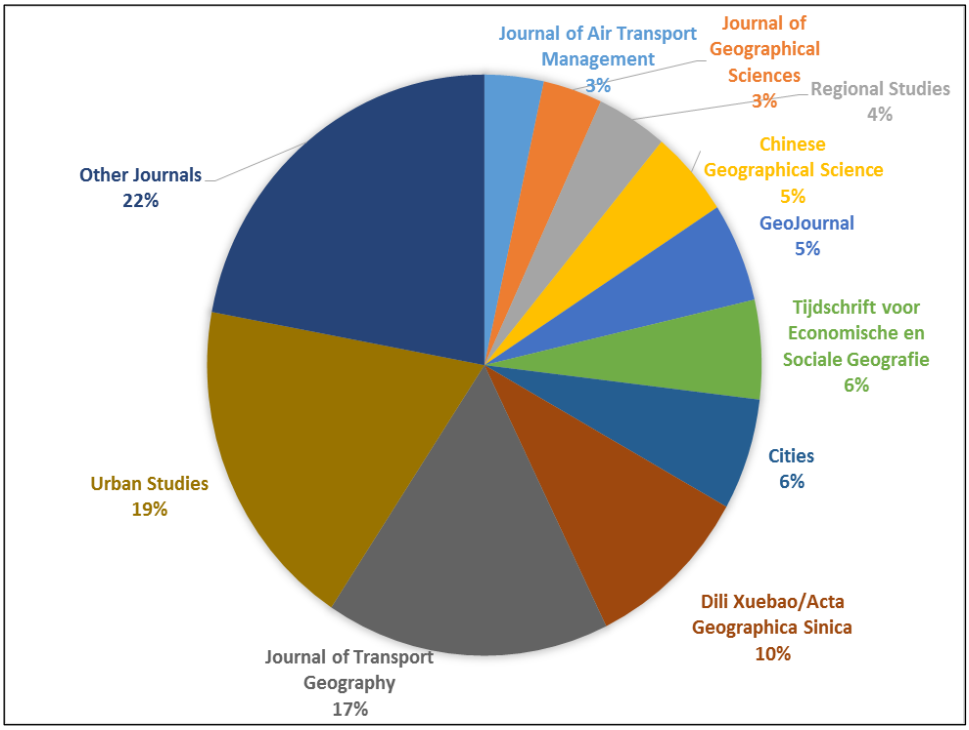

Fig 2. Share of journals in our publication set of 145 papers

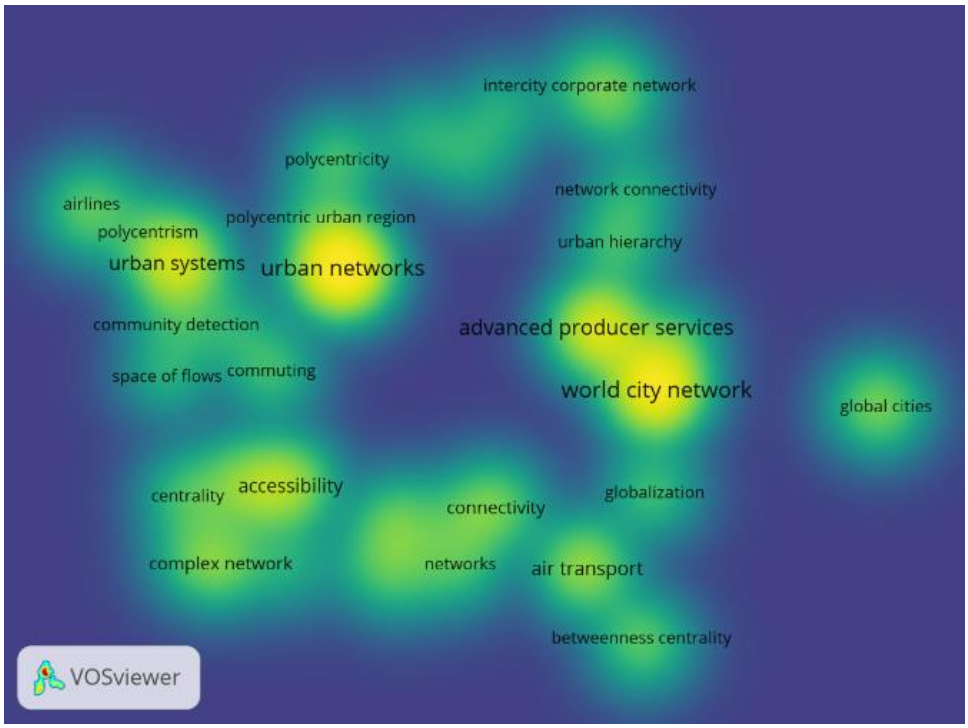

Fig 3. Density Visualization of Co-citation of keywords

3.2. Mapping Intellectual Structures

The journal and author co-citation analysis can map the intellectual structures and identify the emerging trends and paradigm shifts within a specific field (Chen, Hu et al. 2012). The assumption behind this analysis is that when two items (e.g., author and journal) often emerge together in the same paper, it can be said that they are associated in some way or the other (Liu and Gui 2016). In this regard, we visualized the co-authorship patterns of the set of our papers (Figure 4) and presented the statistical results of the journal co-citation analysis (Table 1) as well as the author co-citation analysis (Table 2) by VOS viewer.

The journal co-citation analysis can reflect the relations between all sorts of journals and disciplines. Table 1 presents the most-cited journals as the backbone citation resources of inter-urban relation studies based on internal citations of the selected set of papers. They range from general social science and economics to more specialized journals in the field of transportation. The journal with the largest absolute frequency of internal citations from 1995 to 2020 is the Journal of Urban Studies, with an internal citation count of 1703, which has published the highest number of papers about urban conditions and changes. The Proceedings of the National Academy of Sciences of The United States of America and the Journal of Transport Geography are the next major knowledge sources for this field of study.

The co-authorship map of our set of papers is made up of 201 authors (Figure 4). Nodes in this network represent authors, and the total link strength attribute indicates the total strength of the co-authorship links of a given author with other authors. In order to assess their productivity and influence, Table 2 presents 10 authors with the greatest total link citation strength. Accordingly, Derruder, Witlox, and Tylor are the most productive authors within our publication set. All of them are contributors to the Globalization and World Cities (GaWC) Research Network in the Geography Department at Loughborough University, founded in 1998. This scientific community focuses on research into the external relations of world cities. Their studies were mainly focused on the role of transport and information technology infrastructures in world city network formation, and the potential of quantitative techniques derived from (social) network analysis for examining the GaWC's inter-city datasets.

3.3 Visualization of the Scientific Backbone

Determination of the scientific backbone and discourses deal with the historical references in the research field. It is obvious that a significant number of references remain neglected in the systematic review process due to various reasons, such as being hidden from our search queries, being inaccessible for the public, and so on. To overcome this deficiency, in this section, we used CitNetExplorer to analyze the foundation of the scientific backbone dealing with urban networks and inter-urban relations over time. CiteNetExplorer extracts all cited references and visualizes the citation network of our set of papers. This is done based on comparing highly-cited early references without any further assumptions. The citation network analysis of our publication set retrieved 3983 resources, independent of document type (whether article or the book is covered by the WoS or not), from 1687 to 2019.

The oldest one is Isaac Newton's "Philosophiæ Naturalis Principia Mathematica", published in 1687. This resource shows the penetrating influence of the law of gravity in the primary conceptualizations of urban systems in the classic era. Table 3 focuses on the 20 most frequently cited references out of 3983 relevant papers. In order to explore the evolution of the scientific discourse, these resources are divided into three groups:

1. Selected resources before 1990 (classic paradigm era): except for Christaller' work (Christaller 1933) and his central place theory referred to as the first conceptualization in most texts, other selected items (Table 3) present those thoughts and ideas from classical era which still influence the new literature. In other words, they have exceptional conceptualizations and ideas that have remained valid until now. In this paper, this group of thoughts is recognized as the conceptual underpinning of the new literature on inter-urban relations. In addition, a citation network map of highly cited resources in the classic paradigm (before 1990) is shown in Figure 5. In this map, the historical relations of the co-cited resources in terms of the main evolution in classical theorizing are shown alongside the resources mentioned in Table 3. This map indicates the chronological transition of landmark references in this field of study.

2. Selected resources from the 1990s: these resources present new conceptualizations that had the most influence on bringing new discussions about inter-city relations. These papers were detected by the citation network map. In this paper, these conceptualizations are presented under 'discourse-making ideas in the transition decade'. Figure 6 illustrates the citation network of these resources.

3. Selected resources after 2000: This group of papers forms the core of the evolution in the past 20 years ago, which was earlier referred to as a blooming phase. As shown in Figure 6, the citation network of these resources reveals more ambiguity and complexity around present scientific discourses of interurban relations than before. Therefore, in order to draw a more precise map of this phase of the evolution of theoretical fundamentals, we tried to identify subfields of the new thought using a traditional bottom-up review. Therefore, by describing the dominant conceptualizations and extracting the typology of the new practical approaches for these subfields of thought, the second question of this paper will have a supplementary answer.

Table 1. The top 10 most-cited journals

Frequency of Internal Citations	Journal	Research scope
1703	Urban Studies	Urban conditions and changes
766	Proceedings of the National Academy of Sciences of The United States of America	General science journal, multidisciplinary
425	Journal of Transport Geography	Geographical dimensions of transport, travel and mobility
251	Regional Studies	The economic, social, political and environmental dimensions of urban and regional change
221	European Physical journal	Experimental Physics
219	American Journal of Sociology	The social sciences—sociology, political science, economics, history, anthropology, and statistics—that seriously engage the sociological literature
164	American Behavioral Scientist	Diverse arenas as sociology, international and U.S. politics, behavioral sciences, communication and media, economics, education, ethnic and racial studies, terrorism, and public service
164	Tijdschrift voor Economische en Sociale Geografie	Human geography, economics and econometrics
109	Urban geography	Geography, planning and development
97	Annals of Regional Science	Regional economics, resource management, location theory, urban and regional planning, transportation and communication, human geography, population distribution and environmental quality

(Source: WoS; provided by the VOS viewer)

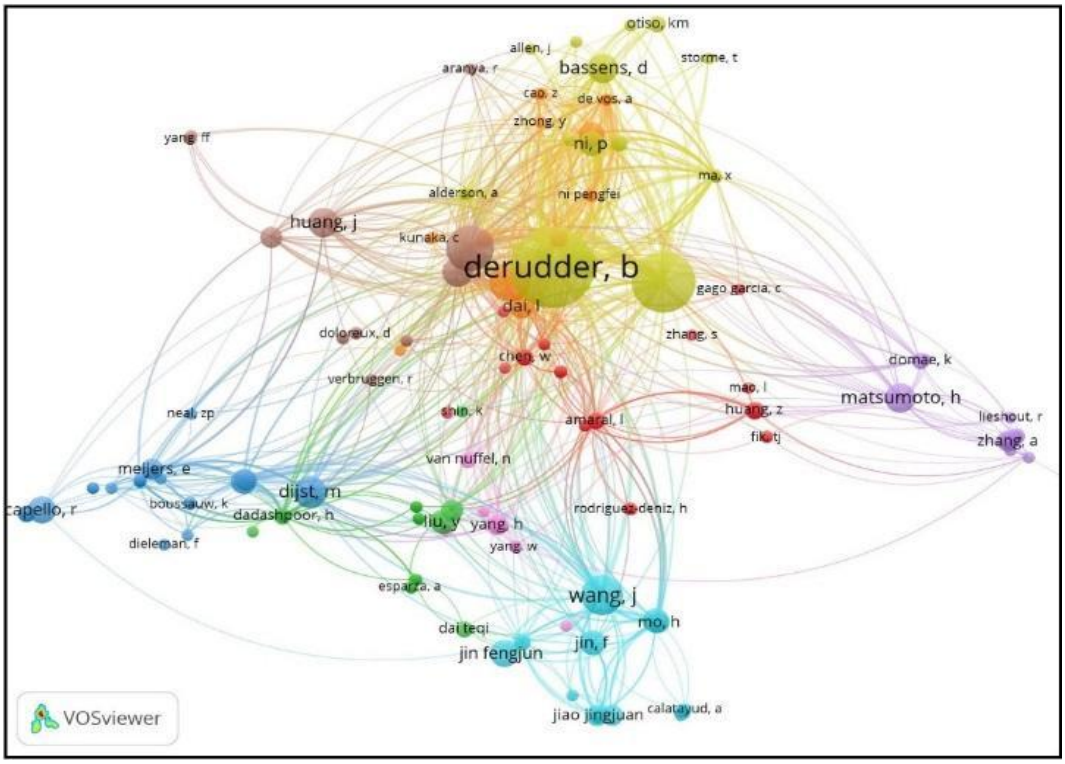

Fig 4. Co-authorship map of all authors from the set of 145 papers
(Source: WoS, provided by the VOSviewer)

Table 2. Top 10 authors and their total link strength in the dataset

No	Source	Documents	Total link Strength
1	Derudder B.	43	1039
2	Witlox F.	25	646
3	Taylor P.J.	14	390
4	Liu X.	11	250
5	Wang J.	11	239
6	Timberlake M.F.	4	232
7	Hoyler M.	6	215
8	Shen W.	4	178
9	Bassens D.	6	161
10	Dijst M.	7	148

(Source: WoS, provided by the VOSviewer)

Table 3. Top 20 landmark resources with the highest internal citation score

	No	Year	Authors	Document	C. Score
Classic paradigm era	1	1933	Christaller	Die zentralen Orte in Süddeutschland (the central places in southern Germany (, (Christaller 1933).	21
	2	1956	Taaffe	Air transportation and United States urban distribution, (Taaffe 1956).	17
	3	1962	Taaffe	The urban hierarchy - an air passenger definition, (Taaffe 1962).	18
	4	1966	Hall	The world cities, (Hall 1966).	17
	5	1969	Jacobs	The Economy of Cities New York, (Jacobs 1969).	24
	6	1977	Pred	City-systems in Advanced Economies, (Pred 1977).	20
	7	1978	Freeman	Centrality in social networks, (Freeman 1978).	24
	8	1986	Friedmann	The world city hypothesis, (Frideman 1986).	33
Transition decade	9	1991	Sassen	The Global City, (Sassen 1991).	43
	10	1993	Camagni	From city hierarchy to city network: reflections about an emerging paradigm, (Camagni 1993).	30
	11	1996	Castells	The Rise of the Network Society. The Information Age: Economy, Society, and Culture, (Manual 1996).	38

	No	Year	Authors	Document	C. Score
Network paradigm era	12	2001	Taylor	Specification of the world city network, (Taylor 2001).	44
	13	2001	Smith and Timberlake	World City Networks and Hierarchies, 1977-1997, (Smith and Timberlake 2001).	41
	14	2001	Sassen	The Global City: New York, London, Tokyo, (Sassen 2004).	33
	15	2002	Taylor et al.	Measurement of the world city network, (Taylor, Catalano et al. 2002).	37
	16	2003	Derudder et al.	Hierarchical tendencies and regional patterns in the world city network: A global urban analysis of 234 cities, (Derudder, Witlox et al. 2003).	27
	17	2004	Taylor and Derudder	World City Network: A Global Urban Analysis, (Taylor and Derudder 2004).	46
	18	2004	Alderson and Beckfield	Power and position in the world city system, (Alderson and Beckfield 2004).	35
	19	2005	Derudder and Witlox	An Appraisal of the Use of Airline Data in Assessing the World City Network: A Research Note on Data, (Derudder and Witlox 2005).	34
	20	2006	Hall and Pain	The polycentric metropolis: learning from mega-city regions in Europe, (Hall and Pain 2006).	30

(Source: WoS, provided by the CiteNetExplorer)

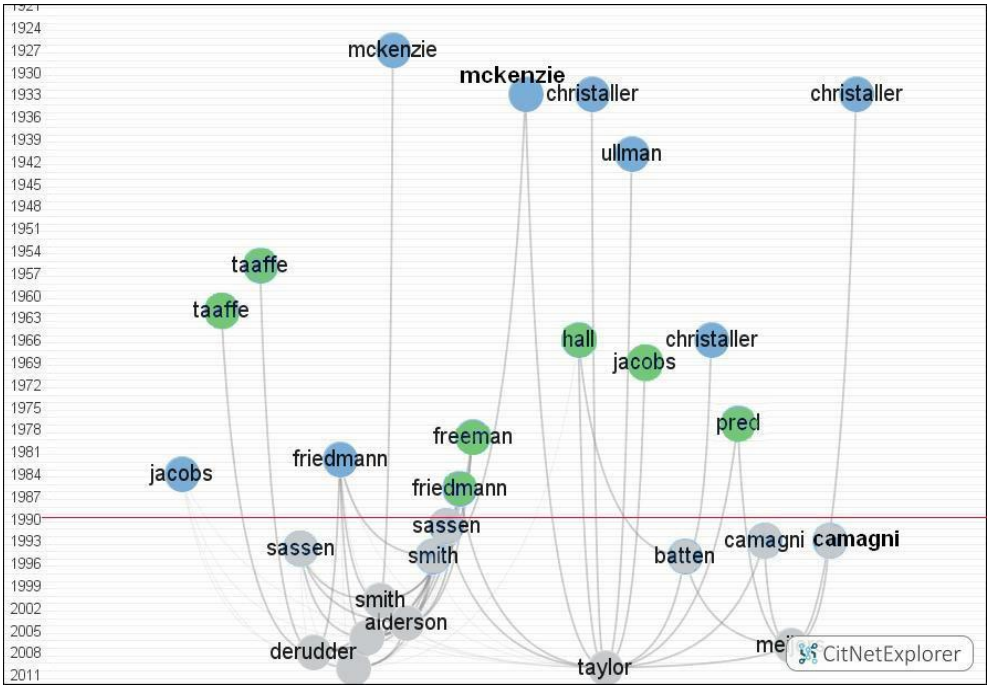

Fig 5. Citation network of the literature with emphasis on intercity relations before 1990

(Source: WoS, CitNetExplorer)

Not that, each node in Figure 5 and Figure 6 represents of its one highly-cited resource, shown with the name first author. Blue nodes are those automatically selected resources which have an internal citation score higher than 15. Green nodes are those influential resources mentioned in Table 3. They have achieved the highest citation score among resources affected by the new evolution on the network. Gray nodes are connecting nodes used solely for better displaying the scientific links. The citation score in Table 3 is based on the number of internal cited references within our set of 145 papers.

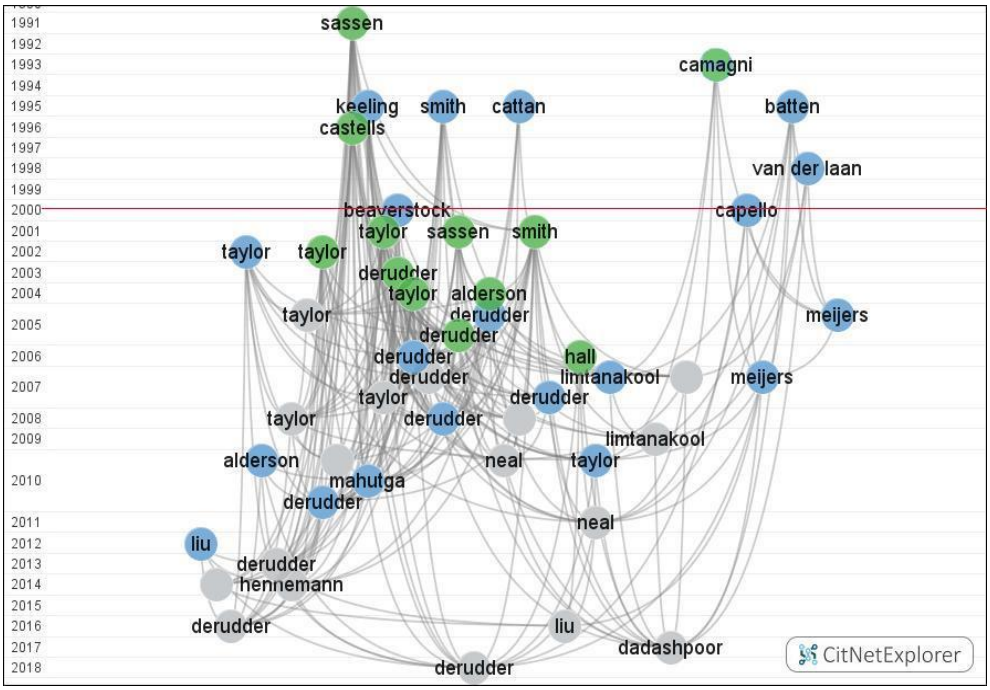

Fig 6. Citation network of the external urban relations literature, landmark papers during the 1990s and from 2000 onward (Source: WoS, CitNetExplorer)

4. DISCUSSION AND RESULTS

It can be recognized that at the end of the 20th century, researchers did not limit themselves to the development of only one or two new concepts and methods as in the past. Instead, they tried to propose and come up with a lot of novel ideas in the field of inter-urban relations. In the following, we discuss the results obtained from the in-depth exploration of the set of our selected studies.

4.1. The Conceptual Underpinning of Inter-Urban Relations before 1990

Since the late 1970s, we can observe the emergence of criticisms for opinions rooted in the classical views and their size-based hierarchy approach (Dadashpoor and Afaghpoor 2016). They provided a fundamental review of the roots and concepts of the ideas derived from the central place theory. Therefore, attentions shifted to focus on the accessibility of the main nodes in urban networks and the degree of interactivity between them, instead of the regularity of population distributions and the size-based classification of cities (Camagni 1993, Meijers 2007).

During this period, many theorized the importance of urban networks. Table 3 presents highly-cited sources and landmark documents presented before the 1990s. Evaluating these texts indicates the presence of five ways in which new views and concepts differ from the thoughts and views derived from the central place theory. In this paper, these thoughts and ideas are described as the conceptual underpinnings of the new inter-urban relations studies. Based on the citation network analysis of our publication set, these have been the most cited concepts and ideas during the last two decades:

The conceptualization of world cities: the first idea or thought that has the highest internal citation score among the papers published before the 1990s should be sought in "the world city hypothesis" of Friedmann (Frideman 1986). Accordingly, world cities were defined as those places which are at the top of an urban hierarchy due to their integration with the international economic relations. The book "the World Cities" by Hall (Hall 1966), which is one of the prominent resources in this group, can be classified under the same thought as well. They explain that at the end of the 20th century, technological innovations and the structural changes of the world economy would drive the economy of cities towards even more dependence on factors acting between cities. It would also cause an increase in the level of relations between cities. This will allow more key exchanges, finally promoting even further development of external relations between cities and economies of scale. Therefore, from an empirical point of view, the central place theory does not work well for the spatial organization of the upper levels of urban places in city systems. This conceptualization implied the arrival of a newer and more network-based approach for the spatial organization of urban systems.

The conceptualization of structural centrality: Freeman (Freeman 1978) presented new concepts of centralization in social networks based on the graph theory. The idea behind measuring the structural centrality in social science presented by Freeman aims to quantify the capacity of a node to influence, or be influenced by, other nodes via its connection topology and its total number of in- and out-flows. This is completely different from the idea of centrality derived from the central place theory. The 'centrality' of a place in the central place theory refers to the extent to which a city serves its surrounding area.

Although this paper did not specifically discuss the urban networks and their external relations, the emerging new concept of centrality in the analysis of social networks has been highly appreciated by researchers in the field of urban networks over the next decades.

The evolved conceptualization of city systems: the third key reference, that obtains the most internal citations, refers to the opinions of Pred (Pred 1977) and his famous definition of 'system of cities' which is still valid today (Peris, Meijers et al. 2018). He presented in his classic study of the space-economy that urban systems are as a set of national or regional cities which are interconnected and argued that any notable changes in economic activities of one of these cities will directly or indirectly cause economic changes in other cities. He concluded that non-hierarchical inter-city links required an alternative theorizing to central place theory. This argument has been used to underpin the concept of complementarity, mutuality, cooperation for the operation of the network over the next decades (Taylor and Derudder 2004). The general theory of systems built a framework for exploring the essence of systems. This is an advantageous concept of urban systems that puts stress on relations between cities.

The idea of using air transportation networks: this idea, which is the fourth most cited fundamental idea, was first proposed by Taaffe (Taaffe 1956, Taaffe 1962) for the analysis of the urban network in the United States. For the first time from a progressive perspective, he talked about the importance of the existence of a strong relationship among the hierarchy of cities in the United States and the air passenger movements, which he found to be associated with city functions (Smith and Timberlake 2001).The practical approach of measuring city connectivity using air traffic data to define a new urban hierarchy provides a valuable window into the urban networks and the process of measuring urban external relations (Neal 2010). Taaffe undermined the classical concepts of distance and hinterland. He described the possibility of investigation and analysis of another type of relation between cities; namely, horizontal relationships based on long-distance travel. Until then, this type of survey was not practically possible to define or conceive, establishing non-vertical long-distance relations between central places.

The new attitude towards the complex intercity economic relations: based on our cited network analysis, Jane Jacobs's hypothesis in the "Economy of Cities" (Jacobs 1969) has been considered as one of the most significant thoughts in the theoretical and foundational development process of urban networks. There was a substantial shift towards considering the urban space as a process rather than a place in Jacobs's thoughts (Taylor, Hoyler et al. 2010). Jacobs considered the nature of the involvement of the theory of urban systems in shaping a new definition for urban relations, which is derived from a materialist theory of the physical and economic relationships between cities. She suggested that inter-city relations were not solely limited to hierarchical relations. On this basis, another theory, apart from the central place theory, was required to interpret non-hierarchical links between cities that are affected by economic complexities and cultural diversity.

Based on the citation analysis processes, these five new ways of thinking and interpreting interactions between cities have attracted the highest attention among scholars in the later decades. They can somehow be considered as the origin for the formation of critical discourses that, after the 1990s, had a further impact on the domain of inter-urban relations thinking.

4.2. The Emergence of New Discourse-Making Ideas in the 1990s

Meijers (Meijers 2007) believes that the source of the network metaphor in spatial phenomena should be related to the extension of research on conceptualizations of urban networks in the 1990s. Studies show that during the 1990s, numerous attempts were made to investigate the spatial organization of urban systems in line with political, economic, social, environmental, technological, and cultural changes (Capello 2000). In the absence of a concrete theoretical framework, these attempts increasingly led to the emergence of a new wave of research around a network-based urban system, organized as a befitting description for modern urban systems (Camagni 1993).

In order to investigate the roots of these new efforts, as highlighted in Table 3, their main references should be sought in three landmark sources, which are introduced and discussed as new discourse-making thoughts and ideas in this paper. These are discussed in the following.

The first landmark reference is Castells' "the Rise of the Network Society". Castells (Manual 1996) introduced the "space of flows" as the material and immaterial components of the global information networks. The space of flows in action in the society of the digital age explains a high level of cultural diversity in space and time, as well as their dynamic interactions. It explains a new type of space that allows the real-time simultaneity of interactions at far distances. Castells (Castells and Blackwell 1998) expresses that our society is increasingly developing alongside flows. Such flows could be the flow of capital, people, goods, information, and thoughts. Castells assumes these spaces of flows as a new form of space made of social customs, where the society creates and dominates a network. By describing the real-time and long-distance economy along with proposing the global information economy, Castells (Castells 2011) develops a new kind of polycentric urban form, which is regarded as the "network cities". Studying Castells' thoughts shows that he examines a chain of topics with a look at the "urban issue" in a generalized view. He covers his opinions about "space", "flows", and "places", and ends by moving towards "informationalism", "network logic", "information city", and "network cities" views.

The second landmark reference with regards to efficient conceptualizations in the 1990s can be found in the thoughts of Sassen (Sassen 1991). She interprets the active companies in the field of advanced producer services (e.g., specialized productive and financial

services) as a noteworthy part of the global economy. She believes that this economic sector serves the global capitals by solving operational issues in the transnational economy. By that means, it would increase the dynamicity and complexity of urban systems. Through the simulation of the relations between cities based on the corporate mechanism of companies, two or more formerly independent cities can potentially and functionally complement each other. Thereby, they join a major extensive economic system by utilizing interactive growth partnerships similar to those seen in the network behavior of companies. In this simulated model, relations between the cities are a flow of ideas, science, information, plans, instructions, staff, and so on.

The same idea can be tracked in the thoughts of Camagni and Salone (Camagni and Salone 1993). As illustrated in Table 3, based on a simulated model of interactions between firms' networks, Camagni and Salone (Camagni and Salone 1993) defined the intercity network as a "system" of horizontal and non-hierarchical relations. They express that the network model is much more applicable to the savings of the services sector, which are even further dominating the economic structures.

Accordingly, these sources from the 1990s can be considered as the discourse-making sources of the network viewpoint and the source for the spread of the central flow theory over the later decades. These landmark sources can be categorized as follows: (1) Castells' thoughts about "network cities" and (2) Sassen, Camagni, and Salone's thoughts about the emergence of the "advanced producer service sector" and "the productive forces" derived from that, as well as the simulation of "network behavior" of this economic sector.

The penetration of these conceptualizations in scientific discourses of that era led to the creation of another wave of studies in the field of urban systems. This wave of researchers used the metaphor "network" for determining the structure and spatial organization of cities, while utilizing the flow data to analyze urban connectedness and external relations. This has resulted in the emergence, expansion, and deepening of urban networks theory in studies on the spatial organization of urban systems. Based on these inclusive developments, several researchers have considered these discussions, descriptions, and critics coherent enough to assume using the terms scientific revolution or paradigm shift (Khun 1970) was appropriate for supporting these changes (Capello 2000, Meijers 2007). Having used this term, they attempted to raise and explain the theoretical standpoint of their thoughts in line with promoting new views against the classical ones.

4.3. New Subfields of Thought

A useful approach for understanding the origins of inter-city relation's conceptual ambiguity related to different methodological traditions, and interdisciplinary contexts in which the research is conducted, involves separating the definitions and properties of conceptualizations of its different subfields (school) of thought.

Reviewing and analyzing resources cited in Table 3 and Figure 6 indicates that authors have presented and applied many different practical approaches with totally distinctive objectives of research in the field of external urban relations. Two major subfields of thought can be identified as follows. The first subfield of external urban relations studies relates to world/global cities studies, which focuses on identifying the urban hierarchy by looking at world/global systems. The second subfield is related to the concept of polycentricity in urban systems, which refers to the existence of several adjacent cities within the same area. In the following sections, the results obtained from reviewing different aspects of these two distinct subfields are presented.

4.3.1. World/Global Cities Research Subfield

This subfield of external urban relation studies corresponds to the research on world cities and the world city networks. They defined world cities as those places at the top of an urban hierarchy which are claimed to be interlinked in the network of business and trade that took them away from their national positions (Taylor and Derudder 2004). Such cities constitute the key nodes or command centers that exert power over other nodes in a system of global cities, and thereby the world economy (Sassen 2002). In fact, globalization is the main cause of economic convergence at the international stage by means of flow in global capital circulation with the help of information and communication technologies (Taylor and Aranya 2008, Dadashpoor and Yousefi 2018). These aspects impact the spatial structure and organization of urban systems (Yousefi and Dadashpoor 2020). They brought new parameters influenced by the process of globalization in the city network framework study two decades ago. This is classified as "global urban hierarchy" in the "world city network" studies (Sassen 2002, Derudder, Cao et al. 2018).

The research on the world cities deals with international cities rankings using two different theoretical approaches. The first theoretical approach is based on classical studies. This approach is mostly seen in the works of Friedmann (Frideman 1986) and Hall (Hall 1966) from the classic era, as noted earlier. Its fundamental measurements are based on the criteria of economics, human resources, cultural experience exchange, and political activities. The second theoretical approach is based on new studies. This theoretical approach is a result of network theory, and it can mostly be seen in GaWC network studies. The result of studies done by these network scholars (GaWC) shows that there is a shift in world-city systems, which does not match the top-down hierarchy stressed in classic views. This research network focuses on investigation into the existence of world-wide transactions. According to this theoretical approach, cities are related to each other in a connected network and a global network hierarchy framework. They need each other and cannot eliminate one another's role. This

relationship is promoting network growth (Sassen 2002, Taylor and Derudder 2004, Derudder, Cao et al. 2018, Derudder and Taylor 2018).

Two major methodology traditions can be distinguished in this new theoretical approach. Here, cities in the global city network are the focus of the new hierarchy studies: follows:

1- Adopting an air traffic-based picture of the urban network: Measuring the air traffic flows between the cities is one of the main experimental approaches for measuring the level of integrity of the cities within the global system of cities. In other words, the air traffic-based approach has been at the center of attention of many authors (Dai, Derudder et al. 2018). Particularly, due to the ability to respond relatively quickly in terms of supply and demand, air traffic flow of individuals is an appropriate indicator for the evaluation of international properties of cities (Neal 2014). This group includes studies which consider the development of a centralized transportation network as one of the results of the experience of economic development, and seek changes in city rankings based on the flow of investment exchanges and trade between regions. These processes lead to an increase in income for these cities, thereby increasing air travel, which boosts the level of intra-regional business communication. In this regard, important research work can be mentioned, which have tried, from this point of view, to examine the relationship between business services and the position of multinational corporations and air transport (Derudder and Witlox 2005, Liu, Derudder et al. 2013, Zhang and Zhang 2016, Matsumoto and Domae 2019). They were looking for developing the idea of explaining and modeling the relations between economic development indicators and properties of cities, as well as the inter-city air traffic level at transnational, regional, and global scales (Dadashpoor, Afaghpoor et al. 2017). They consider air transport to be the criterion for assessing the changes in commercial connections.

2- *Utilizing the advanced producer services network to explain the intercity networking*: In contrast to the direct approach of airflow evaluation, this is an indirect approach based on applying the "interlocking network" model (Derudder and Taylor 2018), which is not relying on real flows between cities. Advanced services are those services that are mostly provided for producers and investors, especially in industrial and manufacturing sectors. Banking services, accounting services, financial services, insurance, legal services, management, and advertisement are the main elements of the advanced service category (Taylor, Derudder et al. 2014). The development and replacement of advanced trade and service firms instead of heavy industries resulted in structural changes and evolution in cities' economic space, especially in metropolises (Derudder, Cao et al. 2018). This change caused the expansion of those urban studies in the recent decade that try to redefine functions of the city economy based on the network theory. This approach tries to present new connections between cities and new multi-kernel patterns in the dominant form of world cities, and to define a new configuration for urban cores in new services (Clark, Harrison et al. 2018). These studies are very important from two aspects: (1) the model conceptually proposed by them is focused on progressive service companies, which is a vital factor in city network formation, and (2) it is important from a methodological perspective because similarity in the models makes it possible to evaluate changes in the general "importance" of the city. It also makes it possible to study changes in cities' position in the structure of the city network (Taylor 2001, Taylor, Derudder et al. 2014, Yang, Derudder et al. 2017, Derudder and Taylor 2018).

4.6. Polycentricity Research Subfield

Polycentrism in studies on the spatial structure and organization of city networks is not a new concept (Hohenberg and Lees 1995, Batty 2001). In theory, a polycentric urban network is a network that has no real dominant node, and the professional products and services are distributed equally among all the nodes (Burger, Van Der Knaap et al. 2014). Even though this definition is valid in academic discourses and planning policies, the polycentricity concept can be interpreted diversely and differently. This definition is sensitive to its local scale. The polycentric system can be defined at different stages of the core city, suburban areas, and metropolis (urban place) (Meijers 2005). Moreover, the focus of papers on the polycentric urban concept is divided into three scales of national, regional (mostly applied in Europe), and global (Limtanakool, Dijst et al. 2007).

A review of the selected papers shows that analyzing and evaluating methods of inter-urban relations in this field are likely to use social, complex network analysis for calculating topological properties. This results in extracting new concepts and structural qualities of the city network, and based on the relation between cities, a general understanding of the internal logic in the city network will be illustrated and formed. In this type of studies, city systems are built from various nodes and relations by which goods and people are transported (Dadashpoor and Saeidi Shirvan 2019). Although information and communication technologies simplified communication, physical relationships are still very important in the modern world (Bertolini and Dijst 2003). Among transportation means, high-speed transportation, such as airlines and high-speed railways, can remarkably mitigate geographical and time limits. They can have an enormous influence on business, tourism, scientific work, political activity, and immigration for maintaining social relations. They are considered crucial in the analysis of the configuration of urban systems (Yang, Dijst et al. 2018). Reviews indicate that there are two main types of practical approaches for evaluating flow configuration between cities in the polycentric urban region studies. These two approaches are as follows:

1. Approaches based on physical flows: this group of practical approaches is used for actual physical flows which match the physical transportation infrastructures between cities, such as air, land, and railway flows of

cargo, passengers, and postage (Derudder, Witlox et al. 2008, Dai, Derudder et al. 2016, Chen, Liu et al. 2018).

2. Approaches based on derived flows: the second group of approaches involves the communication infrastructures. This includes telephone and internet services (Feng, Bo et al. 2016, Yousefi and Dadashpoor 2020), and advanced tele-information contacts (Devriendt, Derudder et al. 2010).

There are strong objections against the second approach, i.e., "the derived flow" (Yang, Dobruszkes et al. 2018). The main argument of critics is that using derived approaches cannot show all the internal characteristics of nodes (i.e., cities). According to critics, it is not possible to interpret the internal features of nodes based on external interactions. This means that the derived relationships of people, information, services, and related nodal features cannot show the routes or the extent of these flows. On the other hand, in experimental studies, the first approach, i.e. utilizing the actual physical flows, in the infrastructure of transportation networks seems the most useful approach for evaluating city networks at national and regional scales compared to other approaches.

5. CONCLUSIONS

This study investigated the latest evolutions and developments in theoretical and practical approaches in the field of research addressing the relationships between cities, which is also referred to as 'urban systems research'. Accordingly, the study identified and reviewed papers published during the last two decades related to the subject matter based on the network paradigm by searching ISI databases, using CitNetExplorer and VOSvewer. Based on the collected data and using the relevant software applications, the structure of historic evolutions was visualized. Citation analysis and the illustration of the citation network in the selected papers led to the bottom-up identification of the borders of proposed ideas from different disciplines by identifying dominant thoughts and ideas of the intellectual space of the network paradigm in urban studies during its formation.

The obtained results mapped the structure of journals focusing on different aspects of intercity relations studies. The map shows that this field of research is boosted by interdisciplinary integrations, e.g. economics, geography, social sciences, urban and regional sciences, transportation management, and so on. The three fitted journal categories (i.e., urban and regional studies, economic geography, and transport geography) reflected the dynamics of the mainstreams in the ongoing research. The results confirmed that the context of the new literature shifted from an economic and social focus to the infrastructural theme of urban networks, which is reflected in a blooming phase. In addition the keyword map and the co-authorship map of the new literature identified core contents of the new conceptualizations corresponding to different schools of thought and scientific communities that have been influential over the last two decades. These scientometric maps also indicated that despite being a vibrant subfield within urban studies, a lack of experimental research on the national scale can be identified. The external urban relational thinking adheres to global scale rather than more micro scales, e.g., national, regional, and local.

The citation network method developed in this paper has proven its capacity for determining the foundation of the scientific backbone by exploring a set of publication patterns in the citations. A substantial advantage of this method of approaching literature is limiting the bias in the selection of the original resources having allowed the inclusion of texts without any further assumptions. In order to explore the evolution of scientific discourse, these landmark resources are divided into three groups, i.e., before the formation of the network paradigm, during the transition, and after the transition.

The conceptual underpinning of inter-urban relations before 1990 indicates very heterogeneous approaches. These approaches can be split into five groups, i.e., (1) the conceptualization of world cities, (2) the conceptualization of social networks analysis, (3) the evolved conceptualization of city systems, (4) the idea of application and analysis of air transportation, and (5) the new attitude toward the appearance of complex intercity economic relations. These new ways of thinking and interpreting the interactions between cities have shifted attention toward the accessibility of the main nodes in urban networks and the degree of interactivity between them, instead of the regularity of population distributions and the size-based classification of cities.

In addition, investigating convergent thoughts in the 1990s identified just two highly-cited discourse-making resources, i.e., (1) Castells' thoughts about "space", "flow", "places", "information city", and "network cities", and (2) Sassen, Camagni, and Salone's thoughts regarding "high-level producer services" and the "productive forces" derived from them, and the simulation of "network behavior" in this economic sector. These two discourse-making fields tried to simplify the metaphor of "network" for determining the structure and spatial organization of cities in order to better understand them.

Contrary to the simplifications of the 1990s, the research perspectives of intercity relations studies after 2000 are increasingly full of complexity and diversity. Reviewing and analyzing resources cited in the citation network map led to the bottom-up identification of the influence of several self-proclaimed schools of thought, which impacted the conceptualizations of this theoretical evolution and practical approach. Even though these self-proclaimed schools manifest very different approaches, they can be recognized and identified based on their classification into two comprehensive groups addressing the systems of cities. These two groups include (1) the world cities subfield of thought, which includes urban studies with a focus on topics related to world cities and the globalization process, and (2) the polycentricity subfield of thought, which includes urban and regional studies with a focus on urban network quantitative analysis and polycentrism. The conceptualization of each one deals with quite specific objects of research, and their practical approaches use novel models and simulations. However, it

seems that these results are not adequate for a shift from multidisciplinarity to interdisciplinarity in intercity relations research.

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REFERENCES

Alderson, A. S. and J. Beckfield (2004). "Power and position in the world city system." American Journal of sociology 109(4): 811-851.

Batten, D. F. (1995). "Network cities: creative urban agglomerations for the 21st century." Urban studies 32(2): 313-327.

Batty, M. (2001). "Polynucleated urban landscapes." Urban studies 38(4): 635-655.

Bertolini, L. and M. Dijst (2003). "Mobility environments and network cities." Journal of urban design 8(1): 27-43.

Boland, A., G. Cherry and R. Dickson (2017). "Doing a systematic review: A student's guide."

Bourne, L. and J. Simmons (1978). "Introduction: the urban system as a unit of analysis." Systems of Cities: Reading on Structure, Growth, and Policy: 1-18.

Bretagnolle, A., E. Daudé and D. Pumain (2006). "From theory to modelling: urban systems as complex systems." Cybergeo: European Journal of Geography.

Burger, M. J., B. Van Der Knaap and R. S. Wall (2014). "Polycentricity and the multiplexity of urban networks." European Planning Studies 22(4): 816-840.

Camagni, R. P. (1993). From city hierarchy to city network: reflections about an emerging paradigm. Structure and change in the space economy, Springer: 66-87.

Camagni, R. P. and C. Salone (1993). "Network urban structures in northern Italy: elements for a theoretical framework." Urban studies 30(6): 1053-1064.

Capello, R. (2000). "The city network paradigm: measuring urban network externalities." Urban Studies 37(11): 1925-1945.

Castells, M. (2011). The rise of the network society, John wiley & sons.

Castells, M. and C. Blackwell (1998). "The information age: economy, society and culture. Volume 1. The rise of the network society."Environment and Planning B: Planning and Design 25: 631-636.

Cattan, N. (1995). "Attractivity and internationalisation of major European cities: the example of air traffic." Urban Studies 32(2): 303-312.

Chen, C., Z. Hu, S. Liu and H. Tseng (2012). "Emerging trends in regenerative medicine: a scientometric analysis in CiteSpace." Expert opinion on biological therapy 12(5): 593-608.

Chen, W., W. Liu, W. Ke and N. Wang (2018). "Understanding spatial structures and organizational patterns of city networks in China: A highway passenger flow perspective." Journal of Geographical Sciences 28(4): 477-494.

Cheng, J., L. Bertolini, F. le Clercq and L. Kapoen (2013). "Understanding urban networks: Comparing a node-, a density-and an accessibility-based view." Cities 31: 165-176.

Christaller, W. (1933). "Die zentralen Orte in Süddeutschland (the central places in southern Germany)." Jena: Gustav Fischer.

Clark, J., J. Harrison and E. Miguelez (2018). Connecting cities, revitalizing regions: the centrality of cities to regional development, Taylor & Francis.

Dadashpoor, H. and A. Afaghpoor (2016). "The new epistemic and theoretical rationality governing the spatial organization of urban systems." Interdisciplinary Studies in the Humanities 8(2): 1-28.

Dadashpoor, H., A. Afaghpoor and A. Allan (2017). "A methodology to assess the spatial configuration of urban systems in Iran from an interaction perspective." GeoJournal 82(1): 109-129.

Dadashpoor, H. and S. Saeidi Shirvan (2019). "Measuring functional polycentricity developments using the flow of goods in Iran: a novel method at a regional scale." International Journal of Urban Sciences 23(4): 551-567.

Dadashpoor, H. and Z. Yousefi (2018). "Centralization or decentralization? A review on the effects of information and communication technology on urban spatial structure." Cities 78: 194-205.

Dai, L., B. Derudder and X. Liu (2016). "Generative network models for simulating urban networks, the case of inter-city transport network in Southeast Asia." Cybergeo: European Journal of Geography.

Dai, L., B. Derudder and X. Liu (2018). "The evolving structure of the Southeast Asian air transport network through the lens of complex networks, 1979–2012." Journal of Transport Geography 68: 67-77.

Derudder, Witlox and Catalano (2003). "Hierarchical tendencies and regional patterns in the world city network: a global urban analysis of 234 cities." Regional Studies 37(9): 875-886.

Derudder, B., Z. Cao, X. Liu, W. Shen, L. Dai, W. Zhang, F. Caset, F. Witlox and P. J. Taylor (2018). "Changing connectivities of Chinese cities in the world city network, 2010–2016." Chinese Geographical Science 28(2): 183-201.

Derudder, B. and P. J. Taylor (2018). "Central flow theory: Comparative connectivities in the world-city network." Regional Studies 52(8): 1029-1040.

Derudder, B. and F. Witlox (2005). "An appraisal of the use of airline data in assessing the world city network: a research note on data." Urban Studies 42(13): 2371-2388.

Derudder, B., F. Witlox, J. Faulconbridge and J. Beaverstock (2008). "Airline data for global city

network research: reviewing and refining existing approaches." GeoJournal 71(1): 5-18.

Devriendt, L., B. Derudder and F. Witlox (2010). "Conceptualizing digital and physical connectivity: The position of European cities in Internet backbone and air traffic flows." Telecommunications Policy 34(8): 417-429.

Ducruet, C. and L. Beauguitte (2014). "Spatial science and network science: review and outcomes of a complex relationship." Networks and Spatial Economics 14(3): 297-316.

Feng, Z., W. Bo and C. Yingxue (2016). "Research on China's city network based on users' friend relationships in online social networks: a case study of Sina Weibo." GeoJournal 81(6): 937-946.

Finfgeld, D. L. (2003). "Metasynthesis: The state of the art—so far." Qualitative health research 13(7): 893-904.

Frank, H. and I. Hatak (2014). "Doing a research literature review." How to get published in the best entrepreneurship journals.

Freeman, L. C. (1978). "Centrality in social networks conceptual clarification." Social networks 1(3): 215-239.

Frideman, J. (1986). "The world city hypothesis: development and change." Urban Studies 23(2): 59-137.

González-Teruel, A., G. González-Alcaide, M. Barrios and M.-F. Abad-García (2015). "Mapping recent information behavior research: an analysis of co-authorship and co-citation networks." Scientometrics 103(2): 687-705.

Haddaway, N., P. Woodcock, B. Macura and A. Collins (2015). "Making literature reviews more reliable through application of lessons from systematic reviews." Conservation Biology 29(6): 1596-1605.

Hall, P. (1966). The World Cities Weidenfeld and Nicolson, London.

Hall, P. G. and K. Pain (2006). The polycentric metropolis: learning from mega-city regions in Europe, Routledge.

Hohenberg, P. M. and L. H. Lees (1995). The Making of Urban Europe, 1000–1994: With a New Preface and a New Chapter, Harvard University Press.

Jacobs, J. (1969). "The Economy of Cities (New York). 4." K. Hopkins,"Economic Growth in Towns in Classical Antiquity.

Ji, H. and W. Gan (2020). Data Visualization for Making Sense of Scientific Literature. 2020 International Conference on Intelligent Transportation, Big Data & Smart City (ICITBS), IEEE.

Kamalski, J. and A. Kirby (2012). "Bibliometrics and urban knowledge transfer." Cities 29: S3-S8.

Khun, T. (1970). The structure of scientific revolutions Chicago, Chicago University Press.

Kulkarni, A. V., B. Aziz, I. Shams and J. W. Busse (2009). "Comparisons of citations in Web of Science, Scopus, and Google Scholar for articles published in general medical journals." Jama 302(10): 1092-1096.

Limtanakool, N., M. Dijst and T. Schwanen (2007). "A theoretical framework and methodology for characterising national urban systems on the basis of flows of people: empirical evidence for France and Germany." Urban Studies 44(11): 2123-2145.

Liu, C. and Q. Gui (2016). "Mapping intellectual structures and dynamics of transport geography research: a scientometric overview from 1982 to 2014." Scientometrics 109(1): 159-184.

Liu, X., B. Derudder and C. G. García (2013). "Exploring the co-evolution of the geographies of air transport aviation and corporate networks." Journal of Transport Geography 30: 26-36.

Liu, Z., Y. Yin, W. Liu and M. Dunford (2015). "Visualizing the intellectual structure and evolution of innovation systems research: a bibliometric analysis." Scientometrics 103(1): 135-158.

Lucio-Arias, D. (2010). Modelling and measuring the dynamics of scientific communication, na.

Lucio-Arias, D. and L. Leydesdorff (2008). "Main-path analysis and path-dependent transitions in HistCite™-based historiograms." Journal of the American Society for Information Science and Technology 59(12): 1948-1962.

Manual, C. (1996). The Rise of the Network Society Malden, Blackwell.

Marx, W., R. Haunschild and L. Bornmann (2017). "The role of climate in the collapse of the maya civilization: A bibliometric analysis of the scientific discourse." Climate 5(4): 88.

Matsumoto, H. and K. Domae (2019). "Assessment of competitive hub status of cities in Europe and Asia from an international air traffic perspective." Journal of Air Transport Management 78: 88-95.

Meijers, E. (2005). "Polycentric urban regions and the quest for synergy: is a network of cities more than the sum of the parts?" Urban studies 42(4): 765-781.

Meijers, E. (2007). "From central place to network model: theory and evidence of a paradigm change." Tijdschrift voor economische en sociale geografie 98(2): 245-259.

Mora, L., R. Bolici and M. Deakin (2017). "The first two decades of smart-city research: A bibliometric analysis." Journal of Urban Technology 24(1): 3-27.

Mora, L., M. Deakin and A. Reid (2019). "Combining co-citation clustering and text-based analysis to reveal the main development paths of smart cities." Technological Forecasting and Social Change 142: 56-69.

Neal, Z. (2010). "Refining the air traffic approach to city networks." Urban Studies 47(10): 2195-2215.

Neal, Z. (2014). "The devil is in the details: Differences in air traffic networks by scale, species, and season." Social networks 38: 63-73.

Neal, Z. P. (2011). "From central places to network bases: A transition in the US urban hierarchy, 1900–2000." City & Community 10(1): 49-75.

Peris, A., E. Meijers and M. van Ham (2018). "The evolution of the systems of cities literature since 1995: schools of thought and their interaction." Networks and Spatial Economics 18(3): 533-554.

Pflieger, G. and C. Rozenblat (2010). Introduction. Urban networks and network theory: the city as the connector of multiple networks, SAGE Publications Sage UK: London, England.

Pred, A. (1977). City-systems in Advanced Economies (Hutchinson, London).

Sassen, S. (1991). "The global city." New York.

Sassen, S. (2002). Global networks, linked cities, Psychology Press.

Sassen, S. (2004). "The global city: Introducing a concept." Brown J. World Aff. 11: 27.

Smith, D. A. and M. Timberlake (1995). "Cities in global matrices: toward mapping the world-system's city system." World cities in a world-system: 79-97.

Smith, D. A. and M. F. Timberlake (2001). "World city networks and hierarchies, 1977-1997: an empirical analysis of global air travel links." American Behavioral Scientist 44(10): 1656-1678.

Taaffe, E. J. (1956). "Air transportation and United States urban distribution." Geographical Review 46(2): 219-238.

Taaffe, E. J. (1962). "The urban hierarchy: An air passenger definition." Economic geography 38(1): 1-14.

Taylor, P., B. Derudder, M. Hoyler, P. Ni and F. Witlox (2014). "City-dyad analyses of China's integration into the world city network." Urban Studies 51(5): 868-882.

Taylor, P. J. (2001). "Specification of the world city network." Geographical analysis 33(2): 181-194.

Taylor, P. J. and R. Aranya (2008). "A global 'urban roller coaster'? Connectivity changes in the world city network, 2000–2004." Regional studies 42(1): 1-16.

Taylor, P. J., G. Catalano and D. R. Walker (2002). "Measurement of the world city network." Urban studies 39(13): 2367-2376.

Taylor, P. J. and B. Derudder (2004). World city network: a global urban analysis, Psychology Press.

Taylor, P. J., M. Hoyler and R. Verbruggen (2010). "External urban relational process: Introducing central flow theory to complement central place theory." Urban studies 47(13): 2803-2818.

Van der Laan, L. (1998). "Changing urban systems: an empirical analysis at two spatial levels." Regional studies 32(3): 235-247.

Van Eck, N. J. and L. Waltman (2011). "Text mining and visualization using VOSviewer." arXiv preprint arXiv: 1109.2058.

Van Eck, N. J. and L. Waltman (2014). "CitNetExplorer: A new software tool for analyzing and visualizing citation networks." Journal of informetrics 8(4): 802-823.

Van Eck, N. J. and L. Waltman (2017). "Citation-based clustering of publications using CitNetExplorer and VOSviewer." Scientometrics 111(2): 1053-1070.

Van Raan, A. F. (2005). "Measurement of central aspects of scientific research: Performance, interdisciplinarity, structure." Measurement: Interdisciplinary Research and Perspectives 3(1): 1-19.

Wang, J., H. Mo, F. Wang and F. Jin (2011). "Exploring the network structure and nodal centrality of China's air transport network: A complex network approach." Journal of Transport Geography 19(4): 712-721.

Yang, H., M. Dijst, P. Witte, H. Van Ginkel and W. Yang (2018). "The spatial structure of high speed railways and urban networks in China: A flow approach." Tijdschrift voor economische en sociale geografie 109(1): 109-128.

Yang, H., F. Dobruszkes, J. Wang, M. Dijst and P. Witte (2018). "Comparing China's urban systems in high-speed railway and airline networks." Journal of Transport Geography 68: 233-244.

Yang, X., B. Derudder, P. J. Taylor, P. Ni and W. Shen (2017). "Asymmetric global network connectivities in the world city network, 2013." Cities 60: 84-90.

Yousefi, Z. and H. Dadashpoor (2020). "How do ICTs affect urban spatial structure? A systematic literature review." Journal of Urban Technology 27(1): 47-65.

Zhang, Y. and A. Zhang (2016). "Determinants of air passenger flows in China and gravity model: deregulation, LCCs, and high-speed rail." Journal of Transport Economics and Policy (JTEP) 50(3): 287-303.

Zhu, Z., A. Zhang and Y. Zhang (2018). "Connectivity of intercity passenger transportation in China: A multi-modal and network approach." Journal of Transport Geography 71: 263-276.

Zitt, M. (2015). "Meso-level retrieval: IR-bibliometrics interplay and hybrid citation-words methods in scientific fields delineation." Scientometrics 102(3): 2223-2245.

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