A Bibliometric Study of Visual Quality Research in the Context of Urban Open Spaces

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Abstract

Visual quality assessment has received much attention in research by forest management and landscape researchers after the mid-twentieth century with the advent of legal frameworks enacted to protect natural resources, including scenery. Since then, the field has gained momentum that is mostly attached to landscape change and assessing the environmental impact of changes. Urbanized areas, however, received less attention and just started to receive some exposure in the last two decades (concurrently with the emergence of new technologies of GIS and remote sensing). Developing a comprehensive understanding of the visual quality assessment research requires a reconnaissance survey of its history and the trends of its research growth. This study undertakes an analysis of visual quality assessment literature in the context of urban settings using bibliometric tools. The paper employs quantitative techniques to analyse 3,221 journal papers retrieved from the Web of Science using keywords co-occurrence, citation burst, and direct citation analyses with the help of VOSViewer, CiteSpace, and Gephi software. Here we show the discipline's status quo, trends, and patterns of development. They confirm the recency of urban-related research. Our study touches on the chronological emergence and decay of major visual quality notions. It also highlights the most central studies and the journals and research groups actively working in the field. Moreover, it points out research gaps related to urban spaces for future studies guidance.

Keywords: Visual quality assessment; Scenic beauty; Landscape visual quality; Urban aesthetics

1 Introduction

The assessment of scene visual quality goes back in history to the Greek philosophers, including Socrates and Plato. Yet the protection of the visual quality of natural landscapes and resources became mandated in the USA just five decades ago as per the National Environmental Policy Act in 1970. In other countries, guidelines for landscapers, like GLVIA in the UK, were established to regulate changes to landscapes so their impacts on visual quality and other ecological systems are mitigated. In many cases, the visual quality is assessed as part of Environmental Impact Assessments (EIA) that precede the permits of new projects. This legal and regulatory movement towards protecting natural landscape scenic beauty has initiated a parallel research movement on landscape visual quality

assessment methodologies and the impact of artificial changes. US Department of Agriculture (USDA), for instance, has funded several research projects and published dozens of works to create tools and methods that can be used to maintain and assess the visual quality of forests managed and administered under its scope. This momentum successfully shaped the formal approach based on the physical content of the landscape and descriptive sets of regulations and guidelines; such an approach is still dominant in landscape and forest management practice.

Bacon (1979) discussed using the Visual Management System (VMS) - a map-based geographical system for forest management- and identified a few physical characteristics of the natural landscape upon which visual quality assessment can be evaluated. The study provides a framework for identifying the landscape character and the respective allowable change. On the contrary, Daniel and Boster (1976) proposed the Scenic Beauty Evaluation (SBE) model based on human perception regardless of physical landscape characteristics. Kaplan (1979) discussed the use of perception-based surveys to identify the visual value of landscape characteristics. While these early studies and others were all published by USDA, they present distinct attempts to tackle landscape visual quality assessment. The first attempt is a map-based evaluation that neglects the public perception, while the second ignores the physical content of the scene. The third links the two ways of evaluation to avoid the dilemma of authority/public mismatch. These two ways of evaluation have initiated the primary lines of thought for following scholarly works. The other lines of thought were mainly branched from these two. Lothian (1991) conducted a chronological review of the two approaches and concluded with the triumph of the subjective approach, as it can be justified by statistical models. He argues that this approach is sincerely objective, as it is connected to communal human perception. In contrast, the objective approach is subjected to criteria determined by one or a few experts.

The objective (formal) approach has been widely considered in regulations and experts' practice because it provides clear and consistent criteria and guidelines for landscapers and practitioners to adhere to, such as those stipulated in GLVIA 3. On the other hand, the subjective approach has been widely investigated and improved in academia. This duality, with the different environmental and psychological layers, produced more sub-schools. Firstly, Daniel (2001) highlighted the potential growth of the field beyond the objective and subjective approaches supported by the new technologies of GIS and remote sensing. He proposed that a new approach will eventually combine the two schools to obtain an optimized correlation between the scene's physical characteristics and the users' psychological status with the help of the prevalent technology. Secondly, and from an environmental perspective, Gobster (1999) argued that the definition of forest aesthetics shouldn't be limited to scenic beauty but should go deeper into the site's physical and ecological characteristics. The study attempted to resolve the dilemma between landscape visual quality and ecological systems' sustainability through "ecological aesthetics". The protection of ecosystems and the ecological value in this approach are of prime importance in maintaining a specific visual quality. Thirdly, the perceptual approach was extended to a cognitive one, as evident in Kaplan's Attention Restorative Theory (ART) (1995), which positively correlates the restoration of users' attention with exposure to naturalness. The theory suggests that such exposure has a healing effect on users, translated to more productiveness in office spaces and schools. This approach was applauded by psychologists who took this theory further to propose more profound assessments of natural scenes and their contribution to enhancing mental health based on human perception, cognition, and experience, as suggested by (Celikors & Wells, 2022).

While this field emphasized forests, natural scenes, and rural settings for a while, given the conditions

of its emergence, recent studies started to discuss the visual quality of open spaces within the built environment. Luckily, these studies took advantage of using advanced methods and technologies like remote sensing, GIS, ML, and LiDAR, in addition to well-established statistical models like AHP and PCA, which helped correlate user preferences with the physical components for several applications. Yet, given the immaturity of visual quality assessments of urban open spaces, there is an urgent need to establish an urban-specific framework that considers using the most advanced tools. Urban areas are much more dynamic in terms of time, place, and vantage point than static homogenous natural scenery. Thus, high-resolution GIS data will facilitate more accurate assessments.

In this study, we investigate the status of this research field by analyzing literature extracted from Web of Science database. This study identifies the prominent directions through research clustering. It will detect the most influential studies and the primary keywords within each cluster. By doing so, this study acts as an entry point to the topic for new researchers as they will get familiar with the key terms, studies, authors, and journals. The significance of this study is also represented by several benefits, including identifying research groups and potentials for collaboration, and detecting theoretical research gaps in the field. The study will also shed light on the climax of the field's various paradigms represented by the phasing of their primary keywords. While classic paradigms could be considered non-active areas, researchers may find it worthy of activating some of their concepts if found valid for the current needs, or they may find it necessary to build up on a hot area with an urgent need. Thus, this study facilitates the alignment of new research works according to such patterns.

Therefore, this study aims to present the status quo of visual quality assessment in urban settings and the trends that have dominated visual quality since the 70s. The objectives of this research are:

- To study the clusters of visual quality assessment research and to map them.

- To identify central studies of the field and their interests, and

- To highlight active research outlets.

2 Methodology

This study uses science-mapping tools to form an understanding of the theoretical structure of the visual quality and scenic beauty field. These maps provide a high-level understanding of the field's trends (based on timelines) and clusters (based on research interests) and facilitate qualitative reviews of the body of knowledge. At the same time, generated trends and clusters draw implicit boundaries of the field's areas and explain the patterns connecting various studies by detecting mutual keywords and citations. By doing so, the most influential studies per cluster can be identified, in addition to the cluster's core concepts.

This study follows the methodology proposed by Darko et al. (2019) for their scientometric study on Green Buildings with few variations to suit the visual quality field and its specific conditions. While their study provided a step-by-step methodology that acts as a recipe for similar studies, they have also highlighted common shortcomings of previous scientometric studies, represented by excluding early studies through specifying a start date, the subjective deduction of research areas, and the lack of meaningful analysis of the extracted data resulting from confusing maps with plenty of overlaps between the clusters' nodes. Such cloudy maps hinder the interpretation of the field's areas and interests. Therefore, it is critical to specify options that mitigate anomalies within the maps, like

selecting author keywords (representing the author's interests) instead of generating them from the abstract (Abstract Keywords). This study considers one main variation to this methodology, given the smaller sample size and the sparse nature of the field. The study will use citation analysis instead of co-authorship, as it provides a better indicator of study influence based on citing and cited studies. Co-authorship analysis has specific use cases where researchers from different entities collaborate to produce a scholarly work. Therefore, it neglects studies by one author and provides very little about those co-authored by researchers from the same organization.

2.1 Data Collection

The first stage involves collecting bibliometric data from the two databases using "Visual Quality," "Scenic Beauty," and "Landscape Visual Quality" terms in combination with the "Urban" term. This combination is used to harvest the most relevant studies, as many use one or more of these terms. Web of Science databases was selected among others for multiple advantages; first, for strict indexing of journals which eliminates predatory journals and not credible publications. Secondly, it exports search results in a friendly format for most bibliometric tools with the ability to select only relevant data fields. The use of filters was necessary to avoid confusion with other fields. For instance, the Image Visual Quality topic, mainly tackled by computer engineering and computer sciences, shares similar keywords to landscape visual quality. The search was also limited to journal articles, as from one side, they represent the de facto form in the urban studies, and the process they go through, including the peer review, makes them the most reliable medium in research, and the most attractive way of publishing for quick yet reliable knowledge accumulation. On the other side, journal articles provide a consistent format for bibliometric data, enabling equal comparisons between scholarly works. Moreover, they facilitate the analysis for geographical distribution for two items; first, the research conducted, thus identifying research gaps in regions of different nature. Second, the interested academic bodies, their geographical distribution, and their level of interest. Such analysis will highlight the need for academic bodies in nonactive regions to initiate collaboration with others.
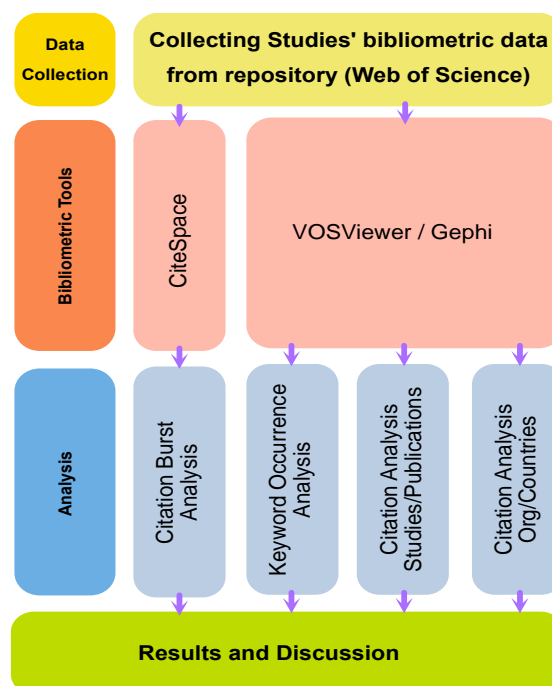
Fig. 1: Diagram of the proposed methodology (Source: Authors)

2.2 Process of Scientometric Analysis

The analysis considered for this study involves three distinct activities, as follows:

1. Keyword co-occurrence illustrates the most critical keywords in the field. It also groups them according to their co-occurrence in the same article. The proposed groups infer the different orientations of investigated studies. The main result of this analysis is the identification of the research clusters. Combined with the Centrality calculations, this analysis will also detect the most influential keywords within clusters. The analysis is mainly based on the incidence of two terms together. The weighted degree centrality metric is calculated based on the number and strength of links for each keyword with others. This metric allows for a more accurate ranking of the most important keywords.

2. Citation burst analysis traces the chronological emergence and decay of keywords in research. Using this technique, it reconstructs the prevalent patterns of the topic over its timespan and detects turning points of these patterns, which can be further linked with clusters mentioned earlier.

3. Study and journal citation analyses list the predominant academic journals with visual quality and scenic beauty as their primary journal aims. These journals are more likely to align the manuscripts they receive with their goals, and therefore, they form important resources for the visual quality body of knowledge.

2.3 Bibliometric Tools

The bibliometric analysis mentioned earlier can be conducted with the help of few tools; each with specific functions and configurations as follows:
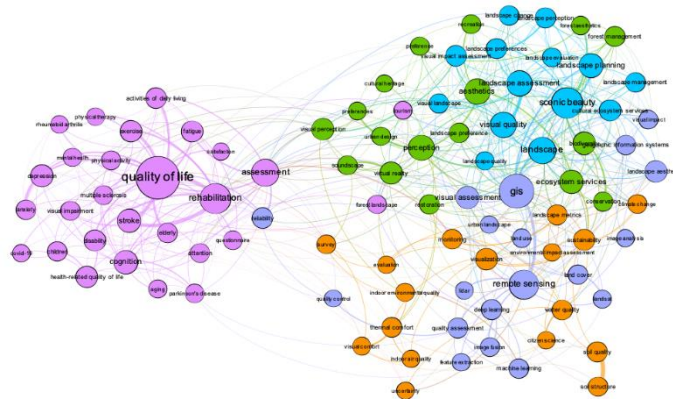
1. VOSViewer for keyword co-occurrence and citation analyses. The main output of the tool is the network maps that express how far the nodes (keywords, authors, journals, countries) are central to the field or a cluster, based on links (lines) moving out to nodes of cited works or moving in from the citing ones. VOSViewer clustering for studies and keywords is based on their citation and co-occurrence. The software suggests several clusters according to a reasonable minimum number of nodes per cluster input.

2. Gephi for centrality calculations and network mapping. The tool uses maps exported by VOSViewer to conduct statistical calculations, including degree centrality and clustering coefficients.

3. CiteSpace for the citation burst analysis. While, VOSViewer provides the average publish year of each node in its overlay network maps, CiteSpace's citation burst analysis generates more informative indicators for the calculated start year and end year for each keyword representing not only the time a keyword became popular in the field but also for how long, and when such keyword started to disappear and replaced by other terms for newer paradigms, interests, methods, and technologies.

3 Results and Discussion

The analysis discussed earlier reveals a few interesting results for the visual quality assessment field. One of the primary outcomes is the capabilities we have explored in the used methodology that could also be extended to other fields as needed. For visual quality analysis in specific, the following results were found.

3.1 Keyword Co-occurrence and Citation Burst Analyses

Keyword occurrence analysis has confirmed the history of the field paradigms discussed earlier. Using this, five clusters were thus generated with a few main keywords describing the interests of each cluster of the studies (Figure 2). The first considers the classical approach for assessing natural landscapes and the impact of changes proposed by landscapers. Checking their weighted centrality, the main keywords of this cluster are found to be scenic beauty, landscape change, landscape management, landscape planning, landscape perception, and forest management.

Fig: 2: Network map for Keyword Co-occurrence analysis

Table 1: Keyword Citation Burst Analysis

Keywords	Begin	End	77 - 2022	Keywords	Begin	End	77 - 2022
Recreation value	1993	1995		Acoustic comfort	2017	2019	
Forest aesthetics	1994	2004		Parkinson's disease	2017	2020	
Ecosystem management	1996	2004		Protected area	2018	2020	
Scenic beauty	2004	2005		Sustainable development	2018	2020	
Aesthetic assessment	2008	2009		Virtual reality	2018	2022	
Forest management	2009	2011		Thermal comfort	2018	2022	
Visual assessment	2009	2010		Public perception	2018	2020	
Visual impact	2011	2016		Ecosystem service	2019	2022	
Landscape planning	2011	2012		Visual quality	2019	2020	
Visual perception	2012	2014		Rural area	2019	2022	
Principal component analysis	2012	2018		Machine learning	2020	2022	
Soil quality	2013	2014		Visual comfort	2020	2022	
Visual impact assessment	2013	2016		Climate change	2020	2022	
Cultural ecosystem service	2015	2019		Urban design	2020	2022	
Landscape perception	2015	2018		Landscape management	2020	2022	
Landscape metrics	2016	2017		Landscape quality	2020	2022	
Outdoor recreation	2017	2018		Landscape aesthetics	2020	2022	
				Indoor air quality	2020	2022	

The research in these clusters is elaborated in the following sections. Compared with other keywords in burst analysis (Table 1), Scenic Beauty, Forest Management, and Forest Aesthetics represent this cluster's classical nature. Landscape terms, however, are prevalent in recent research. In other words, this cluster

represents professionals and authorities with landscaping and forest management backgrounds. It answers their needs for streamlined assessments of landscape decisions, obtaining or issuing the needed permits, and aligning efforts with the legal frameworks for natural resource preservation.

The second cluster represents studies that tackle visual quality assessment as one of the ecosystem services, side by side with the ecological and biodiversity assessments of the land. The cluster's keywords include Ecosystem Services, Biodiversity, Conservation, Restoration, Forest Management, and Aesthetics. The burst analysis failed to assess most of the cluster's keywords. However, it indicates an early presence of ecology-related keywords. The third cluster is associated with the psychological and medical applications of the field, as suggested by its keywords. Quality of Life is the most central term of the cluster, with keywords Cognition, Depression, Mental Health, Rehabilitation, and Attention supporting it. The attention restoration theory is present in this cluster's keywords in addition to medical terms like fatigue and Parkinson's disease. Although the study of psychological aspects began early in the field, the field recently witnessed intensive attention from medical studies. This cluster has extended the subjective approach for scenic beauty evaluations (evaluations built directly on user perception) to more psychological concepts such as Mental Health, Attention, Rehabilitation, and Experience.

The fourth cluster considers the use of relatively new technologies and tools in assessing the landscape visual quality, combining objective and subjective lines of thought as suggested by (Daniel, 2001). With GIS and Remote sensing being the most central in the cluster, other terms for technologies like LiDar, machine and deep learning, and Landsat shape the cluster interests. The preceding technologies used for objective assessments, like VMS, were limited to a few physical and topographical attributes. For instance, landscape character contained only three classes which, when combined with the other three sensitivity levels, can provide several scenarios and decisions made accordingly. The proposed assessments lacked numerical insights and were limited to very few choices for the level of human interventions (preservation, retention, and modification). Newer technologies like GIS, LiDAR, remote sensing, and spatial data management secure more numerical data, whether objective-based such as the site characteristics and components, or subjective-based, like user ranking and preference, allowing endless statistical applications like regression and PCA, and facilitating extensive integration with other modern technologies like deep learning, artificial and convolutional neural networks and virtual reality. Moreover, these technologies have been implemented in a wide range of geography-related sciences, including climatology, agriculture, regional and urban planning, and environmental studies.

The keywords of the fifth cluster indicate the proposed link between the sustainability of the built environment and the visual quality. Sustainability, climate change, soil and water quality, thermal comfort, and indoor environment quality shape the cluster's structure. The quality of views and daylight in buildings is an essential criterion in most green building rating systems. Although there is no direct relationship between most of the cluster's keywords and the visual quality, they generally represent qualities of adequate construction.

In summary, the five clusters are landscape and forest management, ecological, psychological and medical, technology-related, and sustainability-related. The clustering generated by VOSViwer does not suggest a stand-alone cluster for urban studies. Instead, nodes for urban subjects are fragmented between the last two clusters. The concentration of the field is still majorly limited by natural and rural scenery assessments. The same is noticed in studies discussed in the next part as well.

3.2 Citation Analysis – Studies and Journals

After conducting the weighted centrality analysis for the collected studies, it became obvious that most central articles (mostly cited) are quite old. Out of 26 articles with a weighted degree of centrality exceeding 15, only three were published in 2015 or after. Most of the 26 articles were published before 2010. Considering that, around 50% of the collected articles were published in 2017 or after; this indicator highlights the close-knit structure between new research works and traditional ones and the lack of breakthroughs in the field. This also indicates the need for a dedicated investigation of the most recent studies (in the last six years) to inform new research projects about the efforts done recently and to build upon them instead of starting anew or relying on old approaches, some of which became irreverent with the emergence of new methods, tools, and technologies.

The citation analysis for the studies shown in Figure 3 and Table 2, has resulted in 5 clusters in which the first has the highest share (52 out of 162 nodes) and includes the most central nodes. Studies in this cluster discuss the formal application of visual quality assessments to meet regulatory and legal requirements. The second cluster focuses on the influence of site ecology and user demography, and psychology on the landscape's visual quality. The third cluster is linked with assessing the scenic beauty at the forest level and the use of it as a tool for forest management. The fourth cluster of studies employs GIS and remote sensing tools in modeling land aesthetics. The use of GIS and spatial data management allows for large-scale implementation of scenic beauty metrics and facilitates shaping a more accurate understanding of the drivers influencing it in urban, rural, or natural settings. Finally, few studies in the fifth cluster discuss the change in agricultural lands for touristic purposes, especially for abandoned ones. In many European regions, the policies authorities considered for agricultural market liberalization and those related to ecological compensation caused the abandonment of agricultural lands at a massive scale. While this seems to be mainly pronounced in European countries, other pressures can be noticed in other regions where importing food is competitive to its production. The visual quality of abandoned agricultural lands received a great deal of research in this cluster.

In summary, the five clusters are professional-related, ecological/psychological, forest-level assessment, technological, and agricultural/touristic. Similar to keyword co-occurrence analysis, there is no specific concentration on the assessment of urban spaces' visual quality. Both analyses highlight the minimal interest in assessing urban public spaces compared with natural, agricultural, and rural ones. The dimensions discussed here are also psychological, medical, or technological. Urban spaces are fragmented under the hood of some of these dimensions, while most of the studies that discussed urban spaces are mostly recent.

Table 2: Studies clusters and central nodes
(Source: Authors)

Study	Year	Cluster	Weighted Degree
Daniel	2001	1	42
Arriaza, et al.	2004	1	29
Dramstad, et al.	2006	1	26
Palmer & Hoffman	2001	1	25
Bulut & Yilmaz	2008	1	21
Yao, et al.	2012	1	21

Table 3: Journal clusters and central nodes
(Source: Authors)

Journal	Cluster	Weighted Degree
Journal of environmental management	1	349
Forest science	1	190
Environmental monitoring and assessment	1	185
Ecological indicators	1	173
Landscape ecology	1	140
Soil & tillage research	1	124

Tveit	2009	1	20
Bulut & Yilmaz	2009	1	17
Zhao, et al.	2013	1	17
Wang & Zhao	2017	1	16
Meitner	2004	1	16
Hull & Stewart	1992	2	22
Gobster, et al.	2007	2	21
Daniel & Meitner	2001	2	19
Lindemann-Matthies, et al.	2010	2	19
Ode, et al.	2009	2	19
Svobodova, et al.	2012	2	17
Junge, et al.	2015	2	17
Brown & Daniel	1986	3	22
Ribe	2009	3	20
Schirpke, et al.	2016	4	17
Bishop & Hulse	1994	4	16
Hunziker & Kienast	1999	5	24
Schirpke, et al.	2013	5	20
de la Fuente de Val, et al.	2006	5	20
Schirpke, et al.	2019	5	16

Environment and behavior	1	113
Scandinavian journal of forest research	1	107
Soil use and management	1	81
Ecological engineering	1	78
Ecosystem services	1	57
Geoderma	1	54
Environmental management	1	51
Journal of forestry	1	51
Remote sensing	1	43
Sustainable cities and society	1	41
Applied geography	1	35
Renewable energy	1	31
Landscape and urban planning	2	1190
Urban forestry & urban greening	2	259
Journal of environmental psychology	2	217
Sustainability	2	216
Forests	2	209
Landscape research	2	164
Building and environment	2	102
Fresenius environmental bulletin	2	84
Journal of environmental engineering and landscape management	2	57
Water	2	54
International journal of environmental research and public health	2	48
Journal of the acoustical society of America	2	48
Applied acoustics	2	31

Fig 3: Network map for Studies Citation analysis

Fig. 4: Network map for Journal Citation analysis

Citation analysis for the journals shown in Figure 4 and Table 3, revealed the dominance of landscape and environmental studies in the field. Landscape and Urban planning journal is by far the most central journal when it comes to citation, followed by the Journal of environmental management and urban forestry and urban greening journal. Journal of environmental psychology came fourth, while most medical, remote sensing, artificial intelligence, and psychological journals had much lower centrality despite the rapid focus on the landscape visual impacts on human mental health and rehabilitation in the last few years and the new frontiers remote sensing and AI had brought to the topic. Similar to the studies' citation analysis, this can be connected with the reliance on old references, while recent studies have started to explore newer options for methods and technologies.

4 Conclusions

This study provided an overall understanding of the current status of visual quality assessment research using a dataset extracted from the Web of Science. The study has applied systematic bibliometric analyses on the extracted data and found a few patterns that govern the field's intellectual structure. Following are the conclusions:

1. The field has emphasized for long the assessment of rural and natural regions compared to urban areas. This emphasis is linked with the professional needs established by introducing new regulations for changes in the natural landscape.

2. The psychological dimension is evident in many studies and has been further extended to medical and demographical aspects. Together, they form a set of visual-quality applications.

3. The advent of new technologies has recently pushed the field in a new direction. Yet, these tools have endless capabilities to serve the topic, especially at the urban level, which comprises more dramatic views and more diversity in physical features.

4. Study citation analysis revealed the strong attachment of most studies to the earlier fundamental ones, despite the steep acceleration of published articles in the last few years. This invites us to review the recent efforts to shift this field to a new state that tackles the upcoming challenges, especially in the urban domain, similar to the shift witnessed in psychological and medical applications for the field.

Although Visual Quality research started early compared to other urban studies, it did not receive enough density until recently, particularly at the urban level. Therefore, the field needs more attempts to establish a set of methods and tools for public space assessment. This study has also presented a methodology for bibliometric analysis of the field that can be extended to others, or applied to the field's relationship with others, like computer sciences, medical or psychological studies. The study also met multiple challenges. Overlaps with other sciences using similar keywords for different applications were problematic and required deep filtration. For instance, image visual quality, intensely discussed by computer sciences, dominated the search results even though it has no direct relationship with landscape visual quality. Interpreting networks in the absence of a clear relationship between nodes, from another hand, is associated with some subjectivity. Some network maps include heterogeneous clusters with little cues to distinguish their common interests. Finally, using tools withdifferent algorithms caused some inconsistencies in the results. Citation burst analysis, for instance, generated the timelines of keywords different from those extracted by Keyword Co-occurrence analysis, which obstructed forming clear descriptions of the network.

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