BIBLIOMETRIC ANALYSIS ON STREET NETWORK COMPONENTS IN INFLUENCING GENOME OF URBAN MORPHOLOGIES

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ABSTRACT

Bibliometric or thematic analysis is a type of research approach used in the library and information science. This paper aims to analyze the street network elements as one of the city organisms that is integral to the city's cohesive form. The street network also influences the genome of urban morphology. In this research, the qualitative analysis and statistics were used to describe a publication pattern in the given body of literature. The publications from Scopus and Web of Science were compiled and analyzed in depth. The finding showed that urban morphologies' genome had been indeed influenced by the street network components, namely street hierarchy, permeability and legibility, streetscapes and pedestrian movement. The components were mutually present in the urban morphology genome, which can accelerate the movement within the city. The street hierarchy shows that this structure becomes an organism that viral for the city's development. The transition of the street's hierarchical system contributes to the changes or evolution of the city from time to time. Meanwhile, permeability represents the image of the city. The physical and visual images of a city are essential to leapfrog the city to reach the global recognition level. However, the inconsistency of implementation of the permeability element will negatively impact the place. Urban streetscape is essential to avoid a negative impression on the city image, which should have otherwise provided a city's visual richness. Lastly, pedestrian accessibility through appreciation of the street network attracts the movement within the public spaces. In conclusion, the street network components were found to have influenced onto the city's morphology over time and became a backbone for the latter, reflecting the urbanization process. Nevertheless, based on the bibliometric analysis, the study of street network morphology has not been sufficiently extended from many Asian countries' theoretical ground.

Keywords: General bibliometric analysis, street network, urban morphology, and urban planning

INTRODUCTION

Genome is defined as Deoxyribonucleic Acid (DNA) content that provides information about one organism's cell. DNA carries the cell signatures or attributes which generations would then inherit (Goldman, 2016; Stencel, 2013). According to Stencel et al. (2013), the genome's content can function accordingly if the elements within were consistent for an extended period, say across generations. It can be altered and maintained cohesively. Thus, it can be considered as a logical extension of the evolutionary gene. In the context of urban morphology, the influence of elements such as street network can be considered an organism (Strappa et al., 2015) that represents a city circulation. This is similar with a human respiratory system, where the city's design needs to function as a healthy body within which blood system is free to flow (Sennett, 2002). Thus, the city is constantly growing and transform from time to time. This has resulted in the genome of urban morphology; which is the city's DNA. The street network elements are part of the urban morphology elements that delineate the city's circulation and layout. In the late 1950s, the street network is an urban planning and design layout preferred mostly to meet the motor vehicle requirements due to rapid motorization growth. Streets become a structure accommodating heavy traffic designed to meet geometric engineering requirements.To some extent, this has been detrimental to the street functioning as an area of social expression (Moughtin, 2003; Jones, Marshall & Boujenko, 2008, Wan Ismail, 2018; Nor & Mohd Noor, 2018). Various large-scale development projects can be found everywhere and in fact, it is daunting when the encroachment of public space becomes a trend. While streets become wider, the spaces for people to interact become scarce (Liang,2014).

Street network is an essential element to appreciate how human settlements are built, which led to the establishment of the city. Moreover, it connects space between buildings and facilitates the movement of people either using pedal power or motor vehicles. Marshall (2005) highlights that streets incorporated three physical aspects within the city. These are the circulation route, public space and built form. Woolley (2012) identified people, traffic and society as 'arteries' and 'veins' of a city. However, engineers, urban planners and architects would not perceive these three aspects as sufficiently significant because traditional streets have been viewed as too rigid when compared to modern street layouts, which are more free-flowing in design. Thus, the objective of this paper is to analyze the patterns and elements of street network as city organisms that are integral to the cohesive for the city, which in turn influence the genome of urban morphology. Peer-reviewed articles on street networks relating to urban morphology were selected as baselines to provide an overview of the study. Wan et al. (2018) urged designers, planners and policy makers to examine traditional streets with different street cultures and learn from the lessons. Successful street helped redefine the street character as an important public space rather than as a mere channel for movement and as a collector of stories of people, history, achievements and ideology (Kurek, 2020).

LITERATURE REVIEW

Street Network Theories

A street network is a system that connecting lines and points and represents a system of streets or roads (Benson et al., 2016; Zhang, et al., 2017; Marshall et al., 2018). It also considers as one of the elements in urban form and the backbone of the city, which reflects the urbanization process. Street network analysis provides an understanding of how the cities are shaped and developed in a way to attain the dynamic (Paul, 2008; Barthelemy, 2015; Ma, D. et al., 2020). Moreover, street is one of the essential elements in urban form. Urban form builds up towards urban history and morphology studies, which in turn impacted the social, economic, environmental and reconstruction change (Strano et al., 2012; Shpuza,2014; Porta et al., 2014 and Fang et al., 2018). The study of streets can provide information on the urban growth of the city and enlighten the evolution of the urban form in a particular area. According to Cheng (2011), street networks help to identify the transformation of the urban form development, and the evolution of urban form and structure, which can determine the morphology of the city. Urban morphology is derived from the configuration of urban fabrics, natural and human-made structures, street network/layout, architectural complexity, open space, and other physical elements (Moudon, 1997; Li and Yeh, 2004; Sharifah et al., 2013, Sun, 2013; Paul, 2008). Ibrahim and Allater (2017) emphasized that street network and urban form are mutually influencing the morphology of the city over time, demarcating a city's image (Lynch, 1960). According to Oliveira (2016), even though the city faced the urbanization process from past to present time, the streets network offers excellent resistance and stability through the process of transformation. Hence, the street network is a durable and essential component that influences the design of today's cities (Ravari & Mazloomi, 2015). According to bibliometric analysis based on the Scopus, Science Direct, and WoS databases, China is the leading country in the study of street networks, followed by the United States and the United Kingdom. However, Asian country mostly less than four publications from the year 1997 to 2020, and Malaysia have only at least three publications throughout the period.

Street Network Components

Fathi et al. (2020) and Xu (2018) emphasized that the impact and footprint of human activities reflect the city's physical form. The street is one of the primary elements in morphology analysis that exposed to the transformation of the city over time. There are also several street network components influence the morphology of the city, namely street hierarchy, permeability and

legibility, streetscapes, and pedestrian activities. These components reflect the texture of the city's townscape. City's townscape in turn dictates the pedestrian activities. According to Marshall (2005), the introduction of street hierarchy began in Ancient Rome and accentuated during which Leonardo Da Vinci proposed the segregated street systems in the functions of different hierarchy. Ancient Roman cities have been used as traditional examples. Hence, street systems adopted today have been traffic engineering-oriented instead of functioning as urban open spaces. The hierarchy reflects the road capacity and can be a highly structured exercise plan (Yuono, 2019). The street system or hierarchical planning varies from one country to another. Some countries had so many terms in the street system compared to others but eventually, they provide the same meaning and functions of the street. For example, road and traffic in urban areas in the United Kingdom were divided into four hierarchical street terms, which are primary distributor, district distributor, the local distributor, and access road. Meanwhile, Melbourne, Australia and Malaysia use similar hierarchical terms, namely expressway, arterial road, collector road, and local road. In contrast, Belgium has six hierarchical terms consisting of motorway, metropolitan area, trunk road, inter-distance road, through the street, and local street (Marshal, 2005; Paraphantakul, 2014). Regardless of the terms applied in the various countries, characterizing and comparing increase the appreciation of the mechanism governing the formation and evolution of these systems (Barthelemy, 2017). Furthermore, street hierarchy is considered as a way of presenting intended information and conforms to social rules that underlay architectural and urban designs that used to create public, semi-public, and semi-private spaces.

Behnoush (2017) advocated that the city should be easily recognized as urban public space not only by the locals but also by the tourists. It must provide a comprehendible route for accessibility and be easily identified since people perceive and understand the surrounding environment by visualizing urban designs. Permeability is the significant physical quality that shaped the character of the streets (Wan Ismail et al., 2018). Permeable or connectedness is a significant element in the city to integrate all the city's characteristics and environmental factors to the people. The internal connection within the city can spur a sense of belonging among the people, especially regarding the physical form that reflected history, events, and memories associated with the city (Mansouri, 2009). Meanwhile, legibility is a way for people to find their way around the area. There are many ways in which design can create legibility looks to provide ease for the user and make sure the route is sufficiently clear to interpret changes in building form, materials and finishes, landscape features, or some focal point of the building, landmark, gateway or many other designs. From a broader perspective, designers should ensure that journeys through the network are relatively straightforward so that the ability of an element to illustrate a clear image in the view of the observer is enhanced (Bentley, 1985; Lynch, 1990; Tavassolian & Mostafa, 2015).

Shiller and Evan (2006) stressed the conveyance of integration of functions and the spatial relationship of the built environment (Tavsssolian & Nazari, 2015) by city's legibility. Similarly, Behnoush (2017) explained that the urban elements improve the legibility of the city and provide positive impacts especially towards the minds of the citizen. This is through inducing the recall ability of the desirable image of a particular space. Indeed, it enhanced the quality of space noteworthy. Accordingly, the visual hierarchy of streets is an essential component for understanding and perceiving a city that could further shed light on human wayfinding and urban morphology. Streetscape is an urban public space that is built to promote and facilitate the basic necessity and amenities of people as social beings (Vikas, 2006; Harsritanto & Wijayantri, 2017, Hario et al., 2018). Streetscape elements are one of the significant and impact factors to the cities' visual image, which is relevant in achieving the sustainable cities status (Tucker et al., 2004; Askari and Soltani, 2018). However, in many cities, visual image such as streetscape is lacking, and it affects the impression of the city images negatively (Rehan, 2013). There are many ways

to interpret urban streetscape and improve the urban design in the city. Special paving at crosswalks, planter box installation, street furnishings including pedestrian-scale lighting, benches provision, and paving patterns in sidewalks design are some of the alternatives of urban streetscapes that could offer a positive visual images. The design of the physical form strongly influences human behavior and creates a pedestrian realm. Successful streetscapes are designed for pedestrians and cars, and they are shared by cyclists, motorcyclists, bus operators, bus passengers, private vehicle owners, and freight vehicle operators (Carmona, 2017). The street's robustness depends on the number of people engaging in the place while carrying out activities such as walking, chatting, lingering, and gathering.

Most of the scholar agreed that the pedestrian accessibility and street network were correlated (Tsigdinos et al., 2019; Kang, 2017; Ismail & Wan, 2017; Kang, 2017; Hajrasouliha & Yin, 2015; Ozbil et al., 2011). The configuration and design of the street network contribute to pedestrian accessibility, thus attract the pedestrian movement of public space (Tsigdinos et al., 2019) which contribute to social equity and quality of urban life (Kang,2017). Additionally, urban settings for pedestrians are crucially essential in order to create a comfortable pedestrian environment (Agrawal & Schimek, 2007; Lopez-Zetina, Lee, & Friis, 2005) like mixed high development with public transit. Similarly, the configuration of the street network and the physical environment play an utmost role in the movement and continuity of the pedestrians (Javier et al., 2019), where fewer obstacles and higher intersection of the street network will lead to more attractive users to choose to travel in the shortest time (Leslie et al., 2007; Saelens et al., 2003). These street network components play crucial roles in the robustness and vibrancy, which are contents of the genome of urban morphology. All the components were interconnected to create the city and demarcate the built environment. The hierarchical street and the visibility of the city supported by the good ambience of streetscapes will lead to higher densities of the pedestrian movement. Thus, these components will affect the townscapes and street pattern of the city.

The Relation between Street Network with Urban Morphologies
Recording the history of the city or urban morphology is essential, especially in settlement formation as it can become a benchmark for a more significant city in the future. Urban morphology has set the foundation for the identification and comprehension of urban models. This also applies to the comparison with settlement patterns, in terms of form structure and the comparison between the city's morphology and topology (Colaninno, Alhaddad & Cladera, 2015). Nevertheless, the city's morphology, especially in the early settlement, can be a useful guide or an example of city model to generate or produce a more sustainable and resilient city. Furthermore, the city's growth can be determined by the practical and systematic street layout influencing the urban form or urban planning activity. Hence, the city's street system is essential in creating a sustainable and resilient city in the future. Street system also influences urban planning development, which is a tool in the urbanization process (Barthelemy, 2015). Similarly, Li et al. (2017) argued that a good street network is a core factor in the urban context and it is worthy of large-scale researching of the existing urban space, primarily in historic areas. Thus, it can maintain the vitality of urban space as a whole. As Wan et al. (2018) and Shamsudin (2011) mentioned, it is significant to study the morphological form of the town in order to understand its origin, function, and growth. Undoubtedly, it helps to shape the town and its identity through the art of street elements and other physical elements from various eras; from early until the present.
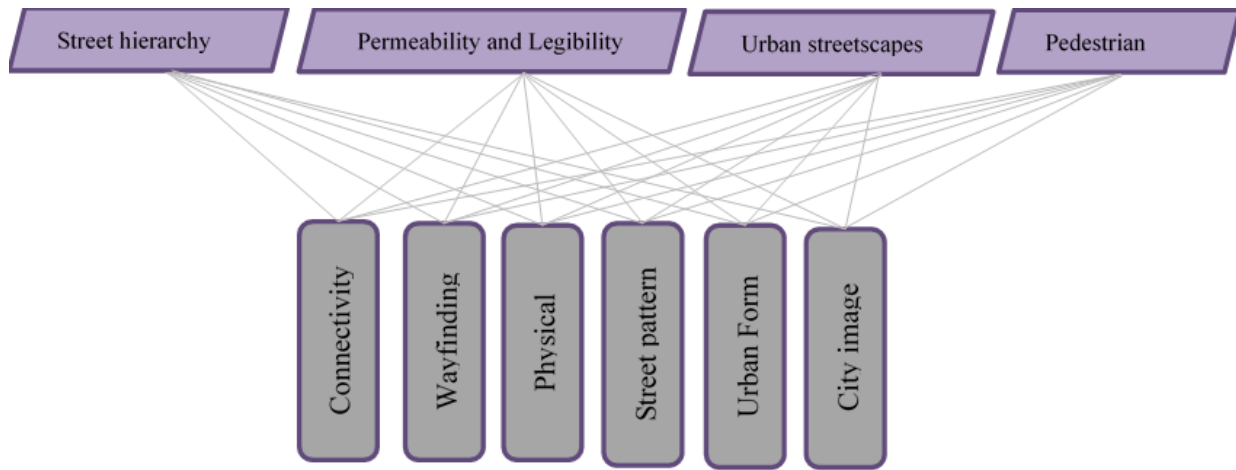
Fig. 1 The relationship of street network elements and the urban morphology

Figure 1 shows the interaction of street network components in the context of urban morphology. The multidirectional relationships are expressed as the growth process of the cities. This is translated into the connectivity of urban form and systematic wayfinding. The latter has avoided the cities from turning into a labyrinth of unconnected and discontinuous pathways (Shariffi, 2018; Dalton, R. & Dalton, N., 2017; Ball, 2004). Thus, street hierarchy enables one to visually experience a city by sensing physical qualities such as urban streetscapes. Street hierarchy is also a three-dimensional object within civic space (Lynch, 1960). In the context of infrastructure, physical element of the street is the essence that form the history and civilization of a place Mehta (2013). Additionally, the components in Figure 1 are interconnected to the morphology of a city. Their interconnection offers a high density of connectivity. This in turn, makes it possible for pedestrian movement in public places to shape the street pattern and image of the city.

Table 1 Street network studies based on study area that related to the urban morphology context

Study Area	Authors
Social Science/ Urban Studies	Boeing, G (2020,2019); Kane, K., Kim, Y.-A. (2020); Pafka, E., Dovey, K., Aschwanden, G.D.P.A. (2020); Nice, K.A., Wijnands, J.S., Middel, A., Zhao, H., Stevenson, M.(2020); Ma, D., Guo, R., Zheng, Y., He, F., Zhu, W.(2020); Zhao, P., Yen, Y., Bailey, E., Sohail, M.T. (2019); Araldi, A., Fusco, G. (2019) Berghauser Pont et al., (2019); Orellana, D., Guerrero, M.L. (2019); Yen, Y., Zhao, P., Sohail, M.T. (2019) Serra, M., Gil, J., Pinho, P. (2017), Blumenfeld-Lieberthal, E., Serok, N., Milner, E.L. (2018); Serra, M., Gil, J., Pinho, P.(2017); Barthelemy, M (2017); Ye, Y., Yeh, A., Zhuang, Y., Van Nes, A., Liu, J. (2017); Oliveira, V., Medeiros, V. (2016); Omer, I., Zafrir-Reuven, O (2015); Ferdous, F (2012
Engineering	Boeing, G.(2020); Torres-Cruz, N., Villordo-Jimenez, I., Montiel-Saavedra, A. (2020)Hu, C.-B., Zhang, F., Gong, F.-Y., Ratti, C., Li, X.(2020); Wurm, M., Taubenböck, H. (2018);Al-Saadi, Z.(2018); Srinurak, N., Mishima, N., Kakon, A.N.(2016); Cai, H., Yao, G., Li, M. (2015)
Arts & Humanities	Rokem, J., Weiss, C.M., Miodownik, D.(2018); Ye, Y., Van Nes, A.(2014), Khirfan, L. (2011); Osmond, P. (2010)
Architecture	Rashid, M; Shateh, H (2012); Mohajeri, N; Gudmundsson, A (2014), Dziubinski, D (2016); Hillier, B (2014)
Remote sensing	Yadav, P., Agrawal, S.(2018); Wurm, M; Taubenbock, H (2018); Li, Y., Wu, J., Zhu, L., Tachibana, K. (2016); Kaczałek, B., Borkowski, A (2016); Laneve, G., Santilli, G., Cadau, E. (2009)

(Source: Scopus and WoS, 2020)

Table 1 shows that the term street network is accepted as a multidisciplinary term in various fields. It is commonly used within the context of morphology studies, in various subjects such as social science, urban studies, engineering, arts and humanities, architecture and remote sensing. Records of Scopus and Web of Science (WOS) (2020) illustrate that various approaches, methods and tools were deployed to analyze street network pattern. Street network studies looking into a city are relevant to demonstrate the city's capability of accelerating the urbanization process within its realm (Ma, D. et al., 2020; Paul, 2008; Barthelemy, 2015; Oliveira, 2016; Shpuza, 2014).

RESEARCH METHODOLOGY

Bibliometric analysis (Pritchard, 1969) is a descriptive statistical expression of analyzing scientific literature (books, articles, and other publications) (Youngblood and Lahti, 2018). This method is currently applied in many subject areas (Vijaylashmi and Ambuja, 2013), and is the method adopted for this study on a selection of sources in Scopus and WOS listing. WOS is a sturdy platform consisting of more than 33, 000 journals and covers almost 256 disciplines including environmental sciences, social sciences, geography, health and medical studies, urban planning and development. Meanwhile, Scopus is the second largest database, which is initiated by Elsevier and launched in 2004. Scopus covers nearly 36, 377 titles from almost 11, 000 publishers. The temporal coverage of Scopus is from 2004 until the present.

For this study, the search was carried out using the terms "urban street network" and "morphology" in the title, abstract and keywords. These descriptive keywords help to limit the selection by only focusing on the street network and morphology terms that would later be narrowing the selection through the use of other eligibility criteria. Eligibility processing would further determine the relevance of the source. There are several steps in sieving the relevance of any one article. Firstly, documents or manuscripts should only be sourced from journal articles, conference papers, or book chapters. This meant that other literature sources are not qualify. These types of literature are often supported by empiricism, which rendered the weightage of literature trend or pattern. Personal review which was susceptible to biasness was found to be illegible for bibliometric analysis of this paper.

Secondly, analysis was only concentrated on sources written using English medium. This was to avoid confusion and issues raised by transliteration. Finally, the publication years between 1997 and 2020 were deemed sufficient for the temporal context set in assessing the literature. A period of 23 years has been argued as adequate to monitor the research trend relevant to the subject matter. The list of publications was obtained and analyzed based in the pre-determined parameter as listed. These are the number of publications per annum, the number of publications by study area, and the number of countries' publications. All in all, a sample of 245 publications were selected for this bibliometric analysis. Table 2 summarizes the inclusion and exclusion criteria.

Table 2 The inclusion and exclusion criteria of eligibility process

Criterion	Eligibility	Exclusion
Literature type	Article, Conference, Book chapter	Review, Letter, Editorial, Press, Early Access
Language	English	Non-English
Timeline	Between 1997-2020	<1997

RESULTS AND DISCUSSIONS

Annual publications varied in numbers for each database. Absence of publication was observed for the years 1998, 1999 and 2002 under the Scopus database. The results are shown in Table 3 and Figure 2. Articles under Web of Science (WoS) that met the criteria began to be published in 2003. There was an absence of publication for the years 2007 and 2010 respectively. An observation made was that publication rose slowly in the beginning years and mostly picked up from 2008 onwards. However, for WoS, the figure dropped from 6 publications in 2012 to only 2 in 2013. Beyond 2008, the rapid increase in publication has been attainable due to the ease of the Internet access and the initiation of multi-platform databases including Google Scholar and Dimensions apart from Scopus and WoS. Google browsing engine became popular since it enabled surfing and searching articles using keywords and offered user-friendly online connections. Additionally, the Internet through social media provided extended social interaction to share mass information, and users could enjoy all value services available. In parallel, studies of urban street networks drew increased attention of the research enthusiasts of city evolution. This has also been attributable to unlimited access of research materials in the borderless world of the Internet.

Table 3 Publication on Web of Science and Scopus based on "Street Network" keyword

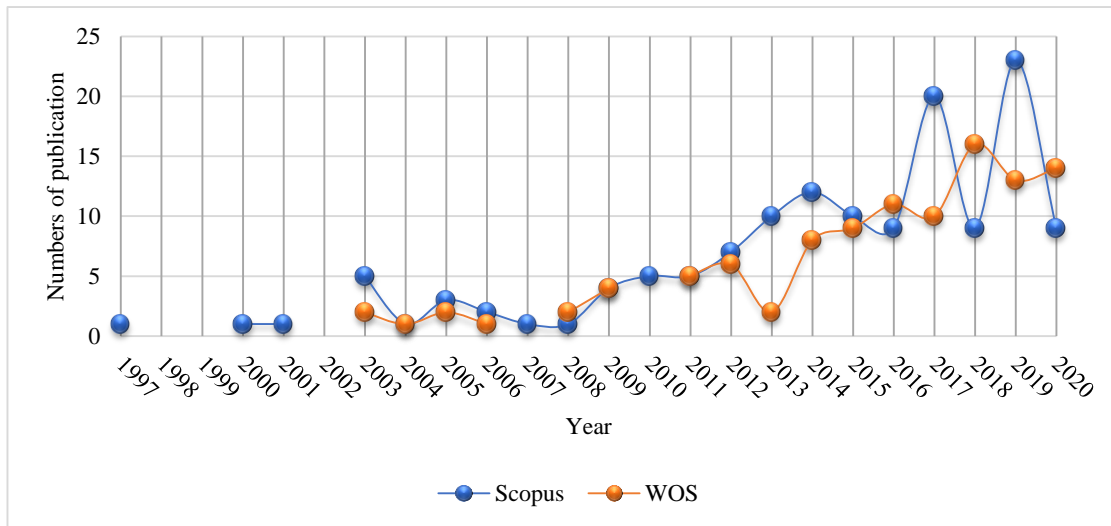| No	Year	Web of Science	Scopus
1	2020	14	9
2	2019	13	23
3	2018	16	9
4	2017	10	20
5	2016	11	9
6	2015	9	10
7	2014	8	12
8	2013	2	10
9	2012	6	7
10	2011	5	5
11	2010	-	5
12	2009	4	4
13	2008	2	1
14	2007	-	1
15	2006	1	2
16	2005	2	3
17	2004	1	1
18	2003	2	5
19	2002	-	-
20	2001	-	1
21	2000	-	1
22	1999	-	-
23	1998	-	-
24	1997	-	1
TOTAL		106	139
		245	

Source: WoS and Scopus (2020)

Fig. 2 Trend of publications by year
(Source: WoS and Scopus, 2020)

Scientific areas of publications under the two sources have been distributed using pie charts in Figure 4, and each respectively provided for Scopus and WoS. The various specialized areas differ between the two databases. Scopus has a higher composition of social sciences publications (29%), followed by Earth and Planetary Sciences (25%). In contrast, WoS has the highest (28%) paper contributions in the field of Environmental Sciences Ecology, followed by Urban Studies (21%). These classification areas were categorized to be related to the background study of this paper and therefore were limited to pertinent key areas only. Other categories have been excluded based on the research objective set earlier. In addition, the papers analyzed did not possess matched keywords. Figure 4 also depicts that, while numerous fields might have some relevance to street networks studies, the database recorded the fields of engineering, computer science and geography as those with the most publications outputs. The relation between street networks and the city development did not only focus on structural form of the street, but also relevant to the culture development, the environment and technology. Hence, there were many possibilities to adopt approaches and methods in order to carry out studies that proving street networks elements as a part of the city's DNA. Moreover, street networks are not the only merely an element studied as a subject of urban morphology. Values for cities' development are also generated when studying this subject under the realm of architecture, history, culture, arts and human settlements. Development process of a city is relevant to all of these research fields.
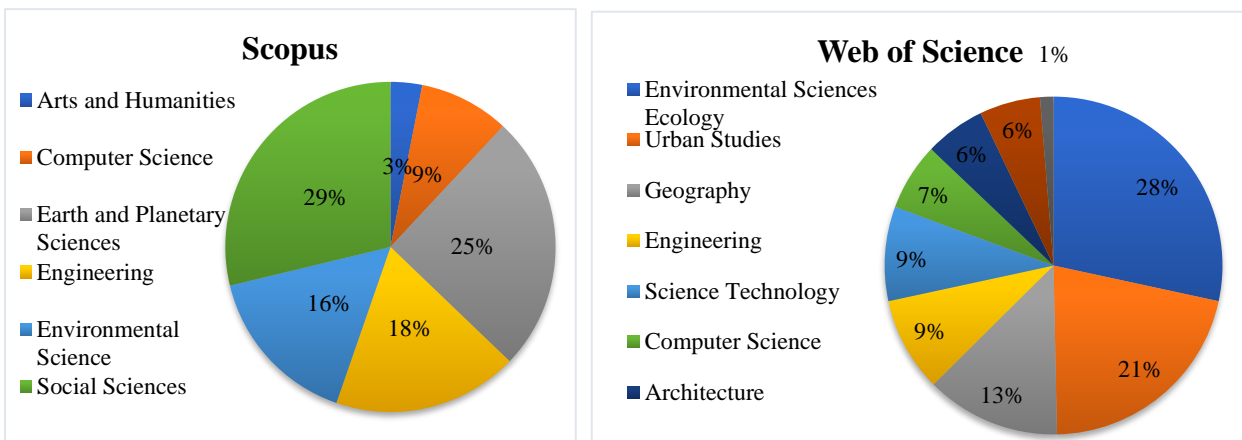

Fig. 2 Distribution of publications by study area from the Scopus database (left) and Web of Science (right)

Figure 5 shows the country of origin of selected papers. The research topic has raised its interest, primarily among researchers in China, the United States and the United Kingdom (respectively sourcing 20%, 15% and 13% of the total publications). China led the country of origin in the race of the highest publications of scientific papers. This may be contributed by the country's overall urban growth and massive expansion in the research activities. Additionally, the advancement of technology, increased research funds allocation and increased of expertise may also drive to the growth of scientific research in this area. China's rapid urban development experiences that caused many changes to take place within the cities may also be the main important factor.

There was a lack of research among Malaysian researchers on this topic, with only 2% publication contributed throughout the 23 years duration. As such, this area is a potential research niche that Malaysia can venture into as the number of heritage and historical cities in the country that can be monitored. A subset research area can focus on the pattern and trend of street networks. China and European countries have proven to have utilized the street network elements in order to examine and comprehend their cities ever since the early development of their civilization until the present time. This was in tandem with the rapid development they have experienced, leading to the vast study opportunities to direct new city development guidelines. Other Asian nations may reflect on or avoid any large-scale urban space demolition in historical areas, by increasing the awareness of the historical cities' value and record the morphology by using urban street networks as a study element.
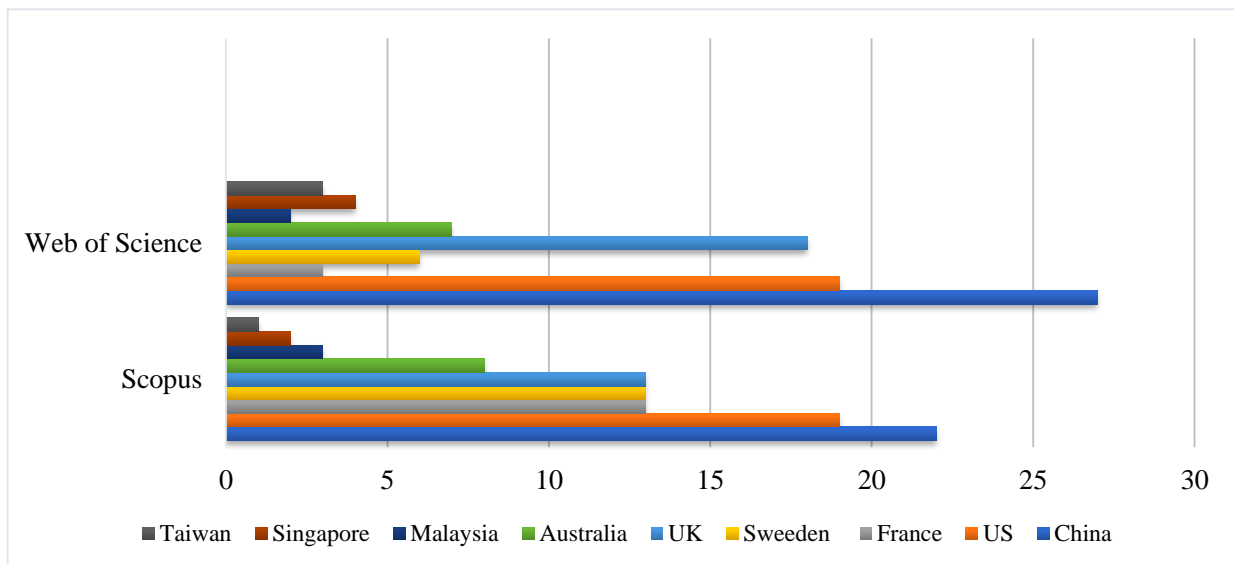

Fig. 3 Distribution of publication by country

CONCLUSIONS

The research findings showed that various street network components recorded the DNA of the urban morphology genome. The inter-relation between street network components, street network, and urban morphology represents cells in a physiological being that created the city's core. Literatures from 1997 until 2020 have been analyzed to reflect some of the interests in this subject matter. An extensive study should be conducted in order to provide comprehensive knowledge of the elements that integral to the formation of the city. Street network elements can be studied as fragmentation of street hierarchy, permeability, legibility, urban streetscapes and pedestrian accessibility. These are influenced by and also considered as a genome of urban morphology. They are the components of evolution and transformation of the city, which emphasized the city's existence and vibrancy. The symbiosis of these components will form the future city. Based on the bibliometric analysis, research in street networks as part of the

morphological process of city development has increased in quantum and field areas from year to year. Street(s) is recorded as an element delineating the history of the city. There are existed various approaches and different methods to study the urban street morphology. This paper's research objective that analyzes the literature has led to the exploration of the origin, function, and growth of the city as perceived from the viewpoint of street networks. The experiences attained through studying the street network layout have brought this paper to the appreciation of human settlements, society and culture as seen from the evaluation of street networks. Recording and documenting street network evolution are fundamental to the portrayal of good traits of or the city's DNA.

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