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Review

A Review of Cityscape Research Based on Dynamic Visual Perception

Xin Jin [1,2,3]

[1] Visual Image Research Base of Chinese Nation, Southeast University, Nanjing 210096, China; jinxin@seu.edu.cn
[2] School of Architecture, Southeast University, Nanjing 210096, China
[3] Key Laboratory of Urban and Architectural Heritage Conservation of Ministry of Education, Southeast University, Nanjing 210096, China

Abstract: Dynamic visual experience is the most common way for people to perceive a cityscape. Previous research reviews on cityscapes have mainly focused on spatial planning, social culture, economic development, ecological protection, etc., with little consideration of the impact of dynamic visual perception on the formation of cityscapes, which hinders the provision of references for the practice of people-centered urban design concepts. Therefore, this article selected 94 works in the relevant literature from 1940 to 2022 to conduct a critical review. First, we conceptualized the cityscape in light of earlier substantial discussions on the intimate relationship between dynamic visual perception and the cityscape. Then, we divided the relevant research from the past century and a half into three periods and summarized theoretical and practical research on the cityscape in these different periods from the perspective of dynamic visual perception. Among these, the refined research on interdisciplinary methods, including Visual Quality Assessment based on dynamic visual perception and visibility analysis algorithms based on digital technology, is emphatically described and discussed. Based on a comprehensive review, this article concludes that the main application scenarios for the existing research on dynamic visual perception are cityscape assessment and decision making. Finally, three avenues for future research are proposed.

Keywords: dynamic visual perception; cityscape; dynamic visual quality assessment; dynamic visual impact assessment; urban design; urban morphology

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1. Introduction

The value of a city can be primarily manifested by its cityscape, which has always been an important component of architectural and urban planning studies [1]. Cityscape is by nature the result of cultural and natural factors and processes which, when associated with land attributes and human activities, express a city's social and economic functions [2]. On the other hand, the cityscape is both a critical part of the urban ecological environment [3] and a significant material carrier of urban image [4]. The significant role played by the cityscape in formulating and shaping city image has been extensively discussed and approved. With its complexity and interactivity, the cityscape constitutes a city exterior space system and provides benefits to civil life and urban development [5]. Therefore, perceptibility is an important attribute of the urban landscape [6]. Visual perception is an important way for people to directly perceive the cityscape as well as an important medium for people to interact with it. The experimental psychologist Treicher confirmed through a large number of experiments that 83% of the information obtained by humans from the outside world comes from visual perception [7]. The value of landscape beauty depends on people's visual perception [8]. Compared with other more objective physical characteristics, visual perception is closer to the real feelings of citizens [9], meaning that it has a more direct effect on urban planning. Creating good visual perception and ensuring the beauty

of the cityscape has been the eternal pursuit of urban planning and urban design since the ancient Greek period [10,11].

As a complex artifact, a city is a complex system supported and influenced by many factors [12]. The complexity of urban physical spaces determines the multiple scales and perspectives of cityscape research. Moreover, the comprehensiveness of urban issues provides research of the cityscape a multi-dimensional value orientation. As Charles Waldheim mentioned that the city is regarded as a converged ecological system in which architecture and open space are landscape elements [3]. Landscape, as the medium of symbol communication, records history and tells stories [13]. Therefore, its information transmission and expression are dynamic processes. On the other hand, considering that the cityscape is closely related to public participation and recreational activities, continuity and experience are spatial characteristics which cannot be ignored in visual cityscape research. To sum up, dynamic visual experience is the most common way for people to perceive the cityscape [14]. Compared with static visual perception, dynamic visual perception emphasizes a continuous visual cognitive process, a state which considers the observer's experiences [15]. With the continuous strengthening and development of the people-centered planning concept, people's dynamic visual perception has gradually become one of the important factors considered in the cityscape [16].

Considering the vitality of dynamic visual perception in affecting the formulation of the affective cityscape in both theory and practice, it is worth discussing how it is related to the cityscape in different time periods. Building on previous studies, in this article we conduct a comprehensive review of cityscape research based on dynamic visual perception. First, we conceptualize the cityscape considering earlier substantial discussions on the intimate relationship between dynamic visual perception and the cityscape. Although many previous articles have explored the definition of the cityscape from the perspectives of spatial planning [17], social culture [18], economic development [19], and more, a consensus agreement on the perspective of dynamic visual perception remains lacking. In the materials and methods section, we explain the research framework and provide an overview of selected works and papers. We divide the related research in the past century and a half into three periods, then examine and summarize the theoretical and practical research on the cityscape based on the perspective of dynamic visual perception in these different periods. Finally, in the conclusions section, we summarize our findings and make suggestions for future research.

2. Conceptualizing the Cityscape from the Perspective of Dynamic Visual Perception

The cityscape refers to the appearance of various material forms composed of the urban physical environment and urban life and the overall comprehensive perception led by visual maintenance [20]. The European Landscape Convention (ELC) proposes that the landscape refers to the environment as well as to the world "perceived by people" [21]. Visual perception is the intuitive feedback and effect presentation of urban morphology in the dimension of urban spatial planning [22], and has always been an important part of architecture and urban planning research and the embodiment of urban value [1].

The development of urban aesthetics research has had a significant impact on people's understanding of the physical environment of the cityscape [12,23,24]. To this day, urban design remains deeply guided and permeated by urban aesthetics [25–27]. According to research on urban aesthetics, the visual perception of the cityscape can be considered as a pivotal medium connecting people to the physical environment of the city [28–30]. When the cognitive approach to the cityscape changes from a single "static view" to a multi-angled "dynamic view", this means that the connotation of the cityscape is extended from "static landscape beauty" to "dynamic landscape beauty". Continuous motion brings about an extension of visual perception in the three-dimensional space of urban landscapes [31], essentially exploring their temporal extension [14]. Studies in neuroimaging have shown that the essence of dynamic vision is the superimposition of the human visual field on successive viewpoints [32], i.e., the continuous acquisition of images during movement

due to the persistence of vision [33]. Dynamic visual perception is the continuous perception generated by this dynamic vision [14]. In light of the above findings, we can provide the following definition of a cityscape from the perspective of dynamic visual perception: cityscape is a collection of images accumulated from people's perception of urban physical space in a state of motion. We believe that cityscape research based on dynamic visual perception is an important means exploration of the cityscape and urban three-dimensional space in the dimension of "the human–landscape relationship", which is itself the product of social development towards a change in the perception of the urban landscape physical environment.

3. Materials and Methods

3.1. Publication Retrieval

This review brings together the traditions of urban planning, urban design, environmental psychology, and other social and environmental sciences. The review process consisted of screening key research articles, reviews, and other studies that specifically address cityscape research related to dynamic visual perception, taken predominantly from the Web of Science core collection database. The key search words included the following: cityscape, urban landscape, dynamic visual perception, motion vision, continuous perception, and dynamic viewing. These terms led to reasonable search rules. At the same time, we sorted and organized relevant books according to the content and keywords of reviews from Google Books. The search was conducted for the publication period between 1900 and 2022, and 157 publications were identified for further screening. The flow of the screening process is shown in Figure 1.

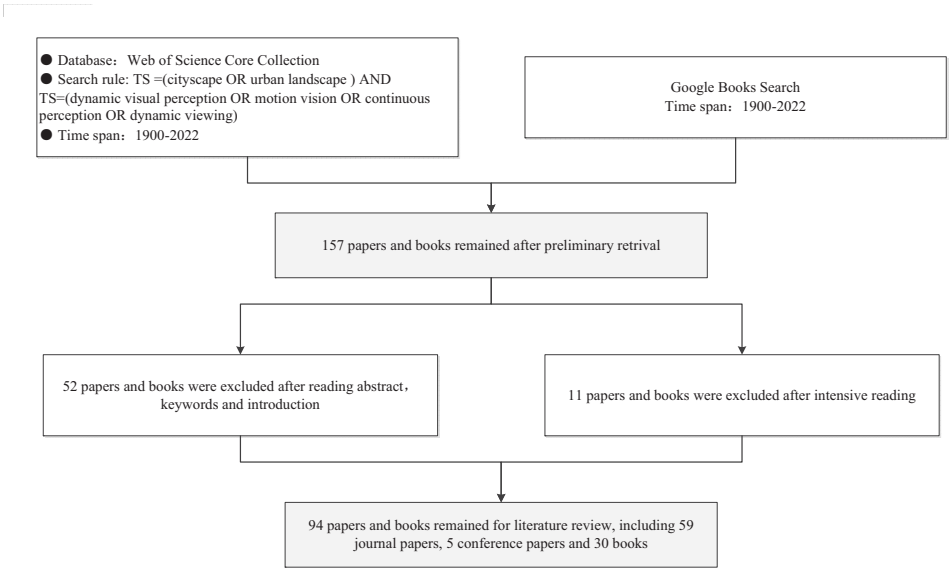

Figure 1. The flow of the screening process.

Rooted in these diverse disciplinary areas and informed by work in aesthetic and environmental philosophy, computer science history, and other branches of the arts and humanities, cityscape research based on dynamic visual perception covers as broad a range of the literature as almost any field of urban studies we are aware of. Considering the definition of a cityscape from the perspective of dynamic visual perception proposed in Section 2, this article focuses on studies of urban morphology and urban design. We conducted extensive reading of the abstracts, keywords, and introductions of all publications. According to the research topic and focus, we excluded 52 related publications in areas such as social culture, economic development, and ecological patterns. The intensive reading stage for the remaining studies required in-depth reading of the full papers. A total of eleven publi-

cations were removed as they did not provide valuable opinions and results for cityscape research from the perspective of dynamic visual perception. Finally, 94 publications were selected for analysis, including 30 books, 59 journal papers, and 5 conference papers.

3.2. Brief Overview of Selected Publications

After intensive reading of all selected publications, they were divided into the categories of Policy Acts, General Theory, Design Practice, and Monographic Study based on their content. According to the research topic and focus, the Monographic Study category was divided into a further three categories: Visual–Aesthetic Values, Visual Quality Assessment, and Visual Impact Assessment. We calculated the distribution of research categories and quantities published annually from 1900 to 2022. Papers and conference papers were counted based on the year of publication, while books were counted based on when they were first published or when their core ideas were proposed. Furthermore, through cluster analysis and consideration of major events (Figure 2) in the field of urban landscape research during social development, the relevant research over the past century and a half was divided into three periods.

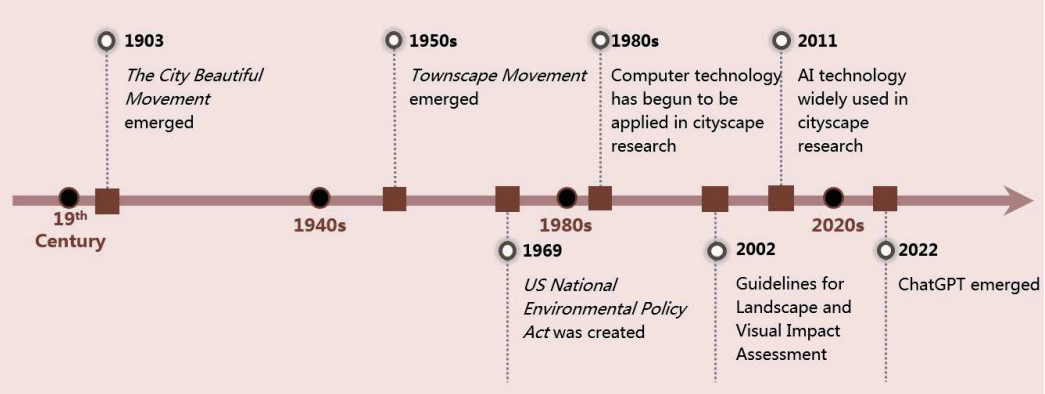

Figure 2. Timeline diagram of the most important events in cityscape research.

It is worth mentioning here that there is no complete and strict alternation of old and new in different periods. We used Sankey diagrams to visualize the relationships between research diagrams and the resulting relationships between different studies over the three periods of time, as shown in Figure 3.

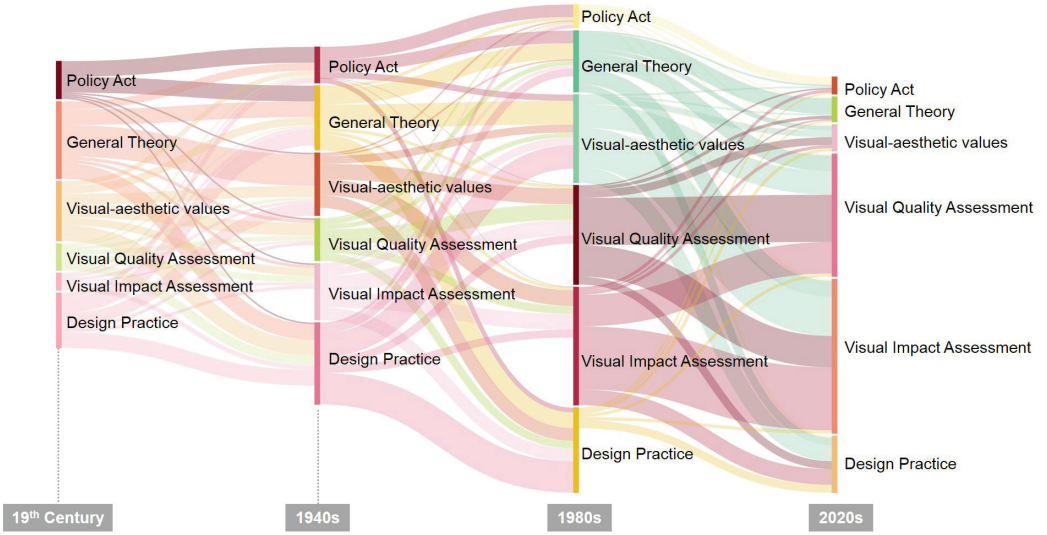

Figure 3. Diagram of the relationship between different studies over three periods.

It can be observed that in research before the 1940s, General Theory and Design Practice dominated. From the 1940s to 1980, while Design Practice continued to hold a dominant position, research on aesthetics and visual assessment began to gradually increase. After the 1980s, Monographic Study, including Visual–Aesthetic Values, Visual Quality Assessment, and Visual Impact Assessment, became dominant, and the proportion of General Theory and Design Practice continued to decrease. Studies on Policy Acts such as the Guidelines for Landscape and Visual Impact Assessment [34] and the US National Environmental Policy Act [35] exist in all three periods; however, their proportions are not significant.

4. Cityscape Research Progress from the Perspective of Dynamic Visual Perception

The study of the cityscape based on dynamic visual perception originated at the end of the nineteenth century, about a century and a half before today. The application of dynamic visual perception in urban design has played different roles in different periods. Prior to 1940, research on dynamic visual perception had only just begun, mainly appearing as an auxiliary concept in the field of urban design. From the 1940s to the 1980s research on dynamic visual perception flourished, with a large amount of theoretical research and design practice work emerging. After the 1980s, research on dynamic visual perception was gradually refined and began to focus on monographic studies, often applied as an interdisciplinary research method in scientific urban design. This change stemmed from the continuous strengthening and development of the human-centered planning concept in the process of social progress, and on the other hand from the development of science and technology providing better objective conditions for describing and quantifying the relationship and connection between dynamic visual perception and the cityscape.

4.1. Pre-1940s: Auxiliary Concepts in Urban Design

During this period, the influence of the cityscape on urban design was gradually discovered by researchers. However, most of these studies focused on the study of static viewpoints, while only a few scholars focused on the changing visual perception experience through dynamic viewing. Moreover, dynamic visual perception was often used as an auxiliary design concept in urban design.

Early cities were formed mainly by the will of rulers or officials [36], and as a result, the cityscape was shaped by the perceptions of the powers that be [37]. When the city was a symbol of imperial wealth or "divine right", prominent landmarks and homogeneous street texture were the focus of cityscape research [38]. Nevertheless, as early as the Renaissance, Alberti expressed that an appreciation for the dynamic perception of curving city streets [39].

Until the 19th century, a large number of architects and planners were involved in urban planning and urban design. The formation of modern cities is based on the reconciliation of multiple elements and has begun to involve human emotions and experiences; thus, the cityscape has gradually become an important part of the creation of urban physical space [40]. By the end of the 19th century, people's perception of the city had gradually changed from "site" to "place" [41]. Cities are no longer just "aggregations of buildings and people" [42]; collective memory, perceptions, cultural heritage, and economic development have become important factors influencing urban development [43].

The City Beautiful Movement has influenced many cities in Europe and the United States to transform the physical space of the environment in order to restore the attractiveness and quality of urban centers [44]. Scholars have begun to realize that visual perception is the most direct way for people to feel space, and is the best way for them to experience spatial emotions and spatial differences [45]. Therefore, the cityscape has changed from a "result of site planning" to a "visual philosophy" approach that guides urban development [41].

As one of the first scholars to propose urban design research based on visual perception and aesthetic principles, Camillo Sitte emphasized the coordination between urban open

space and architecture and discussed the layout, form, and scale of squares and streets in depth, proposing artistic principles suitable for modern urban planning and strategies for the improvement of modern urban systems [46]. Sitte argues that paths can be designed to organize and design human behavior and dynamic visual perceptions, such as slightly winding streets that allow people to widen their horizons as they walk and pay attention to the changes in visual perceptions brought about by the contour lines of buildings, thereby responding to the topography of the place. He attempted to create an ideal system to describe the urban form, simulating the continuous visual perception of people in the city in order to rationally design an "organic" city. Although these artistic principles and ideal systems are not fully applicable to most cities around the world due to the limitations of urban scale and technical methods, Sitte's ideas have profoundly influenced subsequent cityscape research.

Influenced by Sitte, two British planners of the same period, Raymond Unwin and Barrt Parker, analyzed the relationship between streets and squares by studying the sequential street scenes of medieval cities such as Regensburg, Rothenburg, and Buttstedt. In addition, the design concept of dynamically observing the street view was implemented in urban design practices at locations such as New Eastwick, Hampstead Garden Suburb, and Letchworth Garden City [47]. Unwin proposed the Picturesque Approach to streets and other urban spaces from a more rational perspective, namely, that of dynamic visual perception [48]. Today, most people would consider such "imaginary" street view paintings to be impractical; in fact, however, these schemes and ideas take into account normal pedestrian traffic and vehicular traffic, as well as "buildability" in the time dimension.

4.2. 1940s–1980s: Design Methods in Urban Design

During this period, dynamic visual perception was often used as the dominant design method in urban design, and a large number of related theoretical studies were generated. After 1940, scholars of cityscapes based on dynamic visual perception developed the theory of visual planning on the basis of previous studies, refined the factors affecting visual perception, and embarked on typological research, reviewing methods to explore how best to create an attractive cityscape by optimizing urban morphology. By the 1980s, relatively mature theories and methodologies of visual planning were gradually developed. The objective reasons for this development were twofold. The first was the development of photographic technology, which allowed researchers to record urban scenes more objectively by using photographs instead of paintings. The second was the popularization of transportation tools and the diversification of viewing methods, which changed the experience mode of the cityscape, leading to demand for a diversity of cityscape scales. In addition, the post-war urban reconstruction and Townscape Movement in Britain provided important opportunities for the development and practice of visual planning theory. Therefore, "Visual Planning" was proposed as a design method in urban design to address the influence of visual perception on urban morphology in the process of urban development [49]. Several important studies during this period are reviewed below.

Nikolas Pevsner proposed a painterly urban planning method called "semi-accidental loose planning". He defined cities as "a paradigm of landscapes" and traced the roots of the cityscape to the "picturesque" concept of the 18th century [50]. Pevsner advocated guiding urban planning with visual perception, and taking blocks, neighborhoods, and skylines as important components of the cityscape. His case study of the cityscape is not limited to conventional planar analysis, emphasizing the differences in visual perception presented by photos from different viewpoints within the same area [51].

Ivor de Wolfe popularized the theory of Visual Philosophy, which was widely disseminated in the UK, and applied it to Italy [52], taking the Italian cityscape as the research object and using photographs as the research medium to classify landscape systems into nine types based on the regional morphological characteristics of the place. In addition, he reviewed the visual perception of urban landscapes from different urban scales [53]. Wolfe suggested that both the "historical elements" and the "contemporary elements" in a

built environment have a positive impact on the richness of the cityscape, and that there is a "subtle" contradiction between the different urban scales (i.e., pedestrian scale and vehicular scale) [52,54].

Gordon Cullen proposed the concept of Serial Vision, which simulates the continuous visual perception of a person in a walking state by selecting a series of moving viewpoints, taking photographs, and sketching. As one of the most commonly cited viewpoints in the townscape movement, sequence view constructs a "continuous cognitive concept from the dynamic perspective of pedestrians", analyzes urban spatial morphology through image sequences formed by buildings and urban open spaces, and feeds them back into urban design [55]. To express the sequence scenes, Cullen tried two different representations [56]. The first representation was called the "Panorama of the Westminster Precinct" and consisted of six sets of elevation panoramas views from different perspectives. The multiple sets of city facades, presented by moving the camera equidistantly along a preset trajectory, show the "visual differences" formed by different viewpoints of the church facade, the Houses of Parliament, and the Westminster Abbey. This set of images is included in the book "Concise Townscape" [55]. The second representation was a conventional sequential perspective group consisting of eight watercolor renderings and one photomontage. The first representation uses an abstract graphical language that architects and planners would prefer, but which is more difficult for the public to understand. In contrast, the second representation is closer to the realistic view of the simulated reality and more in line with the familiar way of perceiving the city, which was then commonly adopted by Cullen. As a result, the professional and abstract urban façade cannot fully express the dynamic visual perception under real vision, while the sequence perspective, which is dominated by human movement paths and is closer to a real scene reproduction, can resonate more with the public.

With the development of mechanical power and its application in transportation, the concept of the region has gradually been deconstructed into a system composed of a series of complex transportation modes. On this basis, Edmund Bacon proposed the "Simultaneous Movement System", which means that different types of motion constitute a complete cognitive system, and different speeds lead to different visual perceptions [57]. With movement, people acquire continuous visual perception in the built environment and ultimately form a holistic awareness of the environment. The overall understanding is both a simple superposition of all individual spaces and a dynamic process of visual perception changes accompanied by changes in the state of motion.

4.3. Post-1980s: Refined Research on Interdisciplinary Method in Urban Design

Before 1980, cityscape studies based on dynamic visual perception mostly relied on expert experience for qualitative evaluation of pictures due to the lack of clear quantitative evaluation criteria and technical means. In pre-1980 cityscape research, dynamic vision was more strongly incorporated into urban design as a generalized design concept. After 1980, based on the exploration of the formation mechanism of cityscapes and the continuous deep embedding of digital technology into all dimensions of cityscape research, visual perception has usually been applied in scientific urban design as an interdisciplinary method. Conventionally, the development of cityscape research based on dynamic visual perception has strongly promoted the application of advanced digital technology in smart city planning as well as in governance [58]. Refined and multidisciplinary research characterized by big data, human–machine interaction, and an emphasis on quantitative studies provides a new approach to cityscape perception and deep understanding [59]. Contemporary cityscape research based on dynamic visual perception is mostly based on quantitative "visual assessment". Its core is to assess the aesthetic value of the urban landscape through human visual perception or to predict the trend of the change in landscape visual quality according to different urban design strategies [60]. In our review of the literature and our attempts to bring clarity to the range of topics covered, the related research on visual assessment is mainly divided into two main developmental directions, namely, Visual

Quality Assessment for different motion systems and Visual Impact Assessments for multi-viewpoint visibility studies. In both directions, the visual perception acquired by people in different observation states is the main research object, the understanding of the visual scene is the core of the research [61], and the consideration of the continuity of the visual field lays the theoretical foundation for the development of a refined scientific strategy for the urban landscape.

4.3.1. Dynamic Visual Quality Assessment

The National Environmental Policy Act (NEPA), passed in 1969 in the United States, endorsed the need for visual quality in the analysis of environmental values [35]. In the European Landscape Convention (ELC), landscape character, as a similar though broader concept than visual quality, linked landscape perception and visual quality with human rights, social equity, and democratic participation [62]. In 1975, R.S. Crofts proposed two types of landscape assessment methods: the Preference Model, based on qualitative research and the Surrogate Component Model, based on quantitative research [63]. However, because the early academic community was against the use of a quantitative value or value ranking to define Visual Quality Assessments (VQAs), preference models based on qualitative research, including expert evaluation and public preference, became more widely used [64]. According to E.H. Zube et al., there are four major paradigms: the expert paradigm, the psychophysical paradigm, the cognitive paradigm, and the experiential paradigm [65]. Among these, expert evaluation is mostly based on landscape architectural design guidelines, while public preference is mostly applied to the psychophysical paradigm, the cognitive paradigm, and the experiential paradigm [66–68]. Furthermore, T. C. Daniel et al. considered five visual quality evaluation models for evaluating cityscapes on this basis: the Ecological Model, Formal Aesthetic Model, Psychophysical Model, Psychological Model, and the Phenomenological Model [69].

Since the 1990s, humanity has entered an era of data explosion. The rapid iteration of information technologies such as big data, artificial intelligence, mobile internet, and cloud computing have made it possible to collect and process massive amounts of image data, and enabled dynamic visual perception studies on mental cognition, image recognition, and visual impact, which were previously difficult to quantify, in order to find the core of the maximum intersection through the supercomputing power and the probability convergence required for data visualization operations [70]. The quantification of dynamic visual perception has been gradually refined for applications in urban scene analysis and visual quality evaluation [71]. The development of computerized landscape simulation and visualization technologies has provided a more objective and scientific perspective to analyze the dynamic visual perception of humans, alongside methods to quantify the relationship between the built environment and visual characteristics [72]. As a field rich in both practical projects and research results, dynamic visual quality evaluation is characterized by multi-disciplinary integration and multi-dimensional development, and the main research contents include the following two aspects.

The Landscape Visualization Method (LVM) is used to simulate real dynamic views, perform a certain degree of abstraction, and conduct quantitative analysis based on Visual–Aesthetic Values (VAV) [73]. In such studies, both psychophysical models and surrogate component models are usually combined [74,75]. In terms of technical practice, early studies mostly used photomontage and digital imaging techniques to achieve scene reproduction and evaluation [20]; more recently, 3D modeling and augmented reality techniques have been used to anticipate landscape planning schemes or urban design strategies [76]. Theoretical research, mainly through the digital translation of classical aesthetic theories [77], achieves the integration of visual aesthetics, and research results are mostly applied to the study of urban morphology [78] and the selection of indicators for landscape resource management [79]. Sarradin F. et al. used a dynamic visual perception perspective to quantify the morphology of urban open space based on random paths by calculating the spherical projection of the sky patterns for a set of continuous viewpoints and using the

skeletonization method to measure changes in the observer's field of view [80]. Through image recognition technology and a machine learning algorithm, the research team of the Chinese Academy of Sciences quantified the visual perception of people in an urban physical space environment in the process of moving and predicted the perception attributes [71]. A joint study of the University of Michigan and Tongji University used 3D Mobile Mapping to quantify the dynamic visual perception of drivers under different speeds and viewing angles to evaluate the spatial design of intersections [81]. Based on continuous viewpoint dynamic visual perception translation technology, Jin X et al. transformed the perceptual dynamic visual perception of people during movement into objective digital representations or datasets, thereby quantitatively evaluating linear urban landscape morphology [14]. On the other hand, experimental studies with multiple participants have been conducted using open source data and auxiliary instruments based on the relevant results of cognitive psychology and environmental behavior studies. This type of research investigates the factors affecting visual attractiveness through human behavior and activities, quantifies dynamic visual perception, and establishes the connection between the sense of place and visual characteristics of urban environments. The research results are mostly applied to the selection of contextual indicators for place analysis and specialized studies of landscape preferences. The experimental eye movement method can be combined with a questionnaire survey to explore the consistency of the factors influencing landscape preference against different cultural backgrounds. In [82], Ren used questionnaires and experimental eye-movement methods to explore the consistency of landscape preference influences in different cultural contexts. Based on the large "Place Pulse 2.0" dataset released by the MIT Media Lab, researchers from Peking University together with colleagues at the Chinese University of Hong Kong and the Massachusetts Institute of Technology collected dynamic visual perception evaluations from people regarding the external morphology of cities in combination with streetscape image collection and machine learning to quantify and predict human visual perceptions of large-scale cityscapes [72]. Based on human walking activities, Lai et al. took New York City as an example to conduct a quantitative analysis of the visual perception attributes of a cityscape by integrating high-resolution, large-scale, and heterogeneous urban datasets [83].

4.3.2. Dynamic Visual Impact Assessment

Dynamic Visual Impact Assessment and Dynamic Visual Quality Assessment are closely related; both focus on the influence of the morphological changes in open space on the visual aesthetic characteristics of the landscape under a state of motion [9]. However, Dynamic Visual Quality Assessment focuses more on the construction of assessment methods, while Dynamic Visual Impact Assessment focuses more on the specific visual changes of the landscape under project orientation, with an emphasis on accuracy and precision. In the National Environmental Policy Act (NEPA) passed in 1969, the United States recognized the need to consider visual impact in environmental value analysis. Similarly, the European Union adopted the Environmental Impact Assessment (EIA) directive in 1985, and the 2014 revision emphasized the importance of environmental Visual Impact Assessment for the better protection of historical and cultural heritage and landscapes, i.e., focusing on the Dynamic Visual Impact Assessment of artificial landscapes, natural landscapes, and urban open spaces. In the third edition of the Guidelines for Landscape and Visual Impact Assessment [34], visualization and visibility research on key observation points (KOPs) is widely used in Dynamic Visual Impact Assessment. Visibility algorithms based on geographic information science (GIS)-related research provide an instrumental algorithm for visual studies of cityscapes in terms of planning decision analysis.

Research on visibility analysis algorithms is divided into planar visibility analysis and three-dimensional visibility analysis [84]. Based on the mature development of planar visibility analysis research, 3D visibility analysis has been rapidly developed. Usually, visibility analysis algorithms are divided into point-to-point visibility analysis (intervisibility analysis), point-to-area visibility analysis (visibility analysis), and combined multipoint

optimal viewable visibility [85]. Wheatley proposed the concept of "Cumulative View", and called the graph generated by the algebraic accumulation of these sources of visibility information a cumulative viewable graph, which refers to the degree of mutual visibility of points in space [86]. Llobera, on the other hand, redefined the term "Visualscape" in the context of GIS, and incorporated quantitative indicators such as cumulative viewshed, total viewshed, and visual exposure to describe the structure of visual space in the category of the spatial visual environment as a type of description for spatial visual environments [87].

The application of Visual Impact Assessment in multi-viewpoint visibility research has expanded the research object of Visual Impact Assessment from fixed viewpoints and regions to dynamic random paths. Based on different data-driven methods, the application methods mainly include three types. The first type is descriptive analysis, which reveals basic characteristics and laws through the calculation and visualization analysis of the visual field under movement. B.C. Chamberlain et al. established the relationship between visibility assessment and visual perception based on a random path. By quantifying the impact of slope, they calculated Visual Magnitude under a standard viewshed and cumulative viewshed with different weights, then analyzed the dynamic visibility of a cityscape along the path [88]. Michael J. Dawes et al. used isovist fields to undertake a computational and mathematical analysis of the spatial–visual properties of paths through five of Wright's textile-block houses, and assessed Hildebrand's application of prospect–refuge theory [89]. The second type is prediction and decision analysis, which provides a basis for decision making by simulating dynamic visual impact results under different scenarios. J. F. Palmer simulated and calculated the Dynamic Visual Impact Assessment of linear infrastructure on multiple viewpoints in different regions through the image simulation of key viewpoints combined with a GIS-based landscape assessment model (LAM), providing a decision-making basis for related landscape resource management [90,91]. The third type is correlation analysis, which uses techniques such as deep learning or artificial intelligence to mine and analyze dynamic visual impact and explore the correlation between variables. Luyao Xiang et al. conducted on-site measurements, recorded dynamic psychological and physiological stress, and calculated isovist indicators by introducing a new indicator, the isovist time difference, then analyzed its impact on stress to explore the correlation between isovist index level and emotional response [92,93].

In conclusion, preciseness and accuracy are the core of Dynamic Visual Impact Assessment [94]. With the development of new algorithms and computing tools, the objects, indicators, and precision of Dynamic Visual Impact Assessment are expanding, and the research results are mostly being applied to special studies of human-centered urban planning decisions and cityscape management.

5. Conclusions and Future Prospects

Using selected papers from the relevant literature, this paper has defined the concept of the cityscape from the perspective of dynamic visual perception, analyzed its development context, and compared and examined research methods and practices from different periods. This comprehensive review provides an understanding of the cityscape from the perspective of dynamic visual perception based on social development, regarded it as an important exploration of the cityscape in the dimension of the human–landscape relationship.

After nearly a century and a half, city landscape research based on dynamic visual perception has undergone continuous detailed and accurate development, transforming from qualitative expert assessment to quantitative scientific multi-factor evaluation, and from a design approach to specialized research that supports planning decisions.

The key message this paper seeks to impart is that technological development is indeed of great help to the research on cityscapes based on dynamic visual perception. Understanding the urban built environment from the perspective of dynamic visual perception is an important transition in cityscape research from the meso-scale to the micro-scale, leading to a more scientific and refined orientation of quantitative analysis in contemporary dynamic visual perception research. On the one hand, data-driven dynamic perception studies can

be considered as a digital representation of classical theories. By simulating the real vision of human eyes, and in combination with research in related fields such as psychology and visual aesthetics, these studies have digitally demonstrated the classical theories of Camillo Sitte, Gordon Cullen, Edmund N. Bacon, and others. Based on this, the impact of factors such as aesthetic preferences, microclimate, and movement modes on dynamic visual perception can be assessed. On the other hand, dynamic visual perception technologies characterized by big data, human–computer interaction, and quantitative research have provided new methods for assessing cityscapes and predicting urban design decisions. These studies provide specialized research for the assessment of urban morphology and cityscape, or provide multi-scenario decision-making predictions based on different urban design strategies. These application scenarios contribute to scientific urban design and cityscape management to a certain extent. The rapid iteration of information technologies such as big data, artificial intelligence, mobile internet, and cloud computing has made it possible to collect and process massive amounts of data.

However, excessive emphasis on in-depth technical research can limit the application of dynamic visual perception studies in design practice. First, relevant studies may not pay sufficient attention to integrity at the urban scale. Overly refined research methods mean that most of research focuses on a certain parcel of land in a city, and lack the focus on integrity at the urban scale which appeared before 1980. Second, the results of these studies are mostly applied to design strategies. Their role in design practice lies in status quo assessment or decision-making prediction, rarely affecting the process of urban spatial design and urban morphology optimization directly.

Based on our analysis and summary, the main research directions for cityscape research based on dynamic visual perception in the future should include the following:

(1) Research on the dynamic visual perception of multi-scale cityscapes. Guided by the relevant classical theories, it may be possible to reveal the internal mechanisms between dynamic visual perception and the urban morphology of multi-scale cityscapes. The general urban design should be given special consideration at the urban scale, including analysis and research examining spatial structural characteristics and spatial design.

(2) Development and application of a dynamic visual perception assessment system for multiple scenarios. In future studies, a dynamic visual perception assessment system that combines qualitative and quantitative methods under the guidance of multi-scenario decision-making processes should be constructed. Moreover, a visual support platform should be developed with integrated functions for data processing, scenario simulation, assessment result output, and problem diagnosis. This platform could help promote government coordination at all levels and cooperation between different departments of the cityscape's target demand in order to facilitate building height control, spatial quality improvement, city identity, and landscape resource management of the cityscape.

(3) Research on cityscape optimization based on dynamic visual perception. Future studies should utilize research achievements in the fields of deep learning, machine learning, and artificial intelligence in combination with the results of dynamic visual perception assessment to construct a multi-objective optimization model for cityscapes. By setting different rules, research can be carried out on cityscape optimization in terms of spatial design in order to provide a reference optimization design program for related urban design projects and guidance for designers.

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