

Spatial Legibility: Bibliometric and Visualization Analyses Using Vosviewer Software (1975-2023)

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Abstract – Spatial legibility has been associated in the literature as being comprehensible of the space, easy wayfinding in the space, and being able to draw a cognitive map of the space. This study aims to analyze the scope of spatial legibility research using bibliometric analysis and visualization using VOSviewer. The Web of Science database was utilized to gather information on spatial legibility studies. Title, keywords, and abstract requirements were used to construct the search results, which were based on topic categories from spatial legibility research. The Web of Science database research keywords (TS= ("spatial legibility")) OR TS= ("architectural legibility")) OR TS= ("urban legibility")) OR TS= ("legible cities")) OR TS= ("legible city"). It has been determined that the most used words by the authors in their publications are space syntax, legibility, intelligibility, cognitive map, image, landmark, spatial legibility, urban design, way finding, navigation, virtual environment, and perception. To sum up, this article will give an idea to researchers who will research spatial legibility.

Keywords – architectural legibility, spatial legibility, urban legibility, VOSviewer, Web of Science.

DOI: 10.18421/SAR63-01

<https://doi.org/10.18421/SAR63-01>

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Received: 03 August 2023.

Revised: 05 September 2023.

Accepted: 11 September 2023.

Published: 26 September 2023.



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<https://www.sarjournal.com>

1. Introduction

Legibility was described by Kevin Lynch as “the ease with which its part can be recognized and can be organized into a coherent pattern” [1].

Weisman [2] has linked the legibility of locations to the ease of navigational behavior. He emphasized that the general features that determine legibility in locations are signs, perceptual access, architectural differentiation, and plan configuration. Passini [3] has similarly defined the legibility of locations. It stated that legibility is related to environmental quality and directly affects navigation.

Garling [4] stated that the legibility of locations depends on the diversity of locations, the complexity of plans and the level of visual access. Herzog and Leverich [5] describe the concept of legibility in their work as spatial features that can help to find cognitive mapping and direction. In the research by Koseoglu and Onder [6] it is stated that two variables can be used to measure the site legibility. The first is the complexity of the space, and the second is the characteristic of sign elements. Koseoglu [7] has mentioned the subjective and objective aspects of legibility. She has analyzed the concept of legibility in the space with the concepts of being organized, able to navigate, create images. The spatial legibility of the site is evident from the common expression of many theorists that it varies according to the plan, the spatial configuration, the marks on the site and the personal factors, and the legibility of the locations is an important design issue that facilitates the behavior of navigational.

In spatial legibility research, the methods differ in scales as well as in different methods. Some of these researches are at the urban scale, others at the building and indoor scale. Urban-scale studies are image of the city [1]; visual clues and pathway configuration [8]; intelligibility affect [9]; influence of geometry [10].

In addition, other studies at the urban scale are as follows; subjective and objective landmark [11]; syntactic and subjective legibility [12]; spatial knowledge acquisition [13]; using GIS [14]; syntactic legibility of image elements [15]; urban image [16]; spatial legibility parameters of children [17].

Spatial legibility studies at building scale are as follows: conceptual model of architectural legibility [18]; environmental learning [19]; abstract and scenographic imagery [20]. The table below shows a comparison of some urban-scale studies on spatial legibility. Some related urban research on spatial legibility is comparing research methods (Table 1). As shown in Table 1 research area, respondent sampling, research method and analysis element some urban research to related spatial legibility.

2. Bibliometric Analysis of Research on Spatial Legibility.

This article examined a bibliometric analysis of research on spatial legibility. In this research, data analysis in the VOSviewer application of the publications related to legibility was examined. The publication year of these publications, citations to publications, document types, published country/region, and publication Web of Sciences indexes are tabulated. In addition, visual maps of the obtained data were created using the VOSviewer program. With these maps, the most cited publication and the network visualization, overlay visualization and density visualization of the most cited authors were created. In addition, citation sources, co-citation cited source, co-citation cited references, co-citation cited author co-occurrence author keywords analyze were made in VOSviewer program. Various visualization technologies have been utilized for science mapping and bibliometric analysis throughout the last few years [21]. VOSviewer is a widely used tool with a user-friendly graphical interface and is useful for building bibliometric networks of countries, publications, organizations, and authors [22].

Network analysis can be created in different ways. VOSviewer program has a citation, co-citation co-occurrence, co-authorship and bibliographic coupling, was utilized to identify significant emphasis areas and identify influential authors, publications, and sources using VOSviewer as a scientific mapping software tool.

Term co-occurrence analyses were used to find thematic clusters in the issue of spatial legibility. This bibliographic method can be utilized to construct the theme clusters as well as detect the primary core concepts and identified topics [23]. Items are represented in the network visualization by their label and, by default, a circle. The weight of an object determines the size of the label and the circle of an item. The larger the label and the circle of an object, the heavier it is [24]. It was able to specify the theme clusters using the software based on the potency of the linkages between the phrases, as shown in Figure 3 network visualization of the VOSviewer analysis. Types of analysis: co-occurrence unit of analysis: author keyword. It is possible to say that overlay visualization and network visualization are the same, with the exception that the elements are color-coded dissimilarly. In the overlay visualization, items can be colored in two ways. If an item has a score, the color of the item is decided by dividing the score by ten, with colors ranging from blue (lowest score) through green to yellow by default (highest score) [24], as shown in Figure 3 overly visualization of the VOSviewer analysis.

There are two types of density visualization. First density visualization is “item density visualization” and second density visualization is “cluster density visualization”. The color of each point in the item density visualization represents the density of objects at that location. Colors default to blue, green, and yellow. The closer a point's hue is to yellow, the greater the number of things in its vicinity and the higher the weights of those items. The opposite is true: the fewer items in a point's vicinity and the lower the weights of those items, the near the point's hue is to blue. Figure 5 shows the results overly visualization of the VOSviewer analysis. The research questions that this article focuses on are;

- How to visualize bibliometric analysis of research on spatial legibility using VOSviewer?
- What is the number of publications is the spatial legibility research across different document types, index, and countries?
- What is the rate of citations is the spatial legibility research across different authors, documents, sources and countries?
- What are the most common used words by the authors?

Table 1. Comparing research methods in cases of spatial legibility -some related urban research

Classification/ Authors	Research area	Respondent sampling	Research method	Analysis element
(Lynch, 1960)	Boston, Jersey, Los Angeles/United States	60 professional	To draw cognitive map	Path, Edge, Node, District, and Landmark
(Topcu and Topcu, 2012)	Konya/Türkiye	30 undergraduate students	To draw cognitive map	Lynch's analysis and Nasar analysis
(Koseoglu, 2012)	Levent, Beşiktaş, İstanbul/Türkiye	Architecture Students at Yıldız Technical University, 58 participants	Formal analysis, subjective analysis and syntactic (space syntax) analysis	Landmark and Path two types' image elements and route knowledge.
(Safari et al., 2016)	Kuala Lumpur City Center and Ampang Street	86 participants visitors Kuala Lumpur	Surveyed through questionnaires and interviews	Geometry and landmarks
(Ahmadpoor and Smith, 2020)	Nottingham/ United Kingdom	Students of University of Nottingham, 76 participants	To draw cognitive map	Path, Node and Landmark
(Bozdog et al., 2020)	Konya/Türkiye	Students of Selçuk University 30 participants, / Students of Necmettin Erbakan University 35 participants,	Questionnaires and ArcGIS 10.6 software	Path, Edge, Node, District, and Landmark
(Topcu et al., 2021)	Eskişehir/Türkiye	Faculty of Architecture and Design at Eskişehir Technical University, 60 participants	Perception analysis and syntactic (space syntax) analysis	Landmark, Node, District and Path are four types' image elements.
(Burkut, 2022)	Kadıköy, İstanbul/ Türkiye	10-14 age group children residing in Kadıköy, 387 voluntarily participating children	Survey, Cognitive maps, Space Syntax	Landmark and Path
(Atey, 2022)	Uskudar, İstanbul/ Türkiye	40 voluntarily participating	Survey, Cognitive maps	Path, Edge, Node, District, and Landmark

3. Methodology

Research methodology and analysis framework is in Table 2. According to this table the steps followed for bibliometric analysis and visualization of the publications on spatial legibility are as follows (Table 2).

Table 2. Research methodology and analysis framework

Spatial Legibility: Bibliometric analysis and visualization
Research database: Web of Science database
Inclusion criteria: (ts=("spatial legibility")) or ts=("architectural legibility") or ts=("urban legibility") or ts=("legible cities") or ts=("legible city")
Limiting criteria: Topic (title-keywords-abstract). The publication between 1975 to 2023 were examined
Data collection: Web of Science database n=63 publications
Analysis of data: VOSviewer software program
Results

- 1) The first step is to select the database to be researched. Web of Science (formerly Web of Knowledge) is a website that provides subscription-based access to multiple databases that provide comprehensive citation data for many different academic disciplines. These databases were chosen for two primary reasons: firstly, WoS is a multidisciplinary and selective database; secondly, is made up of a number of specialized indexes that are organized by the type of indexed information or by subject by these databases. Also access to multiple databases that provide reference and citation data from academic journals, conference proceedings, and other documents in various academic disciplines.
- 2) The second step was to compile a database of relevant spatial legibility studies. For this purpose, literature search strings containing keywords related to spatial legibility were used. The search sequence used in this study is as follows: Keywords (TS= ("spatial legibility ") OR TS= ("architectural legibility")) OR TS= ("urban legibility")) OR TS= ("legible cities") OR TS= ("legible city"). The search was limited to papers, as well as the "subject section" (title, keywords, and abstracts) to find works primarily focused on spatial legibility.
- 3) The search was carried out on February 20, 2023, using abstracts, keywords, and titles. The research covers the years between 1975 and 2023.

- 4) Data Collection: Index was among the 63 publications found in the Web of Science databases.
- 5) Analysis of Data: VOSviewer Software Program.

4. Results

Results section consists of two parts. The first of these is the results of bibliometric analysis and the second is the result of visualization analysis. Bibliometric analysis includes numerical, statistical and graphical information in the Web of Science database [25].

Visual analysis includes statistical and graphical information and scientific maps provided by the VOSviewer software program [26].

4.1. Results of Bibliometric Analysis

Publications are listed in the Web of Science database and there are 63 publications. The graph of the number of publications and citations has been accessed. Figure 1 show “Spatial Legibility” in publications and citations between 1975 and 2023. There are 7 publications, 73 citations, the highest number of publications in 2018, and 107 citations in 2020, 3 publications (Figure 1).

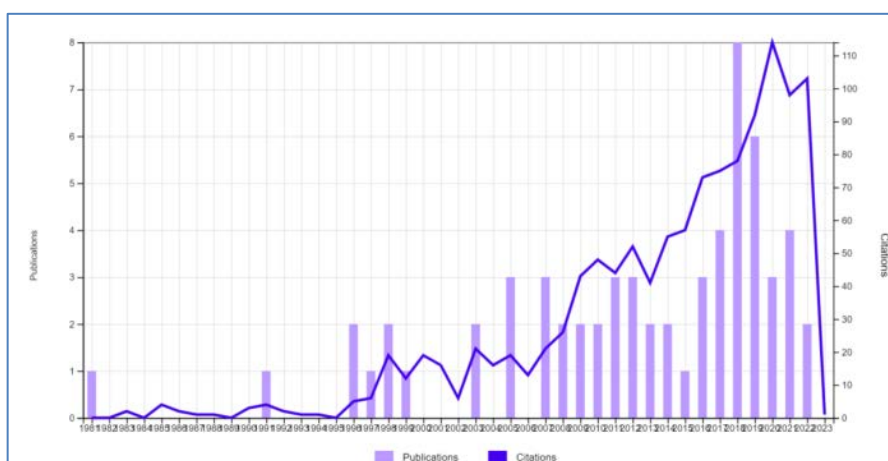


Figure 1. Web of Science (WOS) “Spatial Legibility” Publication and Citations between 1975 to 2023

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Web of Science categories list for spatial legibility research comprises 63 publications. A total of 63 publications were published, 13 in the category of "Environmental Studies" and 11 in the category of "Architecture". Moreover, "Urban Studies" category has 11 publications, "Psychology Multidisciplinary" has 9 publications, and "Geography" category has 7 publications.

Also, there are 5 publications in the “Urban and Regional Planning” and “Environmental Sciences”, 4 publications in the “Computer Science Theory Methods” and “Green Sustainable Science Technology”, 3 publications in the “Construction Building Technology” (Figure 2; Table 3).



Figure 2. Web of Science categories bar chart for spatial legibility (number of result: 15) (Web of Science, 2023)

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Table 3. Web of Science categories list for spatial legibility (Web of Science, 2023)

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Web of Science Categories	Record Count	% of 63
Environmental Studies	13	20,635 %
Architecture	11	17,460 %
Urban Studies	11	17,460 %
Psychology	9	14,286 %
Multidisciplinary	9	14,286 %
Geography	7	11,111 %
Environmental Sciences	5	7,937 %
Urban and Regional Planning	5	7,937 %
Computer Science Theory Methods	4	6,349 %
Green Sustainable Science Technology	4	6,349 %
Construction Building Technology	3	4,762 %

WoS (Web of Science) database documents types: the number of publications in "Article" is 50 publications. Also the number of publications in "Proceeding Papers" consists of 14 publications, the number of publications in "Book chapters" is 4 publications, and the number of publications in "Review Articles" is 2 publications (Table 4).

Table 4. Document types

Documents Types	Number of Publications
Article	50
Proceeding Papers	14
Book Chapters	4
Review Articles	2

Web of Science database in countries/regions; the highest number of publications is USA 22 publications. A total of 9 publications have been published by Turkey, 6 publications have been published by United Kingdom, and 6 publications have been published by China (Table 5).

Table 5. Countries/Regions

Countries/Regions	Number of Publications
USA	22
Turkey	9
United Kingdom	6
China	6

WoS (Web of Science) database with the highest number of publications is index "Social Sciences Citation Index (SSCI)" 22 publications. In addition, "Emerging Sources Citation Index (ESCI)" 14 publications, "Science Citation Index Expanded (SCI-EXPANDED)" 12 publications, "Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH)" 9 publications (Table 6).

Table 6. Web of Science Index

Web of Science Index	Number of Publications
"Social Sciences Citation Index (SSCI)"	22
"Emerging Sources Citation Index (ESCI)"	14
"Science Citation Index Expanded (SCI-EXPANDED)"	12
"Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH)"	9

Publishers with the most publications on Web of Science are Elsevier with 13 publications, Sage with 10 publications, Taylor & Francis with 7 publications, Springer & Nature with 4 publications, and Wiley with 4 publications (Table 7).

Table 7. Web of Science Publishers

Web of Science Publishers	Number of Publications
Elsevier	13
Sage	10
Taylor & Francis	7
Springer Nature	4
Wiley	4

The title with the highest number of publications on Web of Science Publishers is "Environment and Behavior," with 4 publications. There are also 3 publications of "Journal of Environmental Psychology", 3 publications of "Procedia Social and Behavioral Sciences", 2 publications of "Architectural Design", and 2 publications of "Archnet IJAR International Journal of Architectural Research" (Table 8).

Table 8. Publication Titles

Publication Titles	Number of Publications
“Environment and Behavior”	4
“Journal of Environmental Psychology”	3
“Procedia Social and Behavioral Sciences”	3
“Architectural Design “	2
“Archnet IJAR International Journal of Architectural Research”	2

Additionally, a citation report of accessible publications regarding spatial legibility has been created in Web of Science. It was searched according to the most cited publications. According to this; the first most cited article titled “Evaluating Architectural Legibility: Way-Finding in The Built Environment” by Weisman [2], accounting for 215 citations. The second most cited article titled “Individual- And Gender-Related Differences in Indoor Wayfinding” (Lawton [27]. The third most cited article “Evaluation of a Conceptual Model of Architectural Legibility” (O’Neill, [28].

The fourth most cited article “Comparing the Complexity of Wayfinding Tasks in Built Environments” (Raubal and Egenhofer, [29].

According to the Web of Science database [25], the authors with the most citations are in Turkey: by Cubukcu and Nasar [30] article titled “Relation of Physical Form to Spatial Knowledge in Large-Scale Virtual Environments”, by Topcu and Topcu [31] article titled “Visual Presentation of Mental Images in Urban Design Education: Cognitive Maps” and by Koseoglu and Onder [6] article titled “Subjective and Objective Dimensions of Spatial Legibility”.

4.2. Result of Visualization Analysis

The results obtained by analyzing the publications in the Web of Science database with the VOSviewer software are as follows: Citation authors’ analysis minimum number of documents of an author 1, of the 137 countries 137 meets the threshold. In this analysis, the relationships between the authors are visualized by colors and circle sizes. Citation author analysis network visualization is seen in Figure 3, overlay visualization is seen in Figure 4, and density visualization is seen in Figure 5.

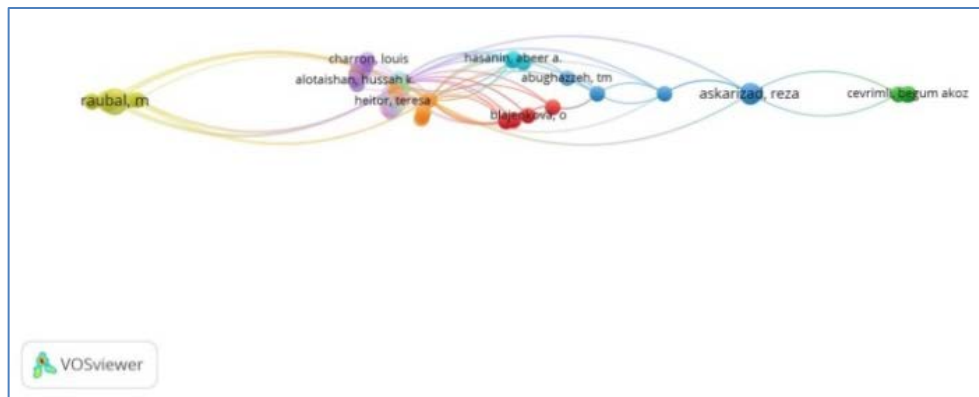


Figure 3. Network visualization (Types of analysis: Citation/Unit of analysis: Authors)

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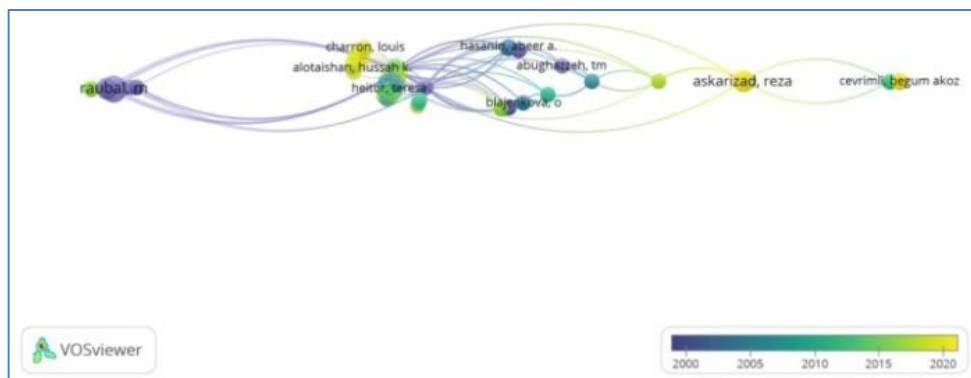


Figure 4. Overlay visualization (Types of analysis: Citation/Unit of analysis: Authors)

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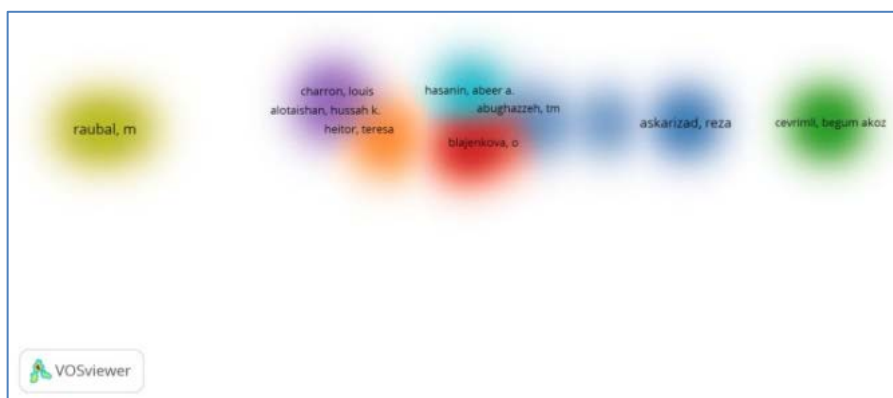


Figure 5. Density visualization (Types of analysis: Citation/Unit of analysis: Authors) (Source: Created by VOSviewer, 2023, Available at: <https://www.vosviewer.com/>). Clarivate Web of Science (Available at: <https://www.webofscience.com/>). © Copyright Elsevier 2023. © Copyright Clarivate 2023. All rights reserved.

Citation country analysis comprises the minimum number of documents of country 1; of the 22 countries 22 meet the threshold. USA 19 documents 455 citations. There are 121 citations in 2 documents from Austria.

There are 4 documents and 26 citations from Canada. There are 9 documents and 68 citations from Turkey. There are 6 documents and 110 citations from UK. Network visualization is seen in Figure 6.

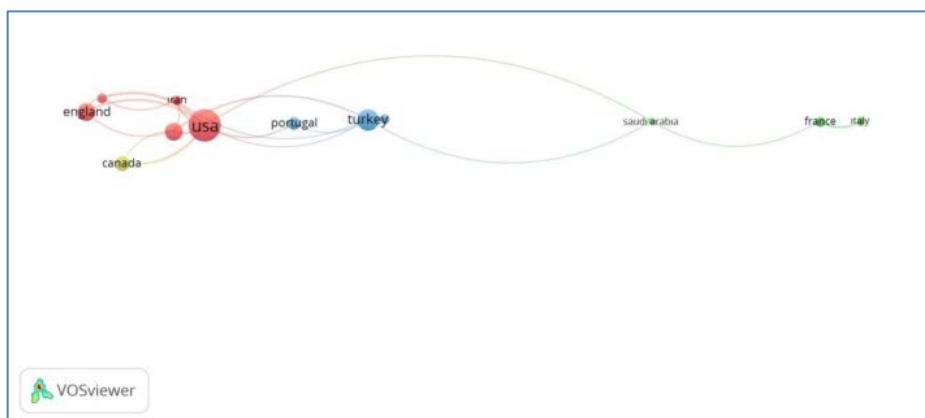


Figure 6. Network visualization (Types of analysis: Citation/Unit of analysis: Countries) (Source: Created by VOSviewer, 2023, Available at: <https://www.vosviewer.com/>). Clarivate Web of Science (Available at: <https://www.webofscience.com/>). © Copyright Elsevier 2023. © Copyright Clarivate 2023. All rights reserved.

Citation documents comprises a analysis comprises a minimum number of citations documents 5; with 57 documents 30 meet the threshold. Weisman [2] has 215 citations, O'Neill [18] has 100 citations, Lawton [27] has 121 citations, Raubal [29] has 26 citations,

Raubal [32] has 54 citations, Cubukcu [30] has 49 citations, Abughazze [33] has a 36 citations, Ramadier [34] has 36 citations. Network visualization is seen in Figure 7.

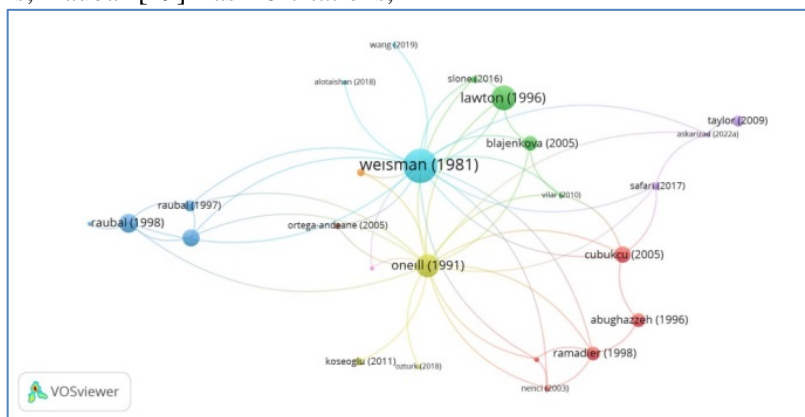


Figure 7. Network visualization (Types of analysis: Citation/Unit of analysis: Document) (Source: Created by VOSviewer, 2023, Available at: <https://www.vosviewer.com/>). Clarivate Web of Science (Available at: <https://www.webofscience.com/>). © Copyright Elsevier 2023. © Copyright Clarivate 2023. All rights reserved.

Citation sources analysis comprises the minimum number of documents of sources 1, of the 48 sources with 48 meet the threshold. “Environment and Behavior” 4 document 485 citations, “Journal of Environmental Psychology” 3 document 114 citations, “Environment and Planning B: Planning

and Design” 1 document 67 citations, “Spatial Information Theory: Cognitive and Computational Foundations” 1 document 54 citations and “Spatial Information Theory: a Theoretical Basis for GIS” 1 document 26 citations. Network visualization is seen in Figure 8.

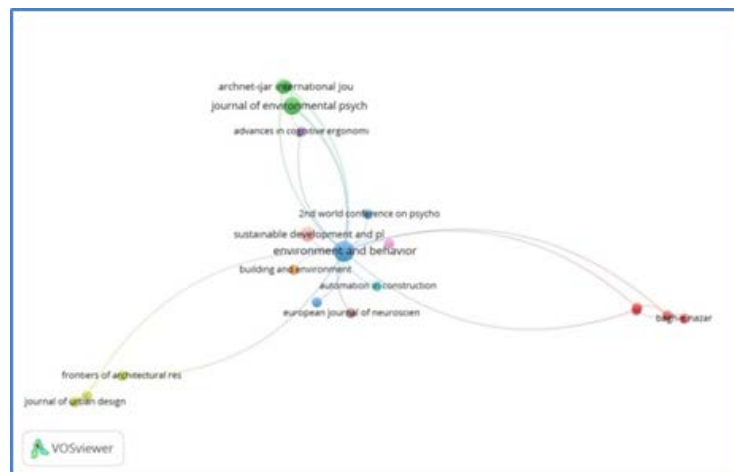


Figure 8. Network visualization (Types of analysis: Citation/Unit of analysis: Sources)

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Co-citation cited author: Co-citation cited author analysis comprises a minimum number of citations of reference 5; of the 1282 cited references 34 meet the threshold. The most influential authors according to

this analysis are: O'Neill [18], Hillier [35], Evans [36] Lynch [1], Golladage [37], Garling [4], Appleyard [38]. Network visualization is seen in Figure 9.

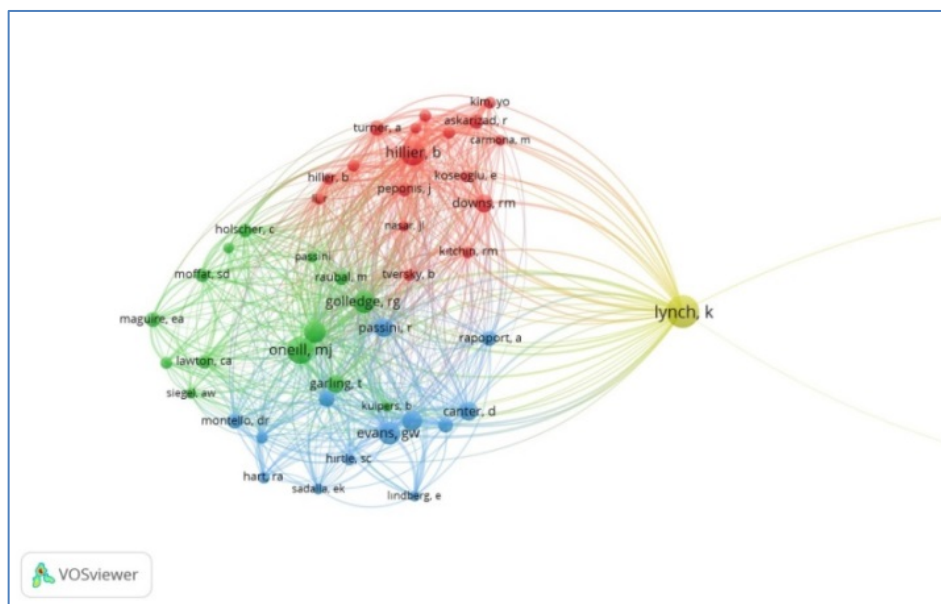


Figure 9. Network visualization (Types of analysis: Co-Citation/Unit of analysis: Cited Authors)

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Co-citation cited references: Co-citation cited reference analysis comprises the minimum number of citations of reference 4; with 1663 cited references 27 meet the threshold. Lynch [1], Weisman [2], Garling [4], O'Neill [18], Evans [36], Golladage [37], Arthur [39], Kuipers [40], Piaget [41] references are the most

used by the authors (Figure 11). Also, Co-citation cited reference analysis comprises a minimum number of citations of reference 3; with 1663 cited references 47 meet the threshold. Network visualization is seen in Figure 10.

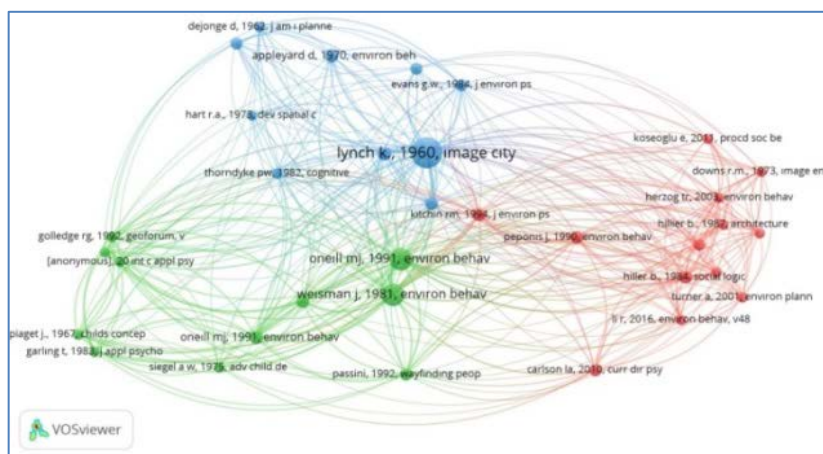


Figure 10. Network visualization (Types of analysis: Co-Citation/Unit of analysis: Cited References) (min:4) (Source: Created by VOSviewer, 2023, Available at: <https://www.vosviewer.com/>). Clarivate Web of Science (Available at: <https://www.webofscience.com/>). © Copyright Elsevier 2023. © Copyright Clarivate 2023. All rights reserved.

Co-citation cited source analysis comprises a minimum number of citations of sources 5; of the 1137 sources 50 meet the threshold. “Environment and Behavior” sources has 144 citations, “Journal of

Environmental Psychology” has 71 citations, “Environment and Planning B: Planning and Design” has 31 citations and “Image City” has 33 citations. Network visualization is seen in Figure 11.

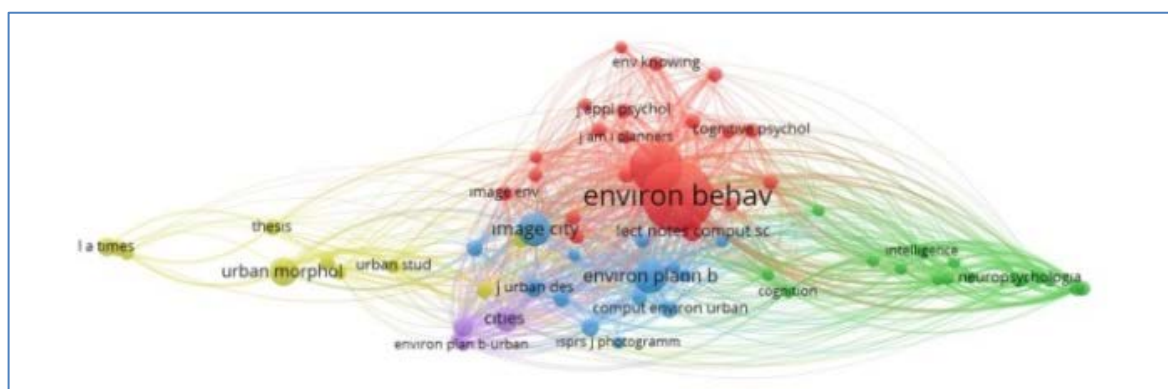


Figure 11. Network visualization (Types of analysis: Co-Citation/Unit of analysis: Cited Sources) (min:5)
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Co-occurrence analysis author keywords in analyzing “image”, “legibility”, “space syntax”, “urban design”, “urban legibility”, “way finding”, “navigation”, “virtual environment”, “perception”,

“spatial cognition”, “spatial legibility”, “urban form” are the words most used by the authors. Network visualization is seen in Figure 18.

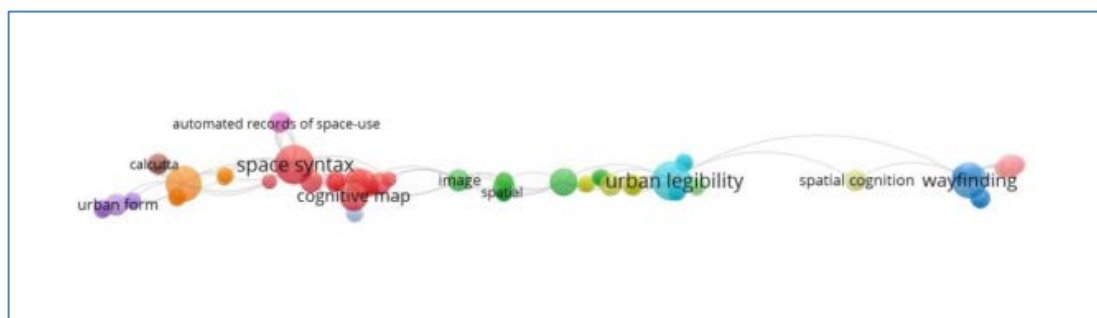


Figure 12. Network visualization (Types of analysis: Co-Occurrences/Unit of analysis: Author Keywords)
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Co-occurrence author keywords analysis result of minimum number of occurrences of a keyword: 2 with 231 keywords 20 meet the threshold in Table 9. (4 Clusters-17 items).

Table 9. Co-occurrence author keywords analysis result of Group item by cluster

Cluster 1 (6 items): Legibility, Space syntax, Eskisehir, Intelligibility, Landmark, Cognitive map.
Cluster 2 (5 items): Urban legibility, Image, Perception, Smartphone, Urban design.
Cluster 3 (4 items): Wayfinding, Navigation, Spatial cognition, Virtual environment.
Cluster 4 (2 items): Spatial legibility, Urban form.

Finally, to summarize, mind the research the figure shows the mind map of the publications on “Spatial Legibility” between 1975 and 2022. The mind maps are used to organize information and thoughts. Mind maps were used to explain the analyzes of bibliometric studies (Lee and Park, [7]; Burkut, [7]). A mind map was created showing the relevant publication, citation, index, author, and affiliation, country, and research areas for Spatial Legibility to suggest future research directions (Figure 13).

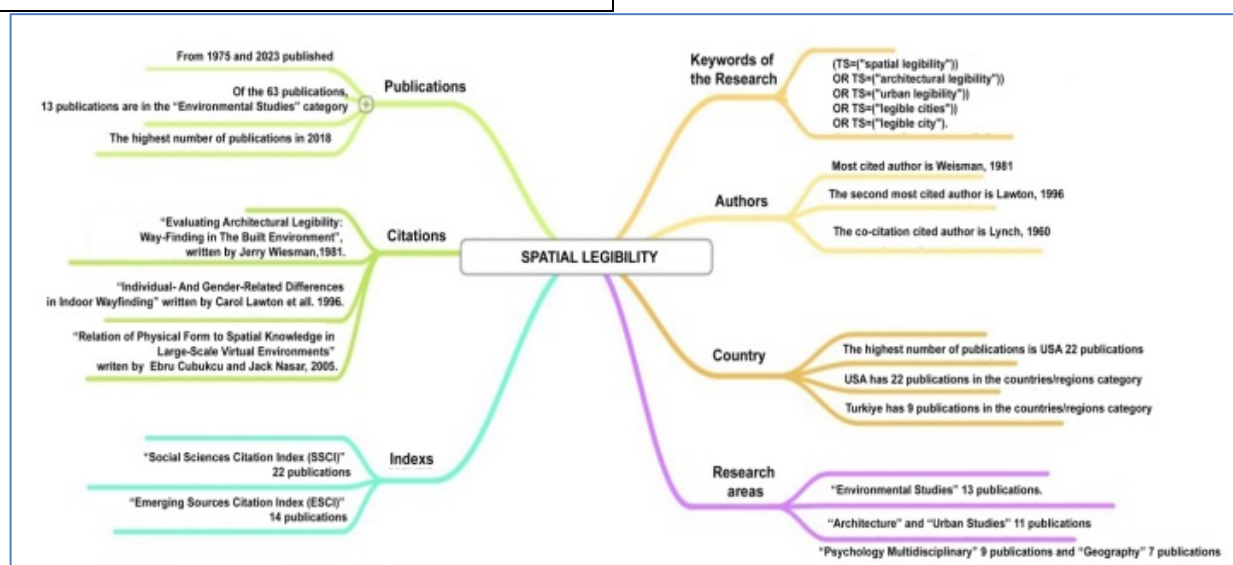


Figure 13. The mind map of visual from the findings of bibliometric analysis creating by authors.

5. Conclusion

In this article, publications in the literature have been reviewed on spatial legibility. 57 publications published in the Web of Science database until March 10th, 2022, have been reached. These publications have been created with bibliometric analysis and visual maps with the VOSviewer program. In bibliometric analysis, the year of publication, category of publication, type of publication, magazine, publication index, and the distribution by country are described in tables. Bibliographic analysis is the VOSviewer software program, citation authors, citation country, citation documents, citation sources, co-citation cited reference, co-citation cited reference, co-citation cited authors, co-citation cited sources, co-occurrence author keywords analysis were performed. The VOSviewer program of these analyzes conducted network visualization and density visualization analyzes.

The USA has the most efficient publications country/region as a result of the analysis. The publications on the field highlight the publication of articles. The most reference document was found to be Weisman [2]. The most referenced source is Environment and Behavior. Lynch [1] is the most referenced source in the co-citation cited reference analysis. The publications in the “Social Sciences Citation Index (SSCI)” index are the most influential. The words that writers use most in their publications are image, legibility, space syntax, urban design and urban legibility; it has been determined to be wayfinding.

Bibliometric analysis is a novel way of analyzing vast amounts of data. However, the results should be regarded with caution due to the study's various limitations. The data was accessed only from the Web of Science database first. Another limitation is studies from 1975-2022 were reviewed to provide an overview. The research examined in this study has been a matter of research numerically.

The publications subject to research have not been critically investigated in terms of quality, content and originality.

There are a few things that can be considered as suggestions for future research. In order to bring up an updated perspective, data from the last ten years have been used in the same way. In addition, a similar search can be done in different data sources (reference manager files; RIS, EndNote, RefWorks or bibliographic files Scopus, Dimensions, PubMed and Lens).

Several issues might be considered in future work. After this research, the following suggestions can be made considering that spatial legibility is a concept, and sub-concepts related to spatial legibility can be examined. The sub-concepts of legibility, such as navigating, creating an image, being able to navigate and drawing cognitive maps, can be examined with bibliometric analysis. The use of bibliographic mapping to visualize research findings is extremely illuminating. In terms of scientific mapping, the role of visualization in architecture is once again appreciated. In conclusion, it is expected to inspire academics working on spatial legibility.

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