Mapping Landscape Spaces

Understanding, interpretation, and the use of spatial-visual landscape characteristics in landscape design

Mei Liu

Mapping Landscape Spaces

Understanding, interpretation, and the use of spatial-visual landscape characteristics in landscape design

Mei Liu

TOC

A+BE | Architecture and the Built Environment | TU Delft BK

20#20

Design | Sirene Ontwerpers, Rotterdam

Cover photo | Mei Liu, Stella Shi

ISBN 978-94-6366-335-9
ISSN 2212-3202

This dissertation is open access at https://doi.org/10.7480/abe.2020.20

Mapping Landscape Spaces

Understanding, interpretation, and the use of spatial-visual landscape characteristics in landscape design

Dissertation

for the purpose of obtaining the degree of doctor
at Delft University of Technology
by the authority of the Rector Magnificus, Prof.dr.ir. T.H.J.J. van der Hagen
chair of the Board for Doctorates
to be defended publicly on
Wednesday, 16 December 2020 at 12:30 o'clock

by

Mei LIU
Master of Arts in Landscape Studies, University of Sheffield, UK
Master of Landscape Architecture, Harbin Institute of Technology (Shenzhen), China
born in Harbin, China

TOC

This dissertation has been approved by the promotors.

Composition of the doctoral committee:

Rector Magnificus	chairperson
Prof. ir. Dirk Sijmons	Delft University of Technology, promotor
Dr. ing. Steffen Nijhuis	Delft University of Technology, promotor

Independent members:

Prof. dr. E. Lange	University of Sheffield, UK
Prof. dr. E. Braae	University of Copenhagen, Denmark
Prof. dr. X. Wang	Southeast University, China
Prof. dr. O. Schroth	Weihenstephan-Triesdorf University of Applied Sciences, Germany
Prof. ir. E.A.J. Luiten	Delft University of Technology
Prof. dr. J.E. Stoter	Delft University of Technology, reserve member

TOC

Acknowledgements

This book could not have been completed without the support and help of a number of individuals. Thank you for your guidance, encouragement, and company, and for letting me fully feel your love and care during this hard but precious time.

I would like to express my deep gratitude to my promotor, Prof. Dirk Sijmons, for his positive flash of thought considering my application and supervising my PhD at TU Delft even after his retirement. I really enjoyed every enlightening meeting with him in EYE or in Delft, and do appreciate all his critical feedback, professional suggestions, and profound wisdom. Meanwhile, I am also extremely lucky to have Dr. Steffen Nijhuis as my promotor, whose academic guidance and patience, rigorous working attitude and enthusiasm inspired and motivated me to overcome every challenge not only in my research but also for everyday life during the past five years. I also would like to thank to all the members in the section of Landscape Architecture at Delft University of Technology, especially Michiel Pouderoijen for providing data and technical back up for this research. Also great thanks to department's secretaries, Margo, Chiara, Danielle, Karin, and Astrid.

I owe special thanks to the scholars and designers I interviewed for this research, Han Lörzing, Frits Palmboom, Eckart Lange, Mark Eker, Eric van der Kooij, Bas Horsting, Olaf Schroth, Philipp Urech, Jaap van der Salm, Rob Koningen, and Honglei Cui. It has been a great honour to discuss this 'advanced but peripheral' issue in a practical context, ask them to share their working experiences, attitudes of data and technology, and their expectations of the future of landscape architecture.

Thanks to James Nelson for dedicating the time to proof-read my dissertation, and Stella Shi for the fantastic graphic design, which significantly improved the quality of the final product. Thanks to Vero Crickx and her patience to make this book.

I have been fortunate to be surrounded by great colleagues who are always generously share their knowledge, provide technical support, introduce valuable interviewees, patiently answer endless questions, and satisfy my curiosity about this complex world. Thanks for their friendship which makes this PhD journey so fun and rewarding, Cinco Yu, Daniele Cannatella, Jiaxiu Cai, Lei Zhong, Liang Xiong, Luiz de Carvalho, Rachel Keeton, Wang Pan, Yuka Yoshida, Yuting Tai.

In addition, I would like to acknowledge my friends in Delft through all the good and bad. Juan Yan and Jiani Liu, thanks for always being there for me. Li Lu, thanks for discussing or debating philosophical issues which has really improved my ability think critically. Tianchen Dai, thanks for not only being my academic friend but also foodfriend. Xue Yu, thanks for the suggestions she gave at the very beginning of my PhD which I truly benefited from. Yan Song, thanks for helping me on big and small matters in any way needed. Special thanks to Evelyn Chen for being my trustworthy friend and keeping company with me travelling around the world. Last but not the least, I would like to thank Zobee for the companionship all the time.

Above all, I would like to thank my parents for their unconditional love and encouragement.

Contents

List of Tables

List of Figures

Summary

Landscape can be perceived and described in many ways. The European Landscape Convention defines it as “an area, as perceived by people, which character is the result of the action and interaction of natural and/or human factors.” (Council of Europe, 2000). Considering the holistic sensory relationship between humans and landscapes, vision, as the principle channel for the cognition of physical world, is the primary factor that shapes people’s experience of the environment, more so than other senses. As Nelson (1977) states, visual aspects help people to recognize and discriminate “beauty”, “finer things”, and “aesthetics”. Landscape design is about the construction and articulation of outdoor space and results in landscape architectonic compositions in order to achieve a set of proposed physical, functional, symbolic, and aesthetic outcomes. Landscape designers mainly elaborate these corporeal and incorporeal notions into physical structures which manipulate distinctive spatial patterns and visual appreciations (in short: spatial-visual characteristics) into a richer interaction between humans and their environment. As either a form-creating result or a problem-solving activity, landscape design is an integrated process that acquires insights through both subjective interpretation and objective analysis/evaluation (in short: an inter-subjective description). This facilitates a collaborative understanding and open communication for the co-construction of landscape architectonic compositions.

In order to thoroughly communicate these three-dimensional forms and functions, vocabulary, representations, and tools (in terms of spatial-visual characteristics) are of fundamental importance for spatial designers to describe, understand, and visualise space. In the field of landscape architecture, designers predominantly concentrate on a more subjective descriptions and focus on personal accounts of space, while landscape researchers focus on the measurement of indicators in order to demonstrably interpret the spatial properties of landscape. These two important priorities both provide valuable clues for understanding landscape spaces, however, a comprehensive overview which explores the knowledge of spatial-visual landscape, combining design vocabulary and visual landscapes indictors, qualitative and quantitative mapping approaches, visual representation and interpretation, is still lacking. Therefore, the central objective of this research is to provide a framework for describing, understanding, and communicating about landscape spatial-visual characteristics in landscape design. This led to the following main research parts:

Spatial-visual Design Vocabulary

Design vocabulary is important for landscape architects to understand, design, and communicate about space. This research first reviews and develops a spatial-visual design vocabulary for the field of landscape architecture in order to provide a systematic framework for interlinking more qualitative and quantitative vocabulary for describing and interpreting landscapes. Based on an analysis of the vocabulary used in the extensive body of literature available on landscape architecture and related disciplines (e.g. urban design, visual arts, landscape ecology, urban morphology, environmental psychology), four dominant categories are selected in describing spatial-visual organisation. The categories identified and discussed are named by the author as sequence, orientation, continuity, and complexity. In addition, a landscape design syntax is generated with a hierarchical structure (vocabulary, perspective, element, characteristic) to help explore and interpret ambiguous spatial-visual concepts of detailed landscape characteristics in a scientific manner.

Spatial-visual Mapping Methods and Tools

Mapping the spatial-visual landscape by means of manual and digital technologies enables landscape architects to describe landscape space more vividly. These visual interpretations and representation approaches can help to strengthen the body of knowledge of spatial design in landscape architecture through the measurement and visualisation of common concepts in the field. These interpretations also allow for the possibility to explore spatial-visual landscape features that were not possible before. The research contributes to increasing this awareness by providing an overview of mapping methods and tools that can be used to study spatial-visual characteristics in the field of landscape architecture and show the potentialities of its application using brief examples. Six categories of mapping methods are identified in this research: compartment analysis, 3D landscapes, grid-cell analysis, visibility analysis, landscape metrics, and eye-tracking analysis. These methods are used to explore crucial spatial-visual characteristics in landscape architecture, such as sequence, orientation, continuity, and complexity, in both an analogue and digital way. Vondelpark, a well-known urban park in the Netherlands, is used as a pilot study to exemplify how these spatial features can be mapped by means of the mapping methods.

Application of Spatial-visual Mapping Methods in Landscape Design Process

With a knowledge of how to map spatial-visual landscape characteristics, it is possible for landscape architects to gain a more complete understanding of landscape compositions and their visual manifestation. However, given the vast range of possibilities, selecting, and applying mapping methods for thinking about landscape space in the design process remains problematic. This is because the emphasis is mainly placed on the digital tools and methods themselves, or the design. To bridge the gap between mapping technology and landscape design, two hypothetical design experiments are conducted in this research which apply appropriate mapping methods and tools to interpret the spatial-visual characteristics at different stages in the design process. The application of a spatial-visual mapping toolbox produces new insights for landscape architects to describe and communicate about landscape space, but also showcases broader analytical, generative, evaluation effectiveness, and the value of digital technology for design purposes.

Application of Spatial-visual Mapping Methods in Landscape Practices

In everyday design practices, mapping landscape spaces is of great importance through practical design work, which effectively refers to the achievement of the design intention and the performance of analysis and evaluation. However, the implementation is also subject to a designer's personal attitude, limitation of knowledge, and access to/proficiency with technology etc. Interviews are conducted with eleven experts with a practical design background, multiple levels of government, and academia, to investigate how and what means are used by spatial designers to map and describe landscape spaces in their day-to-day work. The interviews also focused on whether the spatial-visual mapping methods have potential to be part of a design toolkit in the future of landscape practices. The findings found that after being introduced to the potentiality of spatial-visual mapping methods and tools, via brief examples, most of the interviewees showed increasing interest and a positive attitude about mapping spatial-visual landscape characteristics. In order to implement them in the further development of landscape architecture, educational and research institutions have an important part to play in raising awareness, educating the corresponding values and concerns as well.

Summing up, this research provides a systematic framework to identify and map spatial-visual landscape characteristics for describing, understanding, and communicating about landscape spaces inter-subjectively. It contributes not only to advocate for multidisciplinary theories and technology in landscape design, but also makes them operational for landscape practitioners to deliberate and design spaces thoroughly. The comprehensive overview of design vocabulary opens a new perspective to interpret landscape architectonic compositions and supplements the body of knowledge/principles of spatial-visual aspects for the field of landscape architecture. Mapping applications showcase different methods that address landscape space from a horizontal-vertical, qualitative-quantitative, manual-digital, analogue-measurement perspectives and in combination, to explore unrecognised spatial features and visualise them inter-subjectively. Implementation of different mapping methods and tools in the design process increase the capacity for analysing, generating, and evaluating design interventions, and show potential for integration and implementation into landscape practices and education. It effectively offers landscape and urban designers more precise, explicit, and verifiable spatial clues to preserve landscape qualities, renovate dysfunctional urban spaces, and create sustainable new landscapes addressing current physical, aesthetical, social, and ecological challenges.

Samenvatting

Landschapsontwerp gaat over de vormgeving van buitenruimten en resulteert in landschapsarchitectonische composities van fysieke, functionele, symbolische en esthetische elementen. Deze landschapsarchitectonische composities hebben bepaalde ruimtelijk-visuele kenmerken. Als vormscheppend en probleem-oplossend proces landschapsontwerp integratief van aard warabij gebruik wordt gemaakt van zowel subjectieve interpretatie als objectieve analyse/evaluatie. Om effectief te communiceren over driedimensionale vormen en functies – om visueel-ruimtelijke kenmenrken te kunnen beschrijven, te begrijpen en te visualiseren – zijn vocabulair, representaties en technieken van fundamenteel belang voor ontwerpers. Binnen de landschapsarchitectuur concentreren ontwerpers zich vaak op de meer subjectieve beschrijvingen en richten zich op de persoonlijke ervaring van de ruimte. Landschapsonderzoekers daarentegen, focussen zich vaak op het meten van indicatoren om de ruimtelijke eigenschappen van het landschap objectief onderbouwd te interpreteren. Zowel de meer kwaltitatieve als de kwantiatieve benaderingen zijn waardevol voor het begrijpen en beschrijven van landschappelijke ruimte, maar worden zelden in samenhang met elkaar gebruikt in landschappelijk ontwerp. Het ontbreekt nog steeds aan een synthetisch overzicht van de kennis over het ruimtelijk-visueel landschap, waarbij ontwerpvocabulair en visueel-landschappelijke indicatoren, kwalitatieve en kwantitatieve mappingbenaderingen, visuele representatie en interpretatie worden gecombineerd.Daarom is het centrale doel van dit onderzoek om een kader te bieden voor de beschrijving, het begrip en de communicatie van ruimtelijke-visuele kenmerken in landschapsontwerp. Het onderzoek bestaat uit de volgende onderdelen:

Ruimtelijk-visueel ontwerpvocabulair

Ontwerpvocabulair is belangrijk voor landschapsarchitecten om de ruimte te begrijpen, ontwerpen en erover te communiceren. Dit onderzoek beschouwt en ontwikkelt eerst het ruimtelijk-visuele ontwerpvocabulair binnen de landschapsarchitectuur om vervolgens een systematisch kader te bieden voor het met elkaar verbinden van kwalitatieve en kwantitatieve woordenschatten voor het beschrijven en interpreteren van landschappen. Op basis van een analyse van de woordenschat die wordt gebruikt in de literatuur die beschikbaar is over landschapsarchitectuur en aanverwante vakgebieden (bijvoorbeeld stedenbouw, beeldende kunst, landschapsecologie, stedelijke morfologie, milieupsychologie), zijn vier categorieën geïdentificeerd die dominant zijn in de beschrijving van ruimtelijk-visuele organisatie van landschap. De categorieën zijn: hierarchie, oriëntatie, continuïteit en complexiteit.

Ruimtelijk-visuele analyse en representatiemethoden en -technieken

Door het ruimtelijk-visuele landschap in beeld te brengen door middel van handmatige en digitale mappingmethoden kunnen landschapsarchitecten de ruimte analyseren en representeren. Ook kunnen deze visuele interpretaties en representaties helpen bij het meten en visualiseren van kernbegrippen gangbaar in de landschapsarchitectuur. Bovendien maken deze interpretaties het ook mogelijk om ruimtelijk-visuele landschapselementen te verkennen waar dat voorheen niet mogelijk was. Dit onderzoek geeft een overzicht van mappingmethoden en -technieken die kunnen worden gebruikt om ruimtelijk-visuele kenmerken te bestuderen. Mogelijke toepassingen ervan worden getoond aan de hand van korte voorbeelden. Er worden zes mappingmethoden onderscheiden: compartimentanalyse, 3D-landschappen, rastercelanalyse, zichtbaarheidsanalyse, landschapsmetriek en oogbewegingsanalyse. Deze methoden worden gebruikt om belangrijke ruimtelijk-visuele kenmerken binnen de landschapsarchitectuur te verkennen, zoals hierarchie, oriëntatie, continuïteit en complexiteit, zowel analoog als digitaal. Het Vondelpark, een bekend stadspark in Nederland, wordt als pilotstudie gebruikt om te illustreren hoe deze ruimtelijke kenmerken in kaart kunnen worden gebracht door middel van deze mappingmethoden.

Toepassing van ruimtelijk-visuele mappingmethoden in het landschapsontwerpproces

Met deze mappingmethoden voor het analyseren en verbeelden van ruimtelijk-visuele landschapskenmerken wordt het mogelijk voor landschapsarchitecten om een vollediger begrip te krijgen van landschapscomposities en hun visuele manifestatie. Gezien het grote aantal verschillende methoden blijft het echter problematisch om mappingmethoden te selecteren en toe te passen in het landschapsontwerpproces. Dit komt omdat de nadruk ofwel ligt op de digitale technieken en methoden zelf, ofwel op het ontwerp. Om de kloof tussen mappingtechnologie en landschapsontwerp te overbruggen worden in dit onderzoek twee hypothetische ontwerpexperimenten uitgevoerd, waarin geschikte mappingmethoden en -technieken worden toegepast om de ruimtelijk-visuele kenmerken in verschillende stadia van het ontwerpproces te interpreteren. Deze toepassing van ruimtelijk-visuele mappingtechnieken levert nieuwe inzichten op voor landschapsarchitecten om de landschapsruimte te beschrijven en erover te communiceren, maar toont eveneens een bredere analytische, generatieve en evaluatieve effectiviteit en daarmee de waarde van digitale technologie voor ontwerpdoeleinden in het algemeen.

Toepassing van ruimtelijk-visuele mappingmethoden in landschapspraktijken

In de dagelijkse ontwerppraktijk zijn ruimtelijk-visuele mappingmethoden van groot belang om ontwerpintenties over te brengen en bestaande en toekomstige ontwerpen te analyseren en evalueren. Echter, de toepassing is afhankelijk van de persoonlijke houding van een ontwerper, de kennis, de toegang tot en vaardigheid met de technieken, etc. Voor dit onderzoek zijn tien experts met een praktische ontwerpachtergrond (op verschillende bestuursniveaus binnen de overheid, professionals uit het bedrijfsleven en de academische wereld) geïnterviewd om te onderzoeken hoe en welke ruimtelijk-visuele mappingmethoden in de dagelijkse praktijk worden gebruikt. De interviews richten zich ook op de vraag of en hoe de ruimtelijk-visuele mappingmethoden de ontwerpgereedschapskist kunnen complementeren en welke evt. obstakels er zijn voor implementatie. Na een inleiding over de potentie van ruimtelijk-visuele mappingmethoden en -technieken door middel van korte voorbeelden blijkt de interesse van veel geïnterviewden toegenomen ten aanzien van de mogelijkheden die de technologie te bieden heeft voor het analyseren en representeren van ruimtelijk-visuele landschapskenmerken. Ook worden praktische bezwaren en moeilijkheden benoemd, zoals de beschikbare tijd, data beschikbaarheid en ontbrekende skills om de technologie te gebruiken. Om deze methoden en technieken verder toe te passen hebben onderwijs- en onderzoeksinstellingen een belangrijke rol te vervullen in de bewustwording en toepassing van deze methoden voor toekomstige generaties.

Dit onderzoek biedt een systematisch kader om ruimtelijk-visuele landschapskenmerken te beschrijven, te begrijpen en erover te communiceren op een intersubjectieve manier. Het pleit niet alleen voor het gebruik van van multidisciplinaire theorieën en technologie in landschapsontwerp, maar maakt ze ook operationeel voor landschapsontwerpers om ruimten grondig te kunnen bediscussiëren en ontwerpen. Het synthetische overzicht van het ontwerpvocabulair opent een nieuw perspectief om landschapsarchitectonische composities te interpreteren en vormt een aanvulling op de kennis en principes van ruimtelijk-visuele aspecten binnen de landschapsarchitectuur. De toepassing van mappingmethoden tonen verschillende perspectieven op de landschapsruimte (horizontaal-verticaal, kwalitatief-kwantitatief, handmatig-digitaal, analoog-meting en hun combinaties) en bieden zo een breed scala aan mogelijkheden om onbekende ruimtelijke kenmerken te verkennen en intersubjectief te visualiseren. Het gebruik van verschillende mappingmethoden en -technieken in het ontwerpproces vergroot de capaciteit voor het analyseren, genereren en evalueren van ontwerpinterventies en toont mogelijkheden voor integratie en implementatie in landschapspraktijken en onderwijs.


Vondelpark, Amsterdam (Photo by Mei Liu, 2020)

TOC

1 Introduction

Chapter one introduces and extracts the specific problem field of this research. It proposes a research objective which aims to provide a framework for describing, understanding, and communicating about spatial-visual characteristics in landscape design. Three relative research questions are put forward: 1) What are relevant spatial-visual landscape characteristics for landscape design? 2) What are potential mapping methods and tools to analyse and visualise spatial-visual landscape characteristics? 3) How to apply spatial-visual mapping methods in landscape design from both a theoretical and practice perspective? To achieve the research goal, a methodological framework employing mixed methods is conceived. Scope, relevance, and setup of the research are presented as well.

1.1 Research Outline

Landscape is defined as ‘an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors’ (Council of Europe, 2000). To be a multifaceted subject, it can be perceived and described in many ways. Nijhuis (2015) notes that the nature of landscape is characterised by four main categories: as history, as a scale-continuum, as a process, and as a three-dimensional construction. 1) Understanding landscape as history transforming through time helps to arouse genius loci and conserve the historical value of the lands. 2) As scale-continuum, landscape is considered in a broader context including different scales of content connecting ecological, social, morphological, and functional entities together. 3) Landscape as process treats the landscape as a system which operates the interaction between social and ecological perspectives so as to achieve a balance between human and nature (Figure 1.1). 4) Besides, from a design perspective, landscape can be seen as a three-dimensional construction over time, which elaborates abstract notions into physical structures addressing the composition and configuration of spatial elements. Based on this, landscape designers manipulate distinctive patterns and spatial effects, which go beyond the visual appreciation into a richer understanding of the experience of the environment (Bell, 1999).

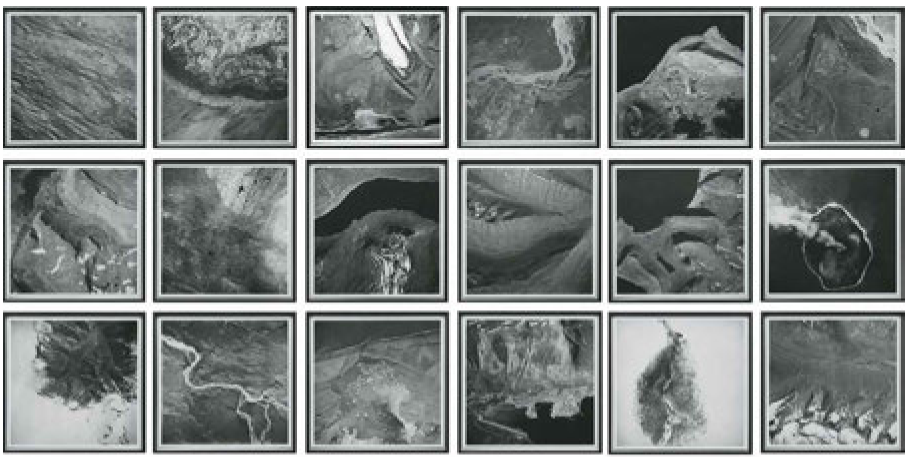


FIG. 1.1 Landscape is shown as a dynamic process, with geographic transformation from multiple dimensions and scales. Cartographic series III, 2004, photo by Jens Ziehe; Aerial photographs (18/30) of the Icelandic terrain that Olafur Eliasson obtained from the National Land Survey of Iceland.

Landscape design is concerned with the physical landscape changes and a function of visual literacy, which verifies the direct connection with comparative proportion (scale) and optics (vision) (Repton, 1803; Thiel, 1981). Concerning the holistic sensory relationship between landscape and the observer, visual aspects are mainly used to embody people's experience of the landscape rather than other senses. Visual sense prompts people to recognise and discriminate 'beauty', 'finer things', and 'aesthetics', by which vision is known as the principle channel for cognition of the material world (Nelson, 1977) (Figure 1.2). As the skeleton of landscape space, spatial organisation and visual effectiveness (in short: spatial-visual characteristics) play an important role as the predominant and intuitionistic mediator between a designers' intentions and the public's understanding of landscape space.

FIG. 1.2 A serial vision of landscape scenes from eye-level perspective. The Arrival of Spring in Woldgate, East Yorkshire in 2011 (12/21), 2011, David Hockney; iPad drawing series capturing the dynamic landscape growth of East Yorkshire from January to May.

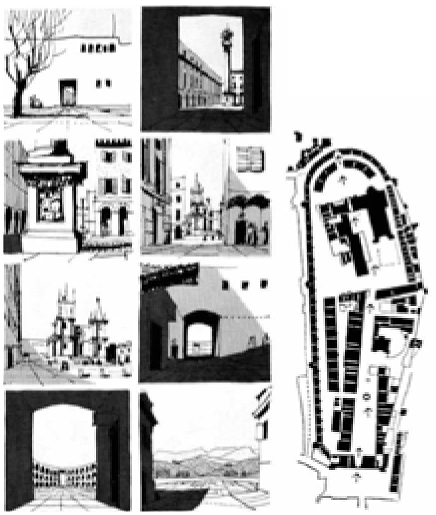
1.1.1 Spatial-visual Characterisation

In order to identify and describe landscape spatial-visual phenomena distinctions are already made between the landscape design practice and landscape research. These two important discourses indicate the fundamental gap of different ways to communicate about landscape. In landscape practice, designers predominantly concentrate on a more subjective understanding and are inclined towards personal descriptions of spaces using design vocabulary and schematic diagrams. Landscape researchers focus on the measurement of indicators and digital technology for mapping which are not friendly for designers to describe spatial properties of landscape more objectively. Although both are concerned with the architecture of landscape, until now there is not a comprehensive framework for understanding and representing spatial-visual characterisation of landscape spaces.

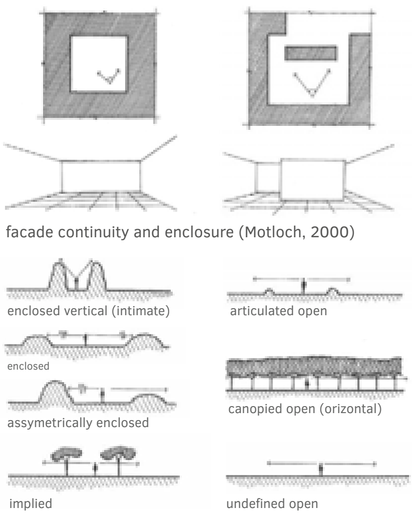
1.1.1.1 Design Vocabulary

In practice, landscape designers use design vocabulary to describe the spatial-visual characteristics of the landscape. This vocabulary is applied to communicate knowledge about space and to describe spatial effects and their experience (Figure 1.3 & 1.4). For example, Loidl and Bernard (2003) describe landscape spaces, elements, and spatial composition in terms of ‘open’, ‘enclosed’ and ‘elongated spaces’ and characterise them in terms of ‘spatial boundaries’, ‘variety/uniformity’, ‘sequence’ etc. Bell (1996) suggests a landscape vocabulary that combines personal preference and physical attributes to describe landscape composition and configuration from a visual perspective. He defines spatial, structural, and ordering principles that describe spatial-visual aspects of landscape in terms of ‘nearness’, ‘enclosure’, ‘interlocking’, ‘continuity’, ‘similarity’, ‘balance’, ‘proportion’, ‘scale’, ‘axis’, ‘symmetry’, ‘hierarchy’, ‘datum’, and ‘transformation’. Robinson (2004) uses the term ‘permeability of enclosure’ to describe landscape spaces in visual and physical perspective.

FIG. 1.3 Example of books introducing design vocabulary and design principles of landscape architecture/urban design; from left to right: Bell, 1999; Dee, 2004; Bell, 1996; Cullen, 1961; Loidl & Bernard, 2003; Curdes, 1993; Robinson, 2004; Simonds, 1997.



serial vision sketches (Cullen, 1961)



spatial type and degree of enclosure (Motloch, 2000)

FIG. 1.4 Examples of spatial-visual characteristics of design vocabulary; Left: serial vision by Cullen (1961); Right: (up) continuity and enclosure; (down) degree of enclosure by Motloch (2000).

Others include the experiential aspects of landscape space and incorporate environmental psychological aspects. Nasar (1994) for instance distinguishes 'attributes of formal aesthetics' and 'attributes of symbolic aesthetics' in spatial configurations determined by shape, volume, degree of enclosure, and proportions of enclosed space. Kaplan and Kaplan (1989) and Ode et al. (2008) emphasise aesthetic preferences in spatial-visual descriptions of landscape such as 'naturalness', 'complexity', 'coherence', 'image-ability', 'visual scale', 'historicity', 'disturbance', and 'ephemera'. From the above, all the terms are used to express the perception of spaces. However, they are vague about the exact detailed spatial-visual characteristics, which is likely to cause a misunderstanding during communication. Therefore, the question remains of how spatial landscape qualities can be evaluated and communicated in a more objective way in the context of landscape design.

1.1.1.2 Visual Landscape Indicators

Studies on landscape characterisation try to integrate subjective aspects of the landscape with quantification as a basis for knowledge acquisition that can feed into landscape design, planning, and policy making. There are different approaches to landscape characterisation. Berendsen (2000) identifies three ways that focus on: (1) the visual landscape; (2) the spatial development (in terms of physical geography, historical geography, soil science etc.); and (3) the internal coherence between landscape factors (biology, physical geography, landscape ecology etc.). Particularly landscape characterisations referring to the visual landscape are of interest in the context of this research. This type of landscape characterisation is also called visual landscape research and combines landscape perception approaches, landscape planning and design concepts, and GIS-based methods and techniques (Nijhuis, 2011) (Figure 1.5). Within this group, approaches can be found that explore spatial-visual aspects from a horizontal and vertical perspective (Antrop, 2007; Nijhuis, 2015). A horizontal perspective explores the landscape from an observer's point of view (from the inside out) and addresses the visual space and characterises spatial attributes or patterns from an eye-level perspective. The vertical perspective considers the landscape from 'above' – the map, or the view from the air – and is about horizontally-referenced analysis of spatial patterns and relationships.

TOC

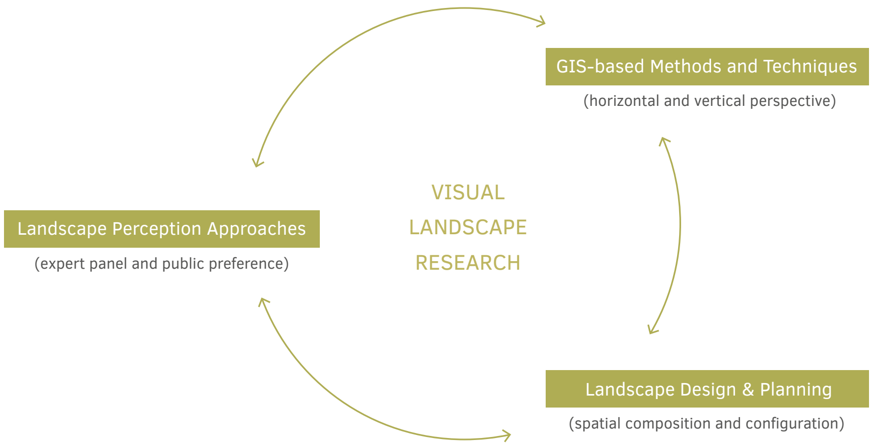


FIG. 1.5 Visual landscape research is determined by the integration of landscape design, planning and policy concepts, landscape perception approaches, and GIS-based methods and tools (Adapted from Nijhuis, 2011).

As exemplified by studies in this field, the development of visual landscape indicators provides clues for spatial design, since integrating qualitative and quantitative aspects of the spatial-visual landscape is at the core of this type of landscape characterisation. It has been widely used in both the exploration of landscape characterisation (EIA/LCA) and detailed visual impact assessment research (LVIA) (Fairclough et al., 2018). A visual landscape indicator gives specific information on the spatial-visual characteristics of the landscape under study. For the description of landscape characteristics, single and composite indicators are used. Individual indicators make single theme measurements, such as 'the amount of water' or 'dense of shrubs', while composite indicators are based on the aggregation of individual measures in complex spatial-temporal relationships, such as 'openness', 'diversity', and 'intensity' (Aspinall & Hill, 2007). Efforts to quantify spatial-visual characteristics and communicate landscape characteristics focus on the strength of qualitative visual landscape indicators (i.e. Ulrich, 1977; Herzog, 1992; Stamps & Nasar, 1997; Turner & Gardner, 1991; Antrop, 2006) or quantitative landscape indicators (i.e. Neill et al., 1988; Turner et al., 1989; Gustafson & Parker, 1992; McGarigal, 2002) (Figure 1.6).

FIG. 1.6 3D landscape visualisation scenes showing different vegetation-created levels of enclosure used to explore people's aesthetic preference in Chinese urban parks (Liu & Schroth, 2019).

Visual indicators, such as 'present or cultural features', 'visual openness', 'the presence of naturalness', and 'visual diversity', are widely used in the field of Environmental Impact Assessment (EIA) and Landscape Character Assessment (LCA), which are dedicated to the interpretation of spatial qualities in the landscape, but also reveal the scenic-perceptual values of the environment (Cassetella & Voghera, 2011). Applications are mainly used for qualitatively or quantitatively evaluating existing landscape resources and the proposed landscape transformations in order to guide planning and policy development (e.g. renewable energy, land allocation) (Schroth, 2010; Macdonald, 2012; Landscape Institute & I.E.M.A, 2013; Fairclough et al., 2018).

However, only a few attempts have been made to connect both qualitative and quantitative aspects of the landscape through visual landscape indicators. For instance, Palmer (2004) developes quantitative procedures to measure the spatial attribute 'landscape spaciousness'. Nijhuis and Reitsma (2011) employ physiognomic approaches to describe 'openness' in urban and rural landscapes. To some extent, these approaches complement and reveal a new way to understand spatial-visual landscape characteristics in an integrated way. To sum up, computer-assisted approaches support specific measurement of certain landscape

TOC

characterisation precisely, however, is it possible to develop visual landscape indicators that address spatial-visual landscape characteristics in such a way that they become useful in describing landscape from a design perspective?

1.1.2 Describe the Landscape in Visual Ways

As a potential solution for integrating different approaches of describing landscape spaces, mapping is a valuable medium to associate information and visualise it for purposes of understanding complex and abstract knowledge of space and fulfil the narrative of landscape (Abram & Hall, 2006). Spatial-visual characteristics are defined as the visual qualities that reveal the spatial attributions of a landscape, which includes qualitative and quantitative aspects of space. Therefore, mapping spatial-visual landscape characteristics could be treated as an important building block for understanding landscape spaces. A series of mapping methods and techniques is essential for visualising, interpreting, and communicating about spatial-visual landscape attributes to show morphological clues, by which the abstract spatial elements are being indexical and put together to present metaphorical notions of spaces (Figure 1.7).

FIG. 1.7 A traditional Chinese landscape drawing using digital tools to interpret older forms, to create and indicate the conflict between nature and urbanity, visualisation, and reality (right: detail). Ambiguous landscape visualisations by the Chinese media artist Yongliang Yang (2006-2007).

1.1.2.1 Visualising Landscapes

Landscape architects are eager to develop and employ manual and digital media that can support visual thinking and a description of landscape space. Hand drawing skills are a crucial means to generate design knowledge since it is a quick way to sketch abstraction into forms and patterns. Meanwhile, designers increasingly rely on showcasing and communicating ideas via digital visual representations (Amoroso, 2015). Digital mediums, like photomontage, computer graphics, 3D models are widely used in spatial design and research realms. Particularly in the field of landscape architecture, digital landscape visualisations combining various data types and technology are crucial for practitioners and researchers to study and present the three-dimensional spatial-visual characteristics of the landscape thoroughly.

Since the 1990s, photorealistic two- and three-dimensional visualisations, 3D modelling, real-time interactive presentations, point cloud models, Virtual Reality (VR), and Augmented Reality (AR) environments are employed to represent landscapes and landscape design ideas (Figure 1.8). Digital landscape modelling in coordination with georeferenced data and photographs play an important role mainly in imitating landscape scenarios and demonstrating the visual impact of a landscape (i.e. Ervin, 2001; Wissen et al., 2008; Lindquist et al., 2016). Moreover, laser-scanning (LiDAR) is applied to the fields of landscape architecture in order to build high-precision spatial models in the form of point cloud models, which demonstrates an enormous potential to express detailed physical qualities of landscape space and promote further spatial analysis (Girot et al., 2013; Urech et al., 2020). Apart from depicting static landscape circumstances, visual thinking through film, video, and multiple time-slice snapshots can effectively reveal spatiotemporal dynamics via the movement through landscape (e.g. serial vision) and the movement of landscape (e.g. seasonal variation, landscape transformation) (Ervin, 2001; Girot & Truniger, 2012; Nijhuis, 2015). Nowadays, the advancement of responsive technology provides new forms of representation, experience, and understanding of landscape space (LAF, 2019). Examples include Google glasses that provide real-time data, analysis, and generative feedback; AR sandbox reacts interactively to the adjustment of landscape terrains; a geomorphology modelling table simulates sediment behaviour to help understand landscape changes (see, for example, Afrooz et al., 2018; Cantrell & Mekies, 2018). Some VR devices even allow movement in virtual landscapes (i.e. Griffon et al., 2011; Portman et al., 2015; Tabrizian, 2018; Ma et al., 2020).

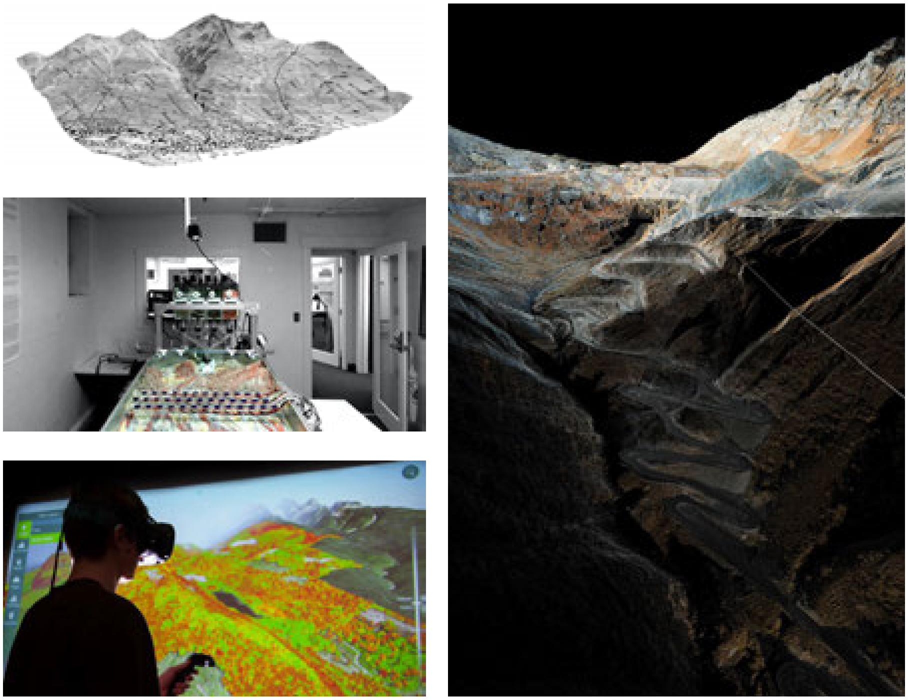


FIG. 1.8 Left: (up) DEM terrain in Rhinoceros (Melson et al., 2015); (middle) Geomorphology modelling table showing sediment behaviour from changes by The University of Virginia School of Architecture (Archinect, 2020); (down) virtual reality (TimberOps) application in land-based resource management and operation planning (The University of British Columbia, 2020). Right: Experimental alpine model based on point cloud technology by ETH (Atlas of Places, 2014).

These types of visualisations help people to immerse themselves in a virtual space and mimic existing or future landscape realities in design processes but are also frequently applied in landscape communication and appraisal purposes. As important instruments in visual thinking and communication, the representation of these visualisations remains evocative and generative of spatial-visual characteristics. However, it is problematic for knowledge acquisition and decision making which are phenomenological in nature and allow different readings (Ervin, 2001; Bishop & Lange, 2005).

Can landscape visualisations be used to acquire knowledge of spatial-visual characteristics and communicate them more objectively? Recent examples show potential in this direction. For instance, Schroth et al. (2009) exemplify that 3D landscape modelling can be used to visualise spatiotemporal climate scenarios in local planning and effectively enables public participation in landscape management. Hassan et al. (2014) showcase possibilities for visualising the landscape as a way of sharing knowledge in participatory design processes. Both examples are focused on both subjective and objective knowledge transfer and achieve active landscape-human interaction.

1.1.2.2 Measuring Landscapes

As mentioned earlier, visual landscape indicators are useful for the measurement, evaluation, and communication of spatial-visual landscape characteristics. A few studies from related research fields have potential approaches to explain the spatial-visual organisation of landscape spaces with quantitative measurements and mappings. From a landscape design perspective, it is important to avoid generalised conclusions based on these indicators. Their application should lead to location-specific strategies and interventions for landscape development. Therefore, the operational value of exploring visual landscape indictors should also be considered.

In the field of landscape metrics, there are clues for the development of landscape indicators that link measurement, spatial description, and performance. For instance, McGarigal (2001) developes ecological indicators, such as ‘density’, ‘proximity’, ‘similarity’, and ‘evenness’, that represent interactions between spatial configuration and ecological processes. Salat (2011) introduces urban morphology indicators, such as ‘intensity’, ‘spatial distribution’, ‘proximity’, ‘connectivity’, ‘diversity’, and ‘form’, that measure urban form in relation to sustainability. Tveit et al. (2006) employ visual landscape indicators, such as ‘coherence’, ‘disturbance’, ‘complexity’ and ‘ephemera’, to address the more experiential performances of the landscape. Also in the Dutch research context, there is a long tradition in visual landscape research from the 1970’s onwards with serious attempts to implement visual landscape indicators into landscape planning and policy (e.g. De Veer, 1977; Burrough et al., 1982; Dijkstra et al., 1985, Alphen et al., 1994; Palmer, 1996; Dijkstra & van Lith-Kranendonk, 2000; Nijhuis, 2011) (Figure 1.9). In parallel, environmental psychology-oriented landscape indicators by De Boer (1979), Coeterier (1994, 1996), and van den Berg (1999) gained influence in Dutch landscape policy.

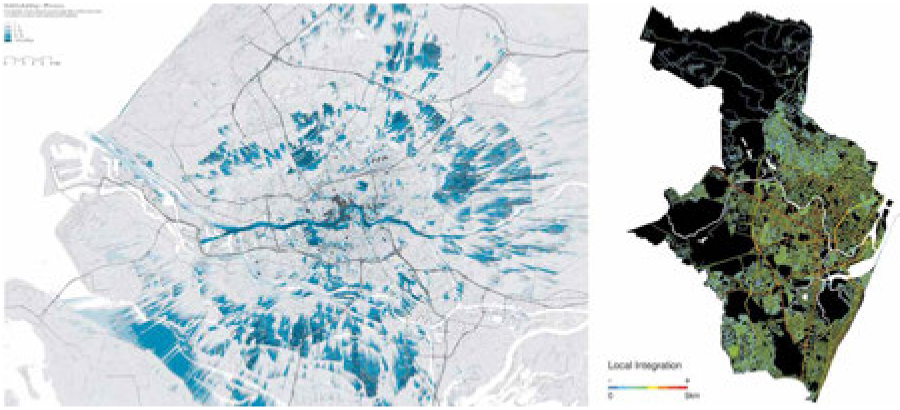


FIG. 1.9 Left: Visibility analysis of high buildings in Rotterdam showing visual coverage and the cluster effect (van der Hoeven & Nijhuis, 2011). Right: Axial map showing local integration of The Capibaribe Park in Recife (Carvalho Filho, 2015).

As exemplified by these studies, operational landscape indicators that link measurement, spatial description and performance are generally used to address planning and policy-oriented landscape issues related to agricultural, ecological, and urban sustainability. However, the link with the practice of landscape design remains underdeveloped because it scarcely connects to aspects of landscape design (e.g. describing landscapes in such a way that designers do).

1.1.3 Problem Statement

The core of landscape design focuses on the construction and articulation of outdoor space and results in landscape architectonic compositions. In order to thoroughly communicate about these three-dimensional forms and functions, vocabulary, representations, and tools in terms of spatial-visual characteristics are of fundamental importance for landscape designers to describe, understand, and visualise landscape spaces.

To convey proposed spatial experiences and create a visual manifestation of landscape space, this research draws on existing studies on design vocabulary in order to provide design principles of spatial-visual organisation. However, the question remains of how these aspects can be evaluated and communicated more objectively in the context of landscape design. While studies on landscape characterisation try to integrate subjective aspects of landscape with quantification as a basis to allow for more precise and accurate clues for the interpretation of spatial attributes. This type of research and applications from visual landscape research are concentrated on communication in participatory landscape management and planning. Though they provide useful clues of landscape spaces, systematic evaluation of spatial-visual landscape characteristics for knowledge acquisition and communication in landscape design is still lacking.

Manual and digital media developed and employed by landscape architects can support thinking and communication about the spatial-visual aspects of landscape architectonic compositions. Manual mapping approaches like hand-drawn maps and sketches, which are widely used by designers, can easily help translate abstract concepts into landscape compositions, while digital visualisation mapping methods, such as 3D visualisation tools, are good at mimicking landscapes scenarios and can assess or predict environmental/landscape changes. However, the interpretation of these visualisations remains relatively subjective, which is problematic for verifiable communication about design decisions. Research on landscape indicators elucidate the spatial compositions and visual performance from a quantitative point view, nevertheless, the link with the practice of landscape design remains underdeveloped because it hardly connects with aspects of landscape design.

To sum up, designers predominantly concentrate on a more subjective understanding and tend to include personal description of space, while landscape researchers focus on the measurement of indicators in order to demonstrably interpret the spatial properties of landscape. Though these two important discourses provide valuable clues for understanding landscape spaces, they indicate the fundamental knowledge and communication gap between landscape practice and academia. Either as a form-creating result or a problem-solving activity, landscape design as an integrated process acquires insights through both subjective interpretations and objective analysis/evaluations (in short: inter-subjective description) to facilitate collaborative understanding and opens communication for the co-construction of landscape architectonic compositions. However, this inter-subjective overview, which explores the knowledge of the spatial-visual landscape according to the phenomena of a subjective-objective duality, is still lacking. Therefore, to develop spatial-visual characteristics that can be used for the interpretation, evaluation, and communication in the realm of landscape design, there is a need to combine design vocabulary and visual landscape indictors, qualitative and quantitative mapping approaches, visual representation, and visual interpretation together. As input for design-based knowledge production, this research contributes to landscape professions by extending design principles of landscape architectonic compositions, providing possibilities to describe and communicate landscape space thoroughly, informing scientific guidance for location-specific design interventions in further landscape research and design domains.

1.2 Research Objective and Research Questions

The central objective of this research is to provide a framework for describing, understanding, and communicating about landscape spatial-visual characteristics in landscape design. To meet this objective, the following research questions need to be addressed:

1. What are relevant spatial-visual landscape characteristics for landscape design? (Chapter 2)
2. What are potential mapping methods and tools to analyse and visualise spatial-visual landscape characteristics? (Chapter 3)
3. How to apply spatial-visual mapping methods in landscape design from both a theoretical and practice perspective? (Chapter 4 & 5)

1.3 Research Methodology

To achieve the objective and answer the research questions, a methodological framework employing mixed methods is conceived and consists of four steps. To answer research question 1, the first step is to conduct a comprehensive literature review about spatial-visual-related design vocabulary to identify what are spatial-visual landscape characteristics from a design perspective. Step 2 focuses on answering the second research question. Here, different mapping methods and tools are applied to describe spatial-visual aspects of landscape space through a pilot study. Step 3 and Step 4 address research question 3, which performs hypothetical design experiments and conducts expert interviews to show how to implement a potential mapping toolbox in the design process, both theoretically and practically (Figure 1.10).

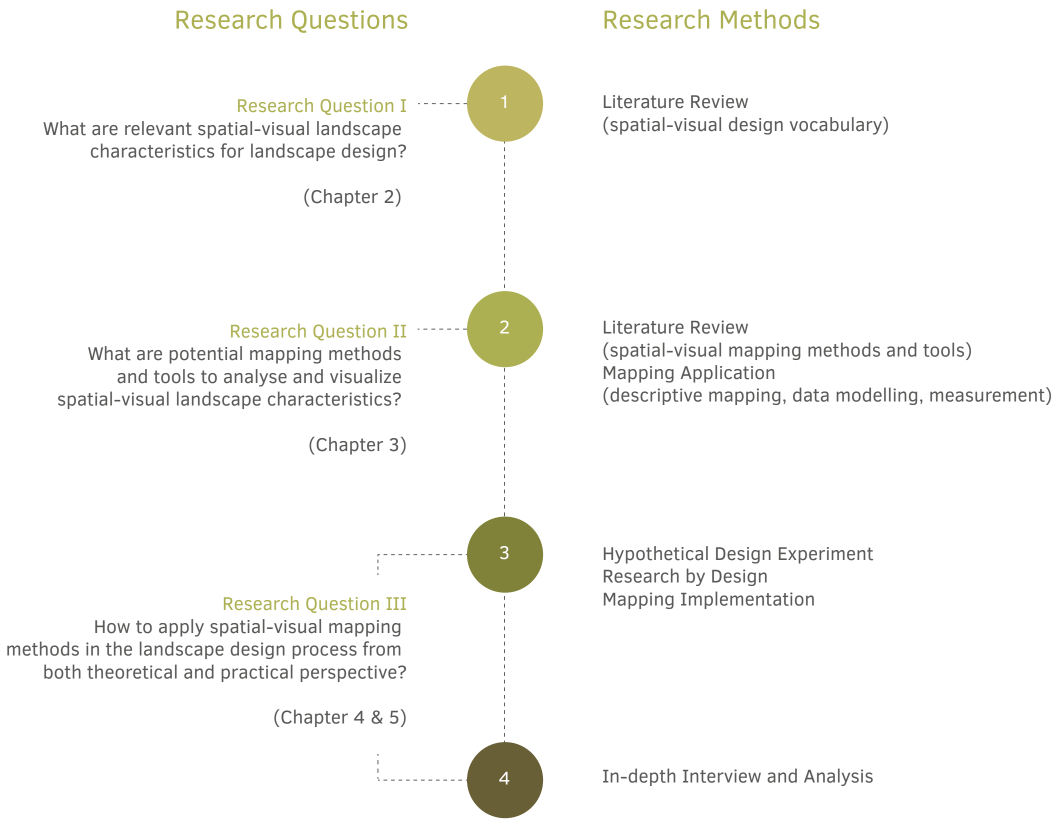


FIG. 1.10 Methodological structure displaying the research questions and corresponding research methods.

First, a literature review is conducted to investigate the dominant design vocabulary designers commonly use, and the potential mapping methods for describing spatial-visual landscape characteristics from both qualitative and quantitative perspectives. This helps to explore the gap between conventional ways of understanding the spatial-visual landscape and developing certain mapping approaches.

Then, to explore the potentiality of mapping landscape spaces inter-subjectively, a pilot study is used to apply multi-dimensional mapping methods and tools to analyse spatial-visual characteristics of the landscape. It underpins the validity of this research and combines the following selection criteria: typical spatial-visual diversity, open-data access, and available peer group. Combining the selection criteria, Vondelpark in Amsterdam, the Netherlands is chosen as an exploratory case for this research. During the application, proceeding the analysis, a variety of research methods are employed, such as field surveys, descriptive mapping, data modelling, and measurements.

TOC

Third, design experiments are performed to show the implementation of mapping spatial-visual landscape characteristics via an iterative design process. Two hypothetical design assignments are created according to the potential challenges of Vondelpark including increasing ground subsidence, increasing flood risk by rainstorms, lack of connectivity with the surrounding neighbourhoods, overcrowding and traversing cyclists. One is a renovation design emphasising the existing spatial-visual organisation of the landscape, while the other is an entirely new design shaping the urban landscape. By means of the design process, the analytical, generative, and evaluation capacities of mapping landscape spaces are discovered and represented in a practical way.

Finally, in-depth interviews with experts were organised, which helped to understand the usage of mapping techniques by practitioners in their daily work, evaluate the application of mapping spatial-visual characteristics in this research, and discuss the future of advanced mapping methods and tools in landscape practices.

1.4 Scope

The subject of this thesis is approached from a rather positivist point of view. It takes an expert approach as the basis because it closely connects to many of the known landscape architecture practices and the digital tools available. However, this does not exclude nor dismiss other ways of understanding space, like phenomenological or psychological approaches. It acknowledges that both the activity and the result of landscape design requires diverse forming criteria to be understood and applied, in order to unearth a meaningful understanding of the space (Loidl & Bernard, 2003). This form-creating process, portrayed as the inner mechanism of landscape design, is of importance to display alternative landscape scenarios. Landscape designers manipulate space creation in terms of three-dimensional architectonic compositions and visual qualities, as a skeleton of the landscape, and in such a way that they can become spatially effective to meet the desires of the user and the conditions of the site.

However, landscape design is a not only a dynamic matter shaped by physical materials and architectonic compositions, but also the emotional experience between human and nature (Sijmons & Van Dorst, 2014). To achieve desired historical, social, and cultural intentions, landscape design provides a physical, functional, symbolic, and aesthetic arrangement of corporeal and non-corporeal aspects, and results in form and a perceptual experience of space (Vroom, 2006). Landscape perception research involves the interests of individuals from an array of disciplines and professions based on personal agendas, including scenic beauty, visual landscape assessment, interactive emotions, symbolic connotations, aesthetic preference etc. (Zube et al., 1982). In order to fully represent the intact quality of landscape space, functional uses, symbolic meanings, and other social, cultural, and ecological aspects are also valued in further research.

Moreover, the mapping approaches adapted and implemented in this thesis employ a normative measurement and interpretation of landscape space, but also exclude the more subjective aspects of landscape perception. Interesting approaches that include more subjective aspects of space perception contain various physiological and phenomenological approaches, which enable the essential expression of the emotional and sensorial awareness of individuals (Figure 1.11). A classic example is provided by Lynch (1960). In his *The Image of City* he uses 'mental maps', created by participants, to show perceptual urban forms based on personal memory and preference. Tversky (1993) conducts study on 'cognitive mapping', which allows people to base the mental representations of space on their everyday experience. In addition to these map-like figures, spatial information also can be converted into abstract, symbolic, or metaphorical modes. With graphic scores and choreographic language, Lawrence and Anna Halprin associate phenomenological experience with environmental awareness to display sensory perceptions, emotions, and intuitive behaviours through space (Haplrin, 1970; Hirsch, 2008; Wasserman, 2012; Meyer, 2016; Olmedo & Christmann, 2018). Furthermore, in the book *The Songlines,* Bruce Chatwin (1987) introduces Aboriginal Australians use songs, as the indigenous memory code, to record the journeys of their ancestors across Australia and communicate the territories with each other. Closely associated with subjective cognition and judgement, these phenomenological mapping approaches are not similar to map structures at all times. Instead, they continue to make inner responses and offer various interpretations of how humans interact with landscape.

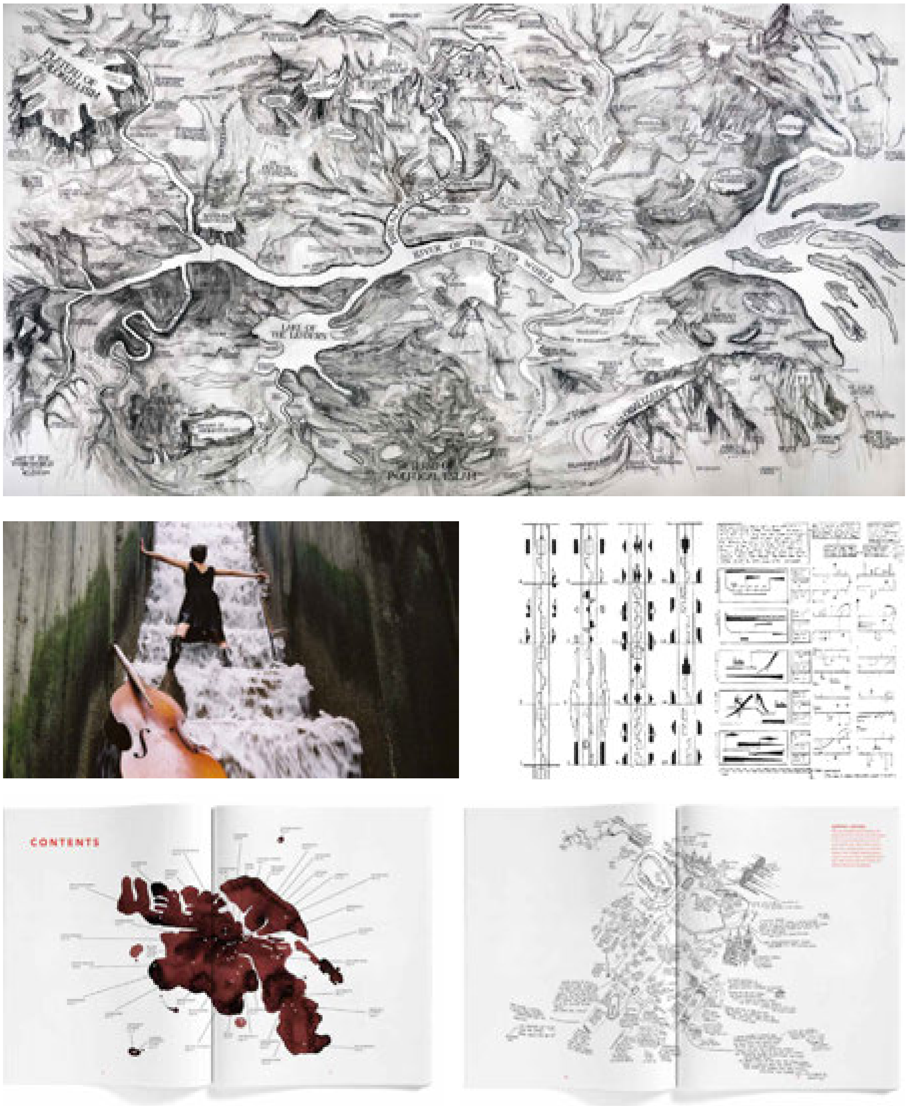


FIG. 1.11 Phenomenological approach of describing, mapping, and understanding spaces. Top: Map of the third world, 2011, Zhijie Qiu; A conceptual map generated by a Chinese artist using cultural narratives (e.g. mythology, politics, religion, and history), and spatial elements (e.g. mountain, river, path, valley) to outline globalisation. Middle: (left) The city dance of Lawrence and Anna Halprin (performance), 2008, The Portland Institute for Contemporary Art; (right) Motation (motion + notation) system created by Lawrence Halprin, 1960s; Emphasising the experience moving through space and scoring the body movement to create landscapes. Bottom: The soft atlas of Amsterdam, 2014, Jan Rothuizen; Dutch artist drew the mental maps of Amsterdam.

1.5 Relevance

Mapping spatial-visual characteristics plays an important role in the interpretation and communication of landscape space. Yet, studies on the systematic process of identifying and mapping of spatial-visual aspects of the landscape, in an inter-subjective manner, are lacking. In this way, this research contributes to the body of knowledge of landscape architecture through the interpretation, evaluation, measurement, and application of spatial-visual landscape characteristics in landscape design. It aims to extend the knowledge and toolbox of understanding landscape architecture through:

Scientific relevance:

(1) This research develops a theoretical framework to parse design vocabulary and identify spatial-visual characteristics through summarising the landscape architectonic compositions of design vocabulary. It extends knowledge-based design principles and prompts the possibility to thoroughly understand and communicate landscape space.

(2) Mapping methods and tools in this research advocate for a multidisciplinary approach that with the inclusion of such disciplines as landscape ecology, urban morphology, and environmental psychology within landscape design, These methods help to extract, translate, and adapt relevant theories and technologies to describe landscape architectonic compositions. It integrates alternative perspectives and disciplines to gain new insights, while connecting qualitative and quantitative ways of revealing spatial relationships and the visual organisation of landscapes in unprecedented ways.

(3) The implementation of combining conventional and advanced mapping methods to interpret spatial-visual aspects of landscape space in the design process helps develop research by design and design by research approaches. The developed mapping methods can be applied in multiple steps in the design process, as analytical, generative, and evaluative tools, while designs produced in different projects can supplement the body of spatial-visual landscape knowledge.

Societal relevance:

(4) The overview of mapping spatial-visual characteristics creates opportunities for landscape architects to describe and understand known and unknown aspects of

landscape space. This provides replicable methods for landscape practitioners to make responsible and knowledge-based design decisions, and support policy making aimed at the development and conservation of landscape characteristics.

(5) Spatial designers have the responsibility to be transparent and consistent in their research, design, and communication, which enable stakeholders to judge the spatial-visual effects of design interventions based on a proper understanding of space. Providing systematic knowledge and instruments explaining spatial-visual landscape characteristics is an important way to acquire information and effectively communicate during the process of landscape policy management, planning, and design etc.

(6) The development of multi-functional mapping methods is indispensable for new generations of landscape architects. Just as important to conventional mapping approaches, this research is a useful step in exploiting digital methods and tools and establishing powerful capacities of integrating, analysing, and graphing the spatial-visual properties of landscape space. It introduces a way for spatial designers to gain a clearer knowledge base and form of communication in the digital culture of landscape architecture.

1.6 Setup of the Research

The dissertation consists of six chapters and four main parts, each with a specific topic (Figure 1.12).

Chapter one introduces and extracts the specific problem field of this research. It proposes a research objective which aims to identify and investigate the methods of mapping spatial-visual characteristics in order to describe landscape spaces from a design perspective. To achieve this goal, three relative research questions are put forward.

Chapter two elaborates on this initial research question and explores how to characterise spatial-visual landscape properties and asks what are potential features for mapping landscape spaces. A comprehensive overview of spatial-visual design vocabulary is provided, by which four predominant categories are used to describe and communicate landscape architectonic compositions. These include sequence, orientation, complexity, and continuity. As a result, a hierarchical syntax structure is summarised to explicate ambiguous spatial-visual concepts and detailed landscape characters.

TOC

Chapter three addresses the second research question which asks what tools can be used to describe the spatial-visual characteristics of landscape space and how. According to visual landscape research, six key mapping methods are proposed including compartment analysis, 3D landscapes, grid-cell analysis, visibility analysis, landscape metrics, and eye-tracking analysis. Vondelpark is selected as a pilot study to show the applications of these potential mapping methods in the interpretation of four spatial-visual design vocabulary.

Chapter four helps to answer research question 3 by evaluating the feasibility and effectiveness of spatial-visual mapping methods via two hypothetical design assignments of Vondelpark to show how to apply spatial-visual mapping methods and tools into the landscape design process. An iterative design process is employed to demonstrate the analytical, generative, and evaluative capacities of the mapping toolbox, which will help designers think about and visualise landscape space in a qualitative and quantitative way.

Chapter five presents the results of interviews conducted with eleven experts from spatial design practices in order to explore how the mapping toolbox can potentially be implemented in the future of landscape practices. The interviews consisted of two parts, each with a group of open-ended questions. First, they explored the way in which designers commonly describe space and the practical applications of mapping methods and tools in their daily design work. The further implementation of this mapping toolbox is discussed and explores the designer's outlook regarding advanced mapping technology, as well as their corresponding values and concerns.

Chapter six presents an integrated discussion and conclusion of this research. It summarises the results from each chapter, discusses the relevance, imposes the limitations of theory, data, technology, and puts forwards a recommendation for the mapping of spatial-visual landscape characteristics in the future of landscape research and design.

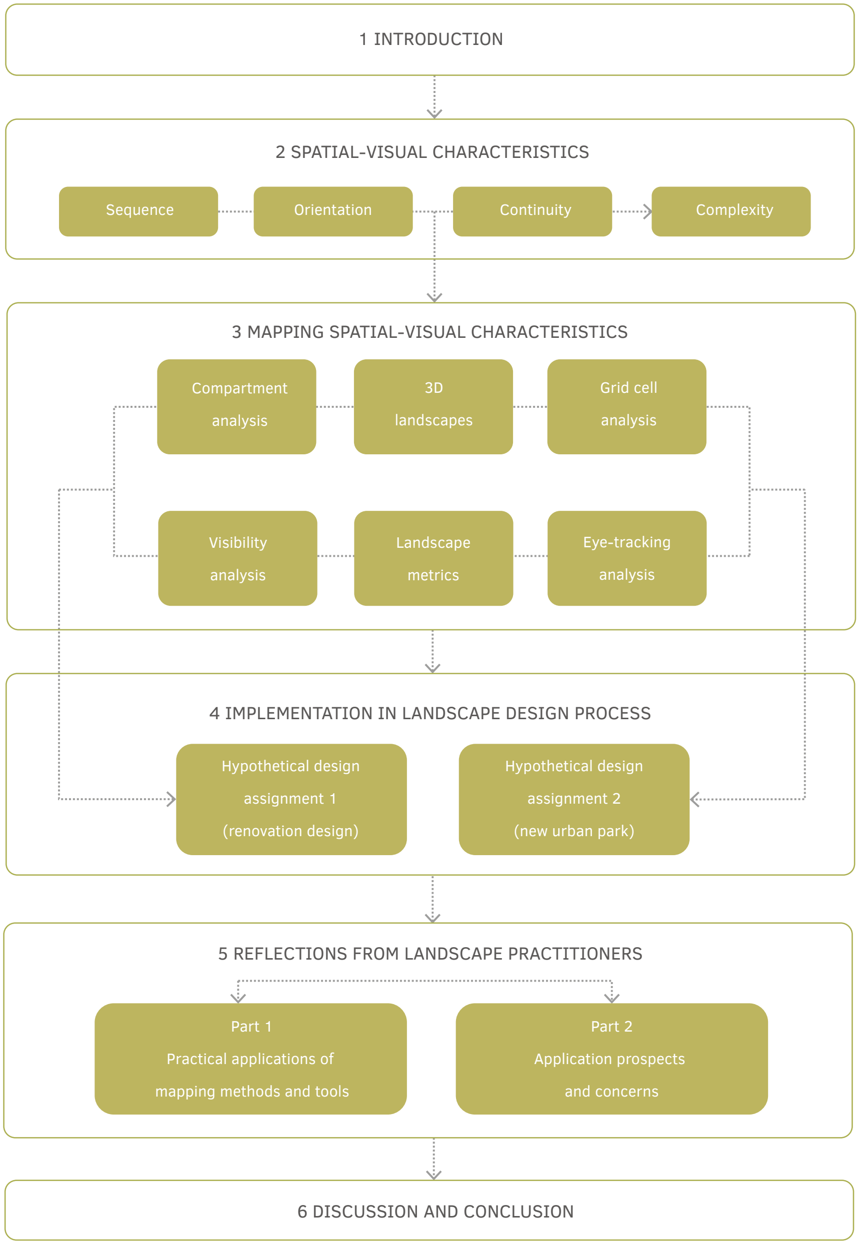


FIG. 1.12 Research strategy scheme and the outline of dissertation.


Vondelpark, Amsterdam (Photo by Mei Liu, 2020)

TOC

Vondelpark, Amsterdam (Photo by Mei Liu, 2020)

TOC

2 Talking About Landscape Spaces

Towards a Spatial-Visual Landscape Design Vocabulary

As the skeleton of a landscape, both spatial composition and visual organisation (i.e. spatial-visual characteristic) play an important role as the predominant and intuitionistic mediators for landscape architects to describe and understand the design mechanisms and effects of space. This chapter provides a systematic framework for reviewing spatial-visual-related design vocabulary for the field of landscape architecture and interlinks qualitative and quantitative approaches for understanding landscape spaces. Based on the analysis of the vocabulary used in the extensive body of literature available in landscape architecture and related disciplines, four dominant categories are selected in describing spatial-visual organisation. These include sequence, orientation, continuity, and complexity. As a result, a hierarchical syntax structure is summarised to explicate ambiguous spatial-visual concepts and detailed landscape characters.

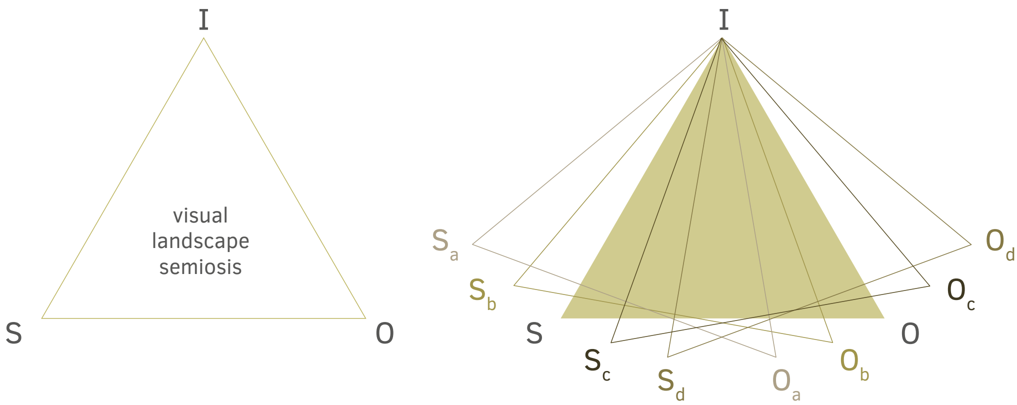
2.1 Introduction

In the field of landscape architecture, landscape design is an important area of knowledge and activity (Evert et al., 2010). It is about the construction and articulation of outdoor spaces which results in landscape architectonic compositions. Landscape architectonic compositions deal with form and meaning. They provide physical, functional, and aesthetic arrangements of a variety of structural elements to achieve desired social, cultural, and ecological outcomes (Vroom, 2006; Nijhuis, 2013a). In order to understand and communicate about the spatial-visual characteristics of landscape architectonic compositions, vocabulary, representation, and tools are of fundamental importance to landscape architecture.

In the field of landscape architecture, semiosis among the representation of design notion, landscape architectonic composition, and a progression of meaning-interpretation plays an important role in order for designers to transform mental design concepts into substantial design interventions (Figure 2.1). Referring to Charles Sanders Peirce's logic of semiotic theory (1839-1914), there is a distinction between the *sign* (a physical representation of a sign), *object* (the real-world reference the sign refers to), and the *interpretant* (the proper interpretation within the mind) (Raaphorst et al., 2018). Design vocabulary and visual representations (*sign-signifier*) are invented and commonly used by spatial designers to raise awareness of certain phenomenon and imply a conscious perception of landscape space. Because everyone has their own personal agenda, there is no identical and stable interpretation of meaning/perception for each sign. Compared to other landscape perceptions (e.g. aesthetic appreciation, environmental amenity, and emotion arousal) that are highly subjective, the spatial-visual experience may lead to a relatively objective (or inter-subjective) understanding and thus can be regarded as common sense for different individuals, which is of fundamental importance in terms of landscape architectonic compositions. These three-dimensional spatial compositions and visual organisations (*object-referent*) constructed by space, path, edge, foci, and threshold are reflected and communicated through alternative signifiers.

To help support the communication of spatial-visual properties in landscape architectonic compositions, landscape architects have always been eager to develop and employ manual and digital media. Conventional methods for operationalising landscape characteristics are hand-drawn maps, sketches, schematic diagrams etc. These methods are powerful tools for describing and interpreting spatial qualities in order to achieve certain spatial design concepts and intentions (Pinzon et al., 2009).

With the development of modern technology, digital and visual representations are widely introduced in landscape research and design. Several examples include photomontages, 3D computer models, photorealistic visualisations, as real time interactive presentations, virtual reality (VR) environments, and point cloud etc. (e.g. Bishop & Lange, 2005; Nijhuis, 2013b). These types of visualisations help designers to mimic existing or proposed landscapes and assist in providing more realistic and intuitive expressions.



S SIGN (signifier)
physical representation of a
sign e.g. vocabulary/map

O OBJECT (referent)
real-world object the sign refers to
e.g. landscape architectonic composition

I INTERPRETANT (signified)
a proper interpretation within the mind
e.g spatial-visual experience

FIG. 2.1 Visual landscape semiosis indicating the relationship among the representation of design notion (sign), landscape architectonic composition (object), and a progression of meaning-interpretation (interpretant) (Adapted from Peirce and his model of semiosis).

The understanding of spatial-visual properties is not only related to the instruments available to analyse and represent spaces, but it is also dependent on vocabulary, and the body of words to discuss and to describe spatial-visual properties.
As put forward by Stahl (2005), “vocabulary knowledge equals to knowledge; the knowledge of a word does not only imply a definition, but it also implies an understanding of how that word fits into the world.” Words make people aware of a certain phenomenon and implies a conscious observation and identification. In other words, a landscape architect’s level of understanding of spatial-visual aspects are related to the vocabulary a landscape architect uses. The design vocabulary that spatial designers use is often based on traditional and personal descriptions and understanding. This results in a lot of missed opportunities for alternative approaches because of a lack of awareness for other options.

Despite its importance, there has only been a few attempts to develop a distinct vocabulary. From a landscape design and qualitative point of view, several researchers elaborate on the two- and three-dimensional layout of the landscape architectonic composition and commonly-used vocabulary to describe the spatial construction of spaces, paths, edges (i.e. surfaces, screens, objects), foci, thresholds, and spatial-visual relationships like sequences, views and vista's (e.g. Simonds, 1997; Motloch, 2000; Dee, 2004; Loidl & Bernard, 2003). Bell (1996) elaborates on spatial landscape elements and organisational structures by employing vocabulary such as 'balance', 'tension', 'rhythm', or 'proportion'. In landscape-focused research , the emphasis is placed on quantitative clues for the development of operational landscape indicators that link measurements, spatial descriptions, and performances, such as 'proximity', 'connectivity', and 'coherence' (McGarigal & Marks, 1995; Tveit et al., 2006; Salat, 2011). From both a qualitative and quantitative perspective, they offer powerful clues to understanding landscape spaces. However, a comprehensive overview of different types of spatial-visual vocabulary available for landscape design is lacking.

To answer research question 1 (what are the spatial-visual landscape characteristics for means of landscape design?), this chapter aims to provide an overview of spatial-visual design vocabulary for understanding and communicating about landscape spaces and contributes to the advancement of the theoretical foundations of landscape architecture in two ways: (1) by reviewing and developing a spatial-visual vocabulary for the field of landscape architecture; and (2) to provide a systematic framework for interlinking more qualitative- and quantitative-oriented vocabulary for understanding landscape spaces.

2.2 Literature Review

2.2.1 Spatial-Visual Vocabulary in Various Research Fields

To fully grasp the range of existing knowledge and scholarship on the topic of landscape architecture, an extensive literature review was conducted. For the analysis, Google Scholar was accessed in April 2018, as this database offers a broad selection of literature including journal articles, conference papers, books, chapters, academic reports, policy documents, conference proceedings, MSc, and PhD theses. The discourse on landscape spaces is not restricted to landscape design but also includes urban design, urban morphology, landscape psychology, landscape ecology, visual design, and visual landscape studies. These are also potential research fields with direct and indirect relations to the spatial-visual aspects of landscape. The search combined keywords ‘spatial and visual’ and the related research fields with the Boolean operation ‘AND’ to find precise matches (e.g. spatial and visual AND landscape design). Content referring to spatial-visual properties of space were to be found either in the title, the keywords, or in the body text, but were not in quoted literature or literature descriptions, figure captions, indices, footnotes, as parts of author descriptions or affiliations.

Using the most relevant literature, an initial design vocabulary cloud with relation to spatial-visual characteristics of landscape and from various research domains was generated (Table 2.1). Landscape architecture and urban design commonly use design vocabulary to describe spatial-visual compositions, for example ‘sequence’, ‘diversity’, ‘unity’, ‘enclosure’, ‘circulation’, ‘integration’, ‘variation’, and ‘connectivity’ (e.g. Lynch, 1960; Simonds, 1961; Bell, 1993; Motloch, 2000; Dee, 2004; Carmona et al., 2010). A few urban design approaches have developed morphological indicators to evaluate urban configurations from a quantitative perspective like ‘intensity’, ‘proximity’, and ‘connectivity’ (e.g. Salat, 2011). The field of landscape ecology also includes indicators to measure visual characters of landscape spaces, such as ‘diversity’, ‘evenness’, and ‘contagion’ (e.g. McGarigal & Marks, 1995). A small part of landscape character assessment and landscape psychology research focuses on people’s perception of spaces via visual concepts, which are ‘enclosure’, ‘variety’, ‘coherence’, ‘legibility’, ‘complexity’, and ‘mystery’ etc. (e.g. Kaplan & Kaplan, 1989; Stamps, 2004; Ode, Tveit, & Fry, 2008; Blumentrath & Tveit, 2014) .

TABLE 2.1 An initial review of design vocabulary describing spatial-visual properties of landscape summarised from the most relevant literatures in related research fields.

Research Field	Design vocabulary of landscape spatial-visual properties	Relevant literatures
Urban design	legibility, contrast, orientation, connectivity, continuity, closure, integration, unity, wholeness, connection, openness, proximity, accessibility, direction, repetition, equilibrium, sequence, order, transition	Lynch, 1960; Cullen, 1961; Alexander, 1977; Thiel, 1961, 1981; Trancik, 1986; Lefebvre, 1991; Carmona et al., 2010; Beirão, 2012;
Landscape architecture/ design	diversity, sequence, nearness, enclosure, openness, interlock, continuity, similarity, balance, tension, rhythm, hierarchy, orientation, circulation, direction, repetition, compactness, transition, congruence, connectivity, coherence, simplicity, movement, variation, transformation, proximity, unity, harmony, contrast, convergence, dominance, continuance, closure, order, equilibrium	Simonds, 1961; Jakle, 1987; Higuchi, 1988; Sanoff, 1991; Bell, 1996, 1999; Motloch, 2000; Loidl & Bernard, 2003; Dee, 2004; Robinson, 2004; Stamps, 2005, 2008; Booth, 1989, 2011; Marciniak, 2011; Nijhuis, 2011, 2015; Kiss, 2017.
Visual landscape	diversity, variety, richness, continuity, openness, enclosure, spaciousness, simplicity, visibility, integration, visual scale, naturalness, contrast, orientation, order, unity, uniformity, balance, intactness, harmony, locomotion	Thiel, 1961, 1981; Ulrich, 1977; Jakle, 1987; Higuchi, 1988; Sanoff, 1991; Sutton, 1992; Bell, 1996; Palmer, 1998, 2000, 2004; Stamps, 2005, 2008; Dramstad et al., 2006; Ode et al., 2008, 2010; Nijhuis, 2011; Tveit, 2009; Tveit et al., 2006, 2014; Blumentrath & Tveit, 2014; Sang et al., 2015; Kiss, 2017.
Landscape psychology	coherence, complexity, legibility, mystery	Appleton, 1975; Ulrich, 1977; Kaplan & Kaplan, 1989; Herzog, 1992; Stamps & Nasar, 1997; Stamp, 2004, 2005, 2008; Ikemi, 2005; Galindo & Hidalgo, 2005.

>>>

TOC

TABLE 2.1 An initial review of design vocabulary describing spatial-visual properties of landscape summarised from the most relevant literatures in related research fields.

Research Field	Design vocabulary of landscape spatial-visual properties	Relevant literatures
Landscape ecology	proximity, similarity, evenness, diversity, richness, contagion, contrast	Baker, 1992; McGarigal & Marks, 1995; Dramstad et al., 1996, 2001, 2006; Gustafson, 1998; Antrop & van Eetvelde, 2000; Urban & Keitt, 2001; Palmer, 2000, 2004; Nassauer & Opdam, 2008; Ode et al., 2008, 2010; Ahern, 2013.
Urban morphology	intensity, distribution, proximity, connectivity, diversity, complexity, wholeness	Alexander, 1977; Klarqvist, 1993; Hillier, 1997. Pont & Haupt, 2010; Salat, 2011;

2.2.2 The Nature of Spatial-Visual Design Vocabulary

In order to grasp the vast amount of spatial-visual design vocabulary, it is important to understand what aspects of landscape spaces are indicated and discussed by this lexicon. To answer this question, it is useful to make a distinction between form and content (Motloch, 2000; Loidl & Bernard, 2003; Steenbergen et al., 2008; Nijhuis, 2015). Content is everything that comprises a landscape architectonic object, and its physical, biological, and cultural substances like landform, vegetation, water, and built structures. Form involves the way in which two- and three-dimensional elements are assembled into a landscape architectonic composition (Nijhuis, 2015). It is constructed of five basic spatial elements containing spaces and mass, edges, paths, foci, and thresholds.

Spatial-visual design vocabulary describes the formal properties and organisations and spatial-visual landscape elements. As shown in Figure 2.2, some design vocabulary categorised as *'properties of the element'* are commonly used to describe the spatial and/or visual properties of landscape elements. For example, the 'enclosure' of the vegetation edge, the 'balance' of space sizes, the 'dominance' of the monument as a landmark, or the 'openness' of the natural space. Meanwhile, some other design vocabulary regarded as *'organisation of the elements'* tend to establish organisational structures and visual relationships among multiple spatial elements to indicate perceptual experiences in landscapes, such as the 'connectivity' of a series of spaces, the 'sequence' in motion, and the navigational 'orientation' of the landscape.

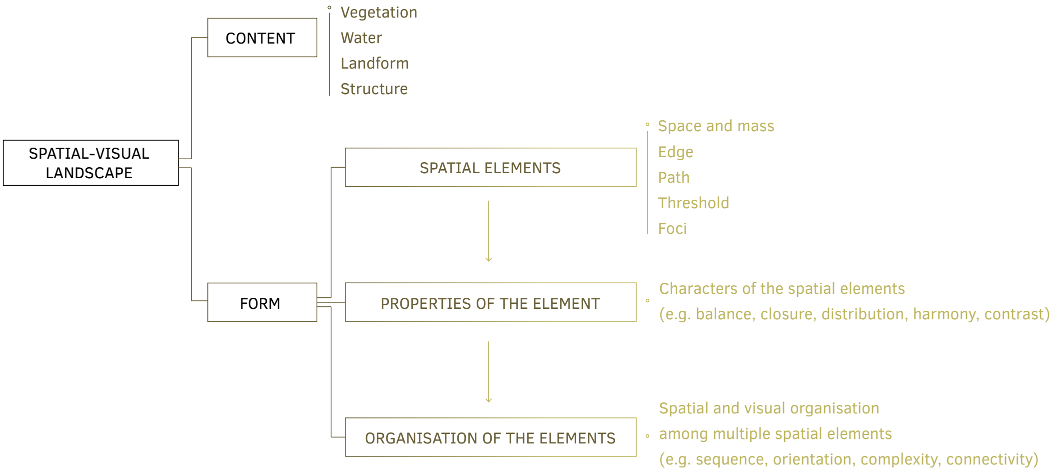


FIG. 2.2 Layers describing the nature of spatial-visual design vocabulary.

As the literature review points out, design vocabulary sometimes overlaps and are not mutually exclusive. ‘*Properties of the element*’, as simple design vocabulary, indicates straightforward spatial-visual effects based on the specific characteristics of spatial elements; while ‘*organisation of the elements*’, as compounded design vocabulary, presents composite structures and organisations of spatial elements. Compounded design vocabulary can be created through the combination of simple design vocabulary. For example, ‘sequence’ can be shaped by the ‘connection’ of a series of spaces with different degrees of ‘enclosure’. Here ‘continuity’, as a compounded design vocabulary, can be formed through the combination of two simple design vocabulary, ‘connection’ and ‘enclosure’. In different research fields, the same design vocabulary might have various interpretations in terms of spatial-visual characteristics. In the context of landscape psychology and visual landscape studies, ‘complexity’ expresses how much a scene contains, which can be determined by the richness of spatial and visual properties of landscape elements, while in landscape ecology, ‘complexity’ is related to the heterogeneity of spatial compositions and configurations, such as evenness, edge density, and shape diversity (Palmer, 2000; Stamps, 2004; Fry et al., 2009). Table 2.2 summarises the spatially- and visually-oriented explanation of the initial design vocabulary from representative references and identifies whether they are used to describe properties of the spatial element or spatial-visual organisation of multiple elements.

TABLE 2.2 The nature of initial spatial-visual design vocabulary.

Design vocabulary	Spatial-visual explanation	Representative reference(s)	Properties of the element (simple)	Organisation of the elements (compounded)
Balance	A concept of equal proportion and visual attraction (on size, shape, colour etc.) of spatial elements, which is in relation to equilibrium, distribution, sequence, continuity etc.	Motloch, 2000; Hansen, 2009, 2010	○	
Circulation	Pathway linking landscape elements such as spaces and focal points allows directional or non-directional movement.	Motloch, 2000	○	○
Closure	Landscape elements formed to enclose a space and create a sense of separation.	Bell, 1999	○	
Coherence	How well elements fit together, which requires a certain of degree of unity form, elements, and detail, referring to the order/unity of a place.	Dee, 2004	○	
Compactness	A landscape ecological concept describing a convoluted, but narrow, patch in the landscape, which relates to the measure of patch elongation.	McGarigal, 2001	○	
Complexity	A diversity or richness of visual and spatial properties of landscape elements; A landscape ecological factor indicates the heterogeneity of spatial compositions and configurations referring to evenness, edge density, and shape diversity.	Palmer, 2000; Stamps, 2004; Fry et al., 2009		○
Congruence	Synonymous with harmony and order. Indicates the consistency of an elements' spatial characteristics making up a scene.	Steinitz, 1967; Galindo & Hidalgo, 2005	○	
Connectivity	The degree of how spatial-visual elements are linked to one another.	Bell, 1999	○	○
Contagion	Landscape ecological index showing the adjacency/cluster of a certain land cover type.	Turner et al., 1989	○	
Continuity	The organisation (e.g. repetition, similarity, harmony, nearness) of spatial elements that shape the landscape in an interrelated image.	Lynch, 1960; Dee, 2004; Booth, 2011	○	○
Contrast	The comparison of landscape elements' attributes and organisation on shape, colour, size, texture etc.	Booth, 2011	○	
Convergence	Elements are grouped as a group/cluster through certain orientation.	Carmona et al., 2010	○	
Direction	The properties or organisation of the elements oriented visual attention and physical movement.	Booth, 2011	○	○

>>>

TABLE 2.2 The nature of initial spatial-visual design vocabulary.

Design vocabulary	Spatial-visual explanation	Representative reference(s)	Properties of the element (simple)	Organisation of the elements (compounded)
Distribution	Scatter pattern with repeated elements separated by space; A landscape ecological concept indicates spatial heterogeneity.	Antrop & Eetvelde, 2000; Booth, 2011	○	
Diversity	A degree of variety and difference of spatial elements indicating the complexity of the spatial pattern.	Antrop & Eetvelde, 2000		○
Dominance	The property of element (size, intensity, or interest) attracts and holds attention, and creates a radial sense spreading out from a centre.	Lynch, 1960	○	
Enclosure	A combination of the shape of elements and their positions enclosing a volume or space.	Bell, 1996	○	
Equilibrium	Distributing elements in order that one composition appears equate to another in terms of visual weight, which is related to stability, balance, and harmony.	Booth, 2011	○	
Evenness	A landscape ecological aesthetic attribute refers to spatial complexity/ coherence perception, and suggests the fragmentation and heterogeneity of the landscapes.	Almusaed, 2018	○	
Harmony	A combination of architectural elements relying on the balance between unity and variety.	Loidl & Bernard, 2003; Marciniak, 2011	○	
Hierarchy	Elements articulated and organised according to the significance of form or spaces (e.g. size, shape, placement) to shape visual dominance, ordering, and continuity.	Ching, 2014	○	
Intactness	Normally used as vegetation intactness; A visual-ecological property relates to unity, harmony, coherence, and connectivity.	Tveit & Fry, 2006; Fry et al., 2009	○	
Integration	A measure of closeness referring to distance from one spatial element to all others from the system as a whole.	Hillier, 1997		○
Interlock	The organisation of elements makes them unified.	Bell, 1996	○	
Legibility	A scene has components aiding wayfinding that helps with orientation.	Kaplan & Kaplan, 1989; Stamps, 2004		○
Locomotion	Refers to the behaviour through a space in order to navigate obstacles and perceive the space, which relates to speed, field of vision, and spatial depth.	Freundschuh & Egenhofer, 1997.	○	

>>>

TOC

TABLE 2.2 The nature of initial spatial-visual design vocabulary.

Design vocabulary	Spatial-visual explanation	Representative reference(s)	Properties of the element (simple)	Organisation of the elements (compounded)
Movement	Physical and visual movement/force is controlled by the characteristics/ organisation of spatial elements which makes the sensation of rhythm, sequence, and direction.	Bell, 1996; Hansen, 2010	○	
Mystery	Three-dimensional interpretation of space showing preference for scenes and complexity with diverse and rich elements, where one would like to see/explore more.	Kaplan & Kaplan, 1989	○	
Naturalness	The degree of a landscape which is to be perceived as a natural state, which visual attribute is related to level of succession, shape index of edge, and number of woodland patches.	Ode et al., 2009	○	
Nearness	Elements appear to be part of a group in a composition which is synonymous with proximity and convergence.	Bell, 1996	○	
Openness	The proportion of open area, the viewshed size, or the depth of view.	Dupont et al., 2014	○	
Order	The organisation of elements makes their relationships visible to each other and the structure as a whole.	Motloch, 2000; Dee, 2004; Ching, 2014	○	○
Orientation	Physical modification of elements affects or indicate a directional moving experience.	Appleton, 1975; Sanoff, 1991; Bell, 1999	○	○
Proximity	Elements are spatially close together to be a group; A landscape ecological index considers the spatial relation of one patch to its neighbours.	Carmona et al., 2010; McGarigal & Marks, 1995		○
Repetition	Repeated elements creating patterns or a sequence.	Loidl & Bernard, 2003; Hansen, 2010	○	
Rhythm	A time-based sequence which repeats a characteristic combination.	Loidl & Bernard, 2003	○	○
Richness	Alternative vocabulary of complexity, evenness, and diversity, which presents landscape ecological aesthetic attribute encouraging people move/see deeper but also indicating how ecosystem functions.	Almusaed, 2018		○
Sequence	A series of elements connect to make a sense of visual or physical ordering.	Cullen, 1961; Loidl & Bernard, 2003	○	○
Similarity	Elements grouped together if their properties are perceived as related.	Thiel, 1981	○	

>>>

TOC

TABLE 2.2 The nature of initial spatial-visual design vocabulary.

Design vocabulary	Spatial-visual explanation	Representative reference(s)	Properties of the element (simple)	Organisation of the elements (compounded)
Spaciousness	Relates to the degree of the landscape having enough space/ filled with solid objects.	Palmer & Lankhorst, 1998	○	
Stability	Physical characteristics in size, style, shape, and their organisation of elements appear a sense of consistency, equilibrium, and continuity.	Carmona et al., 2010	○	
Tension	A result of conflicting visual forces which increases the dynamics/vitality of the landscape.	Bell, 1996; Booth, 2011	○	
Transformation	A spatiotemporal property of landscape space, in which form transformation refers the mutation from one shape to another while visual transformation indicates visual arrays in motion.	Bell, 1996	○	
Transition	Spatial changes between shapes, sizes, and colour etc. Sometimes synonymous to transformation.	Booth, 2011	○	
Uniformity	Common attributes or similarity of elements establish components to a whole.	Loidl & Bernard, 2003	○	
Unity	The organisation of elements appears to be wholeness, completeness, and continuity.	Bell, 1996		○
Variation	Spatial and visual differences in size, shape, colour, and texture etc., which shape contrast, diversity, complexity etc.	Loidl & Bernard, 2003; Almusaed, 2018		○
Visibility	The opportunity to see referring to visual degree in the landscape.	Tveit, 2009	○	
Visual scale	Referring to the experience of landscape spaces' visibility and openness.	Tveit, 2009	○	
Wholeness	Refers to qualities of integration and completeness, in which forms of different elements are summed up in integrated ways.	Dee, 2004		○

2.2.3 Dominant Categories in Describing Spatial-visual Organisation

Concerning the paraphrasing of each spatial-visual design term from representative literatures, detailed inner-mechanisms among landscape elements are revealed according to their structural characteristics and organisations. The '*organisation of elements*' design term, representing spatial-visual experiences in a landscape, is related to one or multiple '*properties of the element*', depicting spatial properties and structures of the element. Also, some terms look different but have synonymous or similar understandings of landscape spaces in spatial-visual aspects.

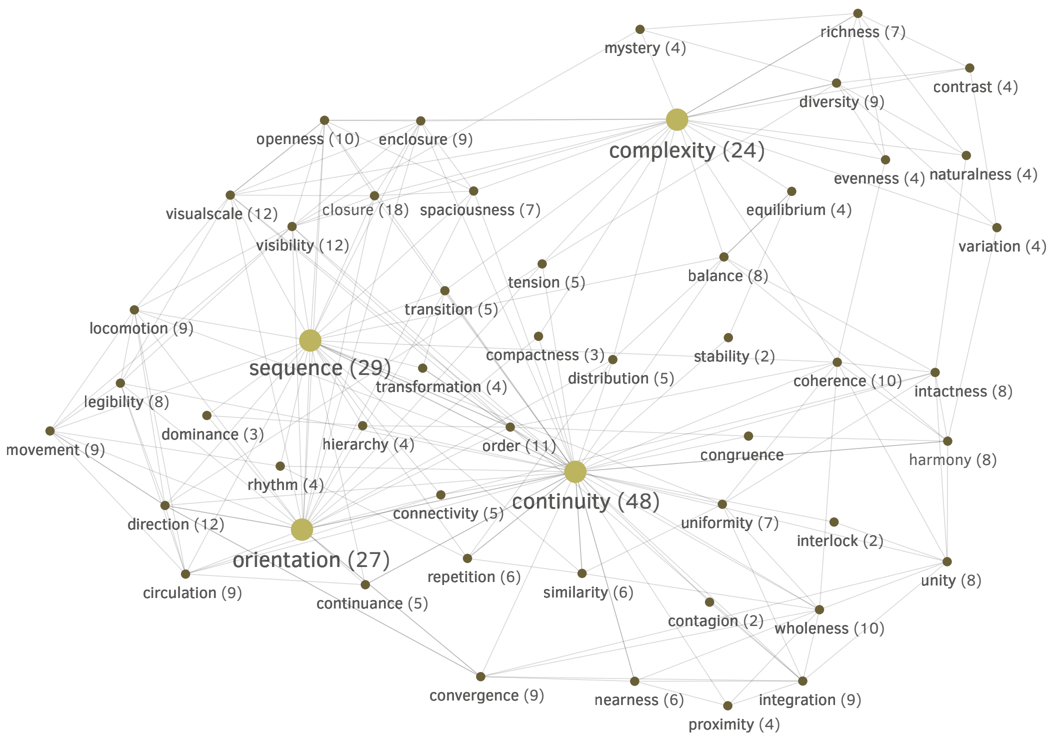


FIG. 2.3 Network analysis showing the relations between the spatial-visual design vocabulary according to the literature review. Nodes are design vocabulary; lines are the direct or indirect relations; numbers mean how many times it is connected with others in the matrix. Four dominant categories (big nodes) are pointed out including sequence, orientation, continuity, and complexity. Automatically conducted by an open visualisation platform Flourish, see input and original output at: https://app.flourish.studio/visualisation/2574736/edit.

To specifically explore and identify the nature of landscape forms in terms of spatial-visual landscape characteristics, a network analysis is conducted here which demonstrates the 'compose and be composed' relations between design vocabulary based on the explanation of each spatial-visual design term displayed in Table 2.2. In the network analysis, each design vocabulary is depicted as a node; while lines are linked if there is direct or indirect relationship between the terms. Figure 2.3 is developed using Flourish, an open source visualisation platform, and automatically generates as a matrix form. As a result, four design vocabulary are most frequently linked with the others, which can be recognised as the predominant '*organisation of the elements*' design vocabulary describing compounded spatial-visual organisation and experience of landscape spaces, which are:

- Vocabulary about a sequential relationship and experience composed by a series of ordered or repeated landscape elements and rhythmical organisation along movement, such as 'sequence'. Synonyms are 'rhythm' and 'order'.

- Vocabulary regarding landscape architectonic compositions which guide physical movement and visual arrays for further wayfinding and exploration. The representative term is orientation, while sometimes 'direction', 'legibility', and 'circulation' are used analogously.

- Vocabulary referring to the construction of spatial elements linked to each other as a whole, which allows going or looking through, for example 'continuity'. It can be related to 'connectivity', 'connection', 'integration', 'proximity', and 'continuance'.

- Vocabulary concerning the diversity and richness of spatial and visual elements in a landscape scene. A typical one is 'complexity'. 'Diversity' and 'richness' are always used as the interchangeable term in the field of landscape design, and together with 'evenness' and in landscape ecology. While 'mystery' is related to 'complexity' complementing the visual effect of predicting preference.

In order to study how landscape elements form together to interpret these main spatial-visual organisations in detail and how they are manifested in visual ways, each design vocabulary and associated synonyms related to landscape design were further analysed using bibliometric analysis (via Google Scholar). For example, 'sequence' combined with 'landscape design' by Boolean operation 'AND' is used as keywords to filter the literature. The top one hundred publications are scanned through abstracts first in order to select relevant references referring to spatial-visual landscape, and then intensive reading is applied to analyse and explore how this potential spatial-visual organisation is structured and represented in order to select the most relevant references.

2.3 Four Dominant Categories in Spatial-Visual Vocabulary

As the literature review points out, sequence, orientation, continuity, and complexity play an important role in the spatial-visual vocabulary of landscape architecture and related spatially oriented disciplines. These terms overlap and are not mutually exclusive. Also, there are synonyms and terms that, at first glance, look different but can have similar meanings in understanding landscape spaces. The following section will explain the compositional mechanisms of landscape elements shaping certain spatial-visual organisations and relevant design vocabulary indicated.

2.3.1 Sequence

An overwhelming majority of research defines 'sequence' as independent nodes that are related and connected with each other through access links, to provide a visual sensation along certain movements through a landscape. In a linear linkage, path structure is the most frequently used element that connects design nodes to create a spatial sequence. This helps build an inner-relationship and perceptive experiences within the landscape. Creating nodes along a route can be done in a number of ways, through the creation of sequential spaces, landmarks, joints, thresholds, and symbolic objects (Lynch, 1960; Simonds, 1961; Litton, 1968; Colville National Forest, 1989; Sutton, 1992; Crandell, 1993; Dee, 2004; Jackson, 2008; Booth, 2011; Entwistle & Knighton, 2013; Kiss, 2017). Regarding roads and highways, topographic elements such as elevation, flat forms, wave forms, and climax forms, play an essential role in shaping sequential experiences (Blumentrath & Tveit, 2014; Qin et al., 2016). In particular, the organisation of views also provides a visual sequence that broadens the observers experience and appreciation (Wright, 1974; O' Malley et al., 2010; Nijhuis, 2011; Apostol et al., 2016).

'Rhythm' as a synonymous term suggests that a composition, through the repetition of similar elements, creates a sequence, which can be seen as a specific unified 'sequence'. Jackson (2008) defines rhythm as a principle closely related to sequence, which is a result of repetition. Characterised by Motloch (2000) and Ching (2014), this coherent sequence is created through repeating landscape patterns, such as line, form, colour, value, or texture.

Other relevant studies point out that an edge is also an important spatial-visual element that shapes a sequence, such as water boundaries, vegetation edges, or the enclosure of an edge along a path. Appleyard, Lynch, and Meyer (1964) describe that the sequence of a landscape can be influenced by changing the enclosure of the water boundary. In this case, the width of the water course is indicated as relaxed flow and accelerated flow to present the sequential changes of landscapes. However, Thiel (1961) analyses and discusses that the sequence as a three-dimensional composition, which are composed by surfaces, screens, and objects in over, side, and under positions. This experience mostly refers to the alternate types of enclosure, the degree of enclosure, the permeability of an edge, the height of an edge etc. (Jakle, 1987; Loidl & Bernard, 2003; Booth, 2011; Nijhuis, 2011; Fathi & Masnavi, 2014).

As exemplified by the literature review, sequences can be mapped from eye-level perspectives, as well as by the use of maps and plans employing qualitative and quantitative mapping methods and tools. In a vertical dimension, schematic hand-drawn maps and graphic notations are commonly used to map the sequence (e.g. Lynch, 1960; Simonds, 1961; Loidl & Bernard, 2003). They depict the composition and configuration of the spatial sequence from a map view. Meanwhile, perspective sketches, graphic notions, and photographs complement the representation from the eye-level perspective (e.g. Cullen, 1961; Dee, 2004; Booth, 2011). In addition to these subjective mappings of the sequence, researchers also keep improving more accurate and unambiguous clues of the spatial-visual attributes of landscapes. For example, Appleyard et al. (1964) use preliminary viewshed analysis to designate the visible scenes along a movement, which indicates the sequence of the road. Ohno and Kondo (1994) exploit a personal computer programme using charts to measure and show the spatial arrangement from the eye-level. Nijhuis (2011) applies isovist analysis (a two-dimensional visibility calculation showing the sight filed polygons) and 3D models to show the serial version of the spatial transition from the piazza to the piazzetta. In 2014, he uses GIS-based viewshed analysis to measure the visual logic of Stourhead and indicates the sequence of different paths. Furthermore, a road design software HintCAD is also used by Qin et al. (2016) which can provide quantitative reference to show the relationship between flat form, wave form, and climax form along the road. A detailed literature review is available in Appendix A-1.

2.3.2 Orientation

The majority of research asserts that creating landmarks or/and openness is important to establish a sense of direction, as well as provide an way to orient oneself in the landscape. Landmarks are foci set in specific positions and indicate a tangible direction dedicated to guide people's movement through the landscape (Lynch, 1981; Chalmers, 1993; Motloch, 2000; Loidl & Bernard, 2003; Nijhuis, 2011). Research and practical experiences in traffic design also show the significance of using foci (such as monument, specimen, and building) to form orientation (Appleyard et al., 1964; Queensland Government, 2013).

Furthermore, Booth (1989) states that space is like liquid which always tends to open views with the least the resistance (Appleton, 1975; Bell, 1999; Yahner et al., 1995; Lyle, 1999; Fu & Rich, 1999; Franco et al., 2003). From a landscape psychology perspective, legibility means the perception of finding your way or back to any given point in the environment, which carries a sense of orientation (Kaplan et al., 1998; Stamps, 2004). The related research also highlights the importance of reference points (i.e. foci) and openness (i.e. space, edge, and visual impact), which are able to enhance the cognition of visual orientation and can make the space more readable (Herzog & Leverich, 2003; de la Fuente de Val et al., 2006).

Edges of water, spaces, and paths are always used for orientation (Cullen, 1961; Newton, 1971; Sanoff, 1991; McClelland, 1998; Ronnen et al., 2005). Moreover, landscape ecologists demonstrate that an edge is an essential spatial element that influences orientation in landscape spaces. Relevant characteristics like the length of an edge and its orientation are measured to show the elasticity of space (Baker, 1992; Baskent, 1999; Dramstad et al., 1996; Beck, 2012). Characteristics of an edge can also indicate the visual orientation by forming an openness to the landscape, such as the height of the edge, relationship between the foreground, middle ground and background, and the permeability of the edge (Clouston, 1977; Smardon et al., 1986; Kaymaz, 2012; Rega, 2014). Also, in the urban context, the continuity of a building facade along a path and an exposed sky helps to maintain a sense of direction (Thwaites et al., 2005).

Most of the literature use maps, graphic notations, and photographs to visualise the orientation of landscapes (e.g. Newton, 1971; Dramstad et al., 1996; Loidl & Bernard, 2003). In order to describe and understand the exact composition and configuration of the space, some preliminary GIS-based measurements are applied to map the orientation (e.g. Chalmers, 1993; Fu & Rich, 1999). Considering the observer's experience in the landscape, photographs and statistical measurements are combined to calculate the legibility that indicate landscape preference (e.g.

Franco et al., 2003; Herzog & Leverich, 2003; de la Fuente de Val et al., 2006). Since approximately 2010, new techniques have been introduced to map the orientation, which combines the map view and the eye-level perspective, containing 3D visualisation and GIS-based viewshed analysis, solar radiation analysis etc. (see, for example, Wissen et al., 2008; Nijhuis, 2011). A detailed literature review is available in Appendix A-2.

2.3.3 Continuity

Continuity has a strong relationship with visual and physical access and strengthens an awareness of the fore way which connects subspaces to the whole. Continuous movement often happens in open spaces, which allows for permeable views and accessibility. These approaches form spatial elements with certain characteristics, such as the openness of space, the permeability of edges, and the layers of a scene (foreground, middle ground and background) (Trancik, 1986; Lefebvre, 1991; Robinson, 2004; Carmona et al., 2010; Pancholi et al., 2015; Exner & Pressel, 2017). In the urban context, the skyline can also provide an eye-level visual experience of continuity (Homma et al., 1998).

The spatial-visual characteristics of continuity generally focuses on the shape of landscape elements, such as the shape of water, spaces, and paths. It indicates edge forms and materials that can directly influence the experience of continuity. For example, enhancing repetitive and similar edge patterns can guide a person's perception of continuity (Lynch, 1960; Bell, 1993; Thwaites, 2001; Talen, 2006; Torreggiani et al., 2014). In addition, the manipulation of landforms such as moderating slope elevation and the angle of elevations could also offer continuity in spaces, views, and motion (Lynch, 1960; Ronnen et al., 2005). In morphological studies, space syntax has become a primary research branch in helping measure the connectivity and the integration of path networks, but also presents the continuity of the spatial system from a larger scale (Hillier, 1997; Weitkamp et al., 2007; Kofi, 2010; van Nes, 2011).

Continuity is also an important indicator for landscape ecology in the urban and rural environment. Landscape infrastructure, such as green corridors, greenways, and river corridors, suggest that the width and creating successive paths are able to enhance spatial continuity for landscape planning (Gustafson, 1998; Jim & Chen, 2003; Alcamo et al., 2008; Nassauer & Opdam, 2008; Liu et al., 2016). Also, a number of detailed characteristics like patch area, patch perimeter, edge to edge distance, and the number of joints are commonly used to calculate indicators for continuity such as the Interspersion/Juxtaposition index, Contagion index, Cohesion index, Isolation index, and Proximity index (Baschak & Brown, 1995; Herrington & Studtmann, 1998; Urban & Keitt, 2001; Blaschke, 2006; Simova & Gdulova, 2012).

Continuity is usually mapped by analogue maps and graphic notations, sometimes with photographs to show the exact composition and configuration of continuity (e.g. Lynch, 1960; Bell, 1993; Dee, 2004; Robinson, 2004; Ronnen et al., 2005; Talen, 2006; Carmona et al., 2010). These analytical diagrams and maps normally show continuous layouts and their compositions from a bird view, while photographs or sketches are applied to indicate the visual continuity from the eye-level perspective. In addition to a schematic visualisation, ArcGIS is also used to represent the spatial and visual continuity more precisely (see, such as, Nijhuis, 2011; Liu et al., 2016). Space syntax-based software is also widely implemented to map the continuity of the urban system (e.g. Klarqvist, 1993; Hillier, 1997; Weitkamp et al., 2007; van Nes, 2011). Furthermore, in the ecological research field, indicators like Contagion, Interspersion, and Juxtaposition can be calculated via landscape metrics software such as Fragstats (McGarigal, 2001). The limitation of these quantitative methods is that they always result in the measurements of indicators, which is very difficult for designers to understand and use in typical design practices (see, for example, Gustafson & Parker, 1992; Urban & Keitt, 2001; Blaschke, 2006; Gaucherel et al., 2012; Simova & Gdulova, 2012). A detailed literature review is available in Appendix A-3.

2.3.4 Complexity

Definitions of complexity have always varied in research domains which mainly includes studies on landscape design, landscape preference assessment, and landscape ecology. Kaplan (1988) proposes that complexity should reflect how much is happening in a particular scene. Landscape morphology and psychology studies have mentioned the importance of visual array and diversity during the perception of complex environments. They predominantly appear as variations of textures, forms, patterns, and colours of visible landscape scenes (Dunnett & Hitchmough, 2004; Fry & Sarlöv-Herlin, 1997; Weinstoerffer & Girardin, 2000; Galindo & Hidalgo, 2005; Mok et al., 2006; Falk & Balling, 2010; Ode et al., 2008; Lindsey et al., 2008; Tveit & Ode, 2014; Shi et al., 2014; Lau et al., 2014). Landforms are widely used to shape diverse experiences within a landscape by changing people's visual perception (Loidl & Bernard, 2003; de la Fuente de Val et al., 2006; Sang et al., 2015). The shape and length of the paths and routes are also frequently used to enhance the complexity of a landscape (Steinitz, 1990; Lynch & Gimblett, 1992; Thwaites, 2001; Weitkamp, 2010). Furthermore, the degree of openness within a landscape is

TOC

significant in promoting motives to explore. Hence, the corresponding spatial-visual characteristics like the degree of an enclosure, the permeability of an edge, and view depth are widely applied to provide opportunities to create a sense of complexity (Ikemi, 2005; Weitkamp, 2010; Nijhuis, 2011; Olwig, 2016).

On the other hand, in landscape ecology, there is a large amount of research dedicated to the calculation of spatial complexity. Depending on the grain size (scale) of landscape, landscape ecologists commonly use quantifiable indicators to describe spatial complexity and to interpret composition and configuration. They can be represented by land-use diversity, edge density, and landscape shape index (McGarigal & Marks, 1995; Dramstad et al., 2001). It indicates a series of explicit indices like Shannon's diversity index, Simpson's diversity index, patch richness density, Shannon's evenness index, and Simpson's evenness index. The corresponding variables referred to indices such as: patch type, patch size, the perimeter of the patch, and the grain size etc. (Turner et al., 1989; Geoghegan et al., 1997; Batistella et al., 2003; Tveit et al., 2006; Persson et al., 2010; Surová et al., 2014). Moreover, in order to gain more inter-subjective clues, Palmer (2000, 2004) establishes a significant relationship between landscape preference appraisals and landscape metrics.

Hand-drawn maps, graphic notations, and sketches are usually used to present the complexity of spaces, for example, Ronnen et al. (2005) and Dee (2004). These descriptive maps are both from horizontal and vertical perspectives combined to present spatial landscape structures and their visual effects. In the assessment of landscape preference, questionnaires, and statistical analyses, together with landscape visualisations are the most commonly used methods and tools for describing complexity from an observer's horizontal perspective. The studies of Palmer & Lankhorst (1998), Stamps (2004), Galindo & Hidalgo (2005), Ikemi (2005), de la Fuente de Val et al. (2006), Shi et al. (2014), de la Fuente de Val & Mühlhauser (2014), Sang, Hägerhäll, and Ode (2015) are examples. There are also some studies, where GISc-based methods and tools, like viewshed analyses and isovists are employed to map openness and then give quantitative clues of the complexity (e.g. Steinitz, 1990; Lynch & Gimblett, 1992; Lindsey et al., 2008; Weitkamp, 2010; Njihuis, 2011). In landscape ecology, there is a large amount of research dedicated to the calculation of spatial complexity. Based on the mechanism of ecological measurement, Fragstats is a spatial pattern analysis program for quantifying the structure of landscapes (see, for example, Batistella et al., 2003; Palmer, 2004; Blaschke, 2006; Mok et al., 2006; Persson et al., 2010; Surová et al., 2014; Sang et al., 2015; Turner et al., 1989; McGarigal & Marks, 1995; Geoghegan et al., 1997; Weinstoerffer & Girardin, 2000; Palmer, 2000; Gulinck et al., 2001; Plexida et al., 2014). A detailed literature review is available in Appendix A-4.

2.3.5 Summary

To conclude, interpretations of spatial-visual landscape design vocabulary are diverse and involves various of research fields. They show spatial structures and visual effects by composing the contents and characteristics of spatial-visual elements from both horizontal and vertical perspectives. Spatial designers such as landscape architects and urban designers predominantly concentrate on empirical descriptions of spatial compositions and visual organisations. While researchers of landscape ecology, urban morphology, and visual landscape studies tend to use indicators and quantitative measurements to explore spatial-visual compositions and configurations. According to the literature synthesised in this paper, the four spatial-visual landscape design vocabulary can be defined as:

- Sequence: a series of ordered objects which directs the visual experience along movements;
- Orientation: the sense of physical and visual access within landscapes to approach a destination;
- Continuity: the level of connectivity between adjacent spaces to guide the flow of experience;
- Complexity: richness in structure and variety of scenes in the landscape.

2.4 From Linguistic Syntax to Landscape Design Syntax

As exemplified by this research, grasping the vocabulary used to describe the spatial-visual organisation of landscapes is complex as it consists of many layers of abstraction. However, using the analysis of syntax in linguistics as a reference, landscape design syntax shows a similar hierarchical structure in dealing with constitutions and procedures for depicting landscape spaces. There are four levels that guide the description and interpretation of a landscape from a design perspective which include: design vocabulary (spatial-visual organisation), perspective, element (component), and characteristic (Figure 2.4).

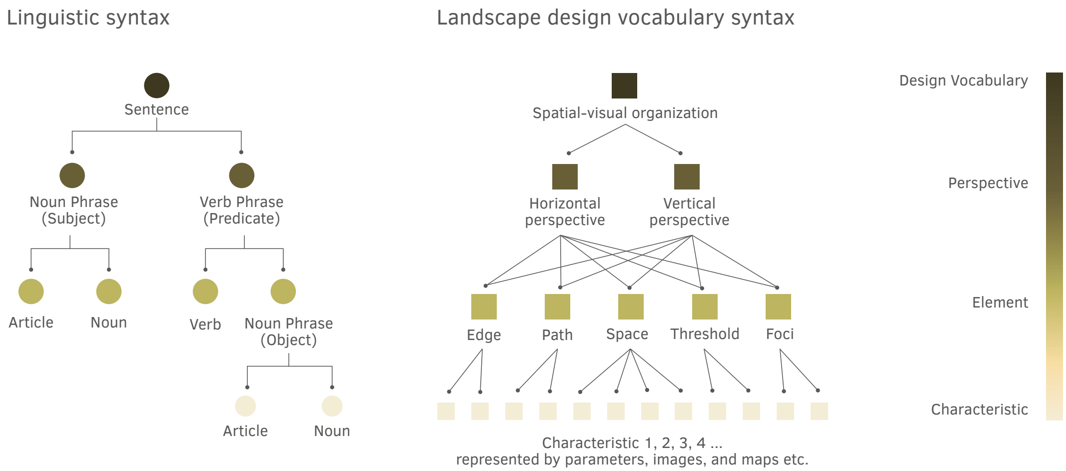


FIG. 2.4 The hierarchical structure of landscape design syntax.

Vocabulary related to spatial-visual organisation is used to describe designers' visual appreciation of distinctive spatial structures (Layer 1). This design vocabulary is always composed of complex spatial compositions and configurations, which can be seen as an umbrella concept. Perspectives are the dimensions that designers use to define landscape spaces (Layer 2). Typically, horizontal, and vertical points of view are the two primary perspectives (Antrop, 2007; Nijhuis, 2015). The horizontal dimension explores the landscape from an observer's point of view (from the inside-out) and addresses the visual space and characterises spatial attributes or patterns from an eye-level perspective. The vertical dimension considers the landscape from 'above' – in the form of a map, or the view from the sky – showing spatial patterns and relationships. Elements are the basic components of a landscape, which are path, space, edge, threshold, and foci (Dee, 2004) (Layer 3). Characteristics indicate the size, shape, and spatial characteristics, which work together to achieve a certain spatial-visual organisation of landscape (Layer 4). This framework of landscape design syntax provides a hierarchical process of developing a spatial-visual organisation from an ambiguous concept to a detailed landscape character. In this study, the characteristics of spatial-visual organisation are as follows (Table 2.3):

TABLE 2.3 The interpretation of spatial-visual characteristics/organisation through a landscape design syntax (see more details in Appendix A).

Spatial-visual characteristics/ organisation	Perspective	Element	Characteristic
Sequence	Vertical perspective	Path	Series of landmarks, joints, connections, spaces, symbolic objects along movements.
		Edge	Shape of water boundary.
	Horizontal perspective	Path & visual impact	Enclosure, views, vistas, screens along the movement; topography of path.
		Edge	Enclosure of edges.
Orientation	Horizontal perspective	Foci & visual impact/ Threshold & visual impact *(with/without path)	Visible landmarks like monuments, buildings, specimen, signposts, gateways, thresholds.
		Edge & visual impact/ Edge & space & visual impact *(with/without path)	Open views (permeability of edge, enclosure of space); height of edge; topography of space; foreground, middle ground, and background.
	Vertical perspective	Path	Shape of path; path patterns (surface, width etc.); direction of path.
		Edge	Shape of water, mountain, space.
	Vertical perspective (ecology)	Space	Elasticity of space (shape of edge; shape of space).
		Edge	Length of edge; direction of edge.
Continuity	Horizontal perspective	Edge & visual impact/ Edge & space & visual impact	Enclosure (permeability of edge, enclosure of space), views along the movement; height of edge; foreground, middle ground, and background.
		Space	Topography of space.
		Path	Horizontal shape of skyline.
	Vertical perspective	Edge	Shape of water edge/space edge/path edge; length of edge/path.
		Foci/threshold *(with/without path)	Bridges, landmarks, linkages, junctions can enhance or decrease the continuity.
		Path	Repetition of nodes' characters (size, shape, form, texture etc.) along the path.
	Vertical perspective (ecology)	Path (corridor)	Width of corridor.
		Edge	Interspersion/juxtaposition/contagion index.
		Space	Proximity index (patch area, nearest neighbour distance).
	Vertical perspective (morphology)	Path & threshold	Connectivity/integration index (the number of paths across the crossing.
		Edge	Gamma index (number of edge).

>>>

TABLE 2.3 The interpretation of spatial-visual characteristics/organisation through a landscape design syntax (see more details in Appendix A).

Spatial-visual characteristics/ organisation	Perspective	Element	Characteristic
Complexity	Horizontal perspective	Visual impact	Visual diversity (types of elements; texture, form, colour of the elements).
		Space & edge & visual impact	Openness (permeability of edge, enclosure of space); height of edge; topography of space; foreground, middle ground, and background; depth between the viewpoint and scenes.
	Vertical perspective	Path	Shape of path (curve); length of path.
	Vertical perspective (ecology)	Edge	Edge density; number of edges; length of field borders; landscape shape index.
		Space	Mean fractal dimension (perimeter/area of patch); patch richness index; patch richness density; Shannon's evenness index; Shannon's diversity index; Simpson's evenness index; Simpson's diversity index.

2.5 Conclusion

In this chapter, a comprehensive overview of design vocabulary, in terms of spatial-visual characteristics, have been developed. As the skeleton of a landscape, both spatial composition and visual organisation (i.e. spatial-visual characteristic) play an important role as the predominant and intuitionistic mediators for landscape architects to describe and understand the design mechanisms and effects of space. This chapter provides a systematic framework for reviewing spatial-visual-related design vocabulary for the field of landscape architecture and interlinks qualitative and quantitative approaches for understanding landscape spaces. Based on the analysis of vocabulary used in the extensive body of literature available on landscape architecture and related disciplines, four dominant categories in describing spatial-visual organisation are identified and discussed. In addition, a landscape design syntax is developed to help understand and describe the visual manifestation of landscape spaces, how space is organised, and determines what role principles play (and in what order) from a qualitative and quantitative perspective. This research is a useful step in establishing a better knowledge base and form of communication for spatial designers through design vocabulary. However, an empirical combination of design vocabulary and landscape metrics is still lacking. It is a necessity to provide mixed approaches to fill the gap between practices and academia. Therefore, merging different mapping methods to achieve comprehensive notions of landscape space is a prospect for further development in landscape studies.

Vondelpark, Amsterdam (Photo by Mei Liu, 2020)

TOC

Vondelpark, Amsterdam (Photo by Mei Liu, 2020)

TOC

3 Mapping Landscape Spaces

Methods for Understanding Spatial-Visual Characteristics in Landscape Design

This chapter is based on a published article:

Liu, M., & Nijhuis, S. (2020). Mapping landscape spaces: Methods for understanding spatial-visual characteristics in landscape design. Environmental Impact Assessment Review, 82.

Mapping landscape spaces by means of manual and digital technology enables landscape architects to describe, understand, and interpret spatial-visual properties of landscape. This chapter aims to contribute to the increase of awareness by providing an overview of mapping methods and tools that can be used to study spatial-visual characteristics in the field of landscape architecture, and show the potentialities of its application by brief examples. Six key categories of mapping methods are proposed, including compartment analysis, 3D landscapes, grid-cell analysis, visibility analysis, landscape metrics, and eye-tracking analysis. Vondelpark, a well-known urban park in the Netherlands, is selected as a pilot study to show the applications of these potential mapping methods in the interpretation of four spatial-visual design vocabulary.

3.1 Introduction

Description, understanding, and visualisation of landscape spaces is at the heart of spatial design in landscape architecture. Landscape spaces, as three-dimensional constructions, mainly articulate the spatial organisation and visual manifestation of open spaces, surfaces, screens, volumes, and their relationship to each other and the context (Simonds, 1997; Motloch, 2000; Doherty & Waldheim, 2016). The basic premise is that the shape of space, plasticity, and appearance of spatial elements in the landscape determine the relationship between design and perception. Landscape design, as such, addresses the form and functioning of space, which creates an intended or unintended spatial dynamic, such as a spatial sequence, the opening of a landscape panorama, or the production of optical illusions. The underlying spatial-visual mechanisms of spatial dynamics are an important subject to study. Not only to understand what spatial effects can be achieved by conceiving certain spatial compositions (and to be able to communicate about it) but also to strengthen the theoretical foundations of the discipline.

There is a long tradition of mapping landscape spaces in the field of landscape architecture. Mapping landscape spaces is about grasping the spatial-visual properties of landscape through manually and digitally produced visualisations. Manual methods for operationalising landscape characteristics are hand-drawn maps, sketches, and schematic diagrams etc. (e.g. Simonds, 1997; Loidl & Bernard, 2003; Dee, 2004). These methods are powerful tools for understanding and describing spatial qualities, which assists in communicating certain spatial design concepts and intentions (Pinzon Cortes et al., 2009). With the development of digital technology, digital visual representations are becoming more widely used in the field of landscape research and design such as photomontages, computer models, 2D and 3D photorealistic visualisations, as well as real time interactive presentations, and virtual reality (VR) environments (e.g. Ervin, 2001; Dinkov & Vatseva, 2016; Bianchetti, 2017; Lin et al., 2018; Bruns & Chamberlain, 2019). They are widely used to help mimic existing or proposed landscapes and to assess or predict environmental/landscape change. Digital visualisations of landscape designs are mostly used for the presentation and communication of ideas, but the interpretation of these visualisations remains relatively subjective, which is problematic for knowledge acquisition and decision-making (Ervin, 2001; Bishop & Lange, 2005).

On the other hand, there are advanced methods, devices, algorithms, and types of data that enable the development of indictors of certain landscape features. These, mostly quantitative, approaches have the potential to measure and visualise spatial-visual aspects of landscape space and deepen the knowledge of their relationship to ecological, morphological, and/or geographical features (e.g. Palmer & Lankhorst, 1998; Antrop, 2007; Weitkamp, 2010; Sunak & Madlener, 2016; Swetnam & Tweed, 2018; Wang et al., 2019). However, these methods are generally used to address planning and policy-oriented landscape issues related to agriculture, ecology, and urban sustainability. Digital methods incorporating measurement tools are hardly used in the field of landscape architecture for analysing and describing spatial-visual aspects of landscape. The link between the possibilities that technology has to offer, and the practice of landscape design remains underdeveloped. A lack of awareness in the field of landscape architecture itself seems to be the most significant reason for this (e.g. Drummond & French, 2008; Göçmen & Ventura, 2010; Nijhuis, 2016).

This chapter responds to research question 2: What are potential mapping methods and tools to analyse and visualise spatial-visual landscape characteristics? It aims to increase awareness by providing an overview of mapping methods and tools that can be used to study spatial-visual characteristics in the field of landscape architecture and show the potential of its application through brief examples. This chapter introduces six categories of mapping methods: compartment analysis, 3D landscapes, grid-cell analysis, visibility analysis, landscape metrics, and eye-tracking analysis. These methods are used to explore, for spatial design in landscape architecture, crucial spatial-visual categories such as sequence, orientation, continuity, and complexity in an analogue and digital way. Vondelpark, a well-known urban park in Amsterdam, the Netherlands, is used to exemplify how these spatial features can be mapped by means of these methods.

3.2 Methods for Visual Landscape Research in Landscape Architecture

Landscape architecture can be broken down into three principle knowledge areas: landscape planning, landscape design, and landscape management (Stiles, 1994). Here, the focus is on landscape design which is concerned with spatial form and meaning, the development of design principles, and the organisation of a physical, functional, and aesthetic arrangement of a variety of structural landscape elements in order to achieve desired social, cultural and ecological outcomes (Nijhuis, 2015). The cultivation of spatial intelligence in landscape architecture is therefore of crucial importance. In visual landscape research, the development of knowledge on the spatial-visual aspects of a landscape is put forward as an important knowledge field. Mapping landscape spaces is the main subject of visual landscape research. Visual landscape research integrates concepts, landscape perception approaches, and mapping methods and techniques (Nijhuis et al., 2011). In the field of landscape perception research, there are a vast amount of theories, methods, and applications available that can be divided in two main discourses, expert and public preference approaches (Sevenant, 2010). In the expert approach, analysis and evaluation is performed by experts and trained observers, such as landscape architects and geographers. In public preference approaches, psychophysical, psychological, and phenomenological methods are used to test or evaluate the visual properties and experience of a landscape. Though both discourses are not mutually exclusive, this article focusses mainly on expert approaches to visual landscape research, the mode in which landscape architects usually operate within.

Literature reveals that there are six dominant mapping methods available for visual landscape research (updated and adapted from Nijhuis et al., 2011):

- Compartment analysis considers the visible landscape as a set of concave compartments and the maps are used to distinguish the relationship between space and mass from a vertical perspective.
- 3D landscapes identifies the visual landscape from an observer's point of view, which utilises two- to three-dimensional visualisations and addresses spatial-visual characteristics horizontally.
- Grid-cell analysis evaluates the landscape by calculating different spatial properties by means of grid-shaped polygons or raster cells.
- Visibility analysis is a three-dimensional visibility calculation based on raster analysis, which shows the geographical area visible from a given position from the observer's perspective.
- Landscape metrics conducts a spatial analysis of land-use patches in landscape ecology, which quantifies potential metrics of landscape compositions and configurations vertically via raster or vector.
- Eye-tracking analysis is a system that records eye movements and fixations while observing scenes in-situ to interpret spatial-visual characteristics.

These spatial-visual landscape mapping methods can be categorised according to horizontal/vertical perspectives and qualitative/quantitative approaches (Figure 3.1). The horizontal perspective explores the landscape from an observer's point of view and addresses the spatial-visual characteristics from an eye-level perspective. The vertical perspective considers the landscape from 'above' and analyses spatial patterns and relationships from a map view (Nijhuis, 2011). Qualitative approaches here are termed as the empirical interpretation of observation, while quantitative approaches gather numerical information or translates knowledge into numbers in order to describe and analyse certain phenomena more objectively (Kanagy & Kragbill, 1999).

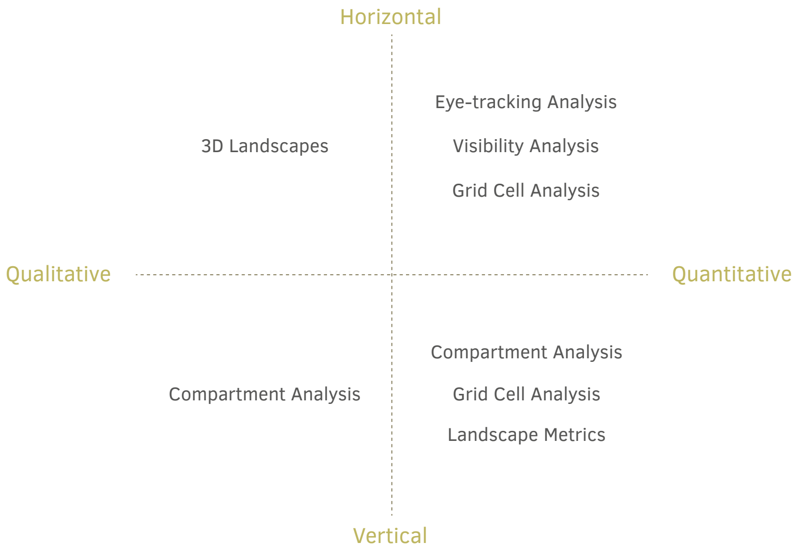


FIG. 3.1 Characteristics of different mapping methods and tools.

To understand and describe the visual manifestation of landscape spaces, how space is organised, and what ordering principles play a role, landscape architecture employs a specific vocabulary that is fundamental to the discipline. Several researchers elaborate on the two- and three-dimensional physical layout of the landscape architectonic composition and provide vocabulary to describe the spatial construction of spaces, paths, edges (i.e. surfaces, screens, objects), foci, thresholds, and visual relationships like sequence, sightlines, and panorama (e.g. Simonds, 1997; Motloch, 2000; Dee, 2004). In landscape research, the emphasis is often on quantitative clues in the form of landscape indicators that link measurements, spatial descriptions, and performances, such as ‘proximity’, ‘connectivity’, and ‘coherence’ (McGarigal & Marks, 1995; Tveit et al., 2006; Salat, 2011).

To understand the vast amount of spatial-visual design vocabulary, this chapter uses four dominant categories of design vocabulary, which are commonly used in landscape architecture to explore the spatial-visual phenomena related to landscape design: sequence, orientation, continuity, and complexity. The six mapping methods will be used to address the four spatial-visual features or design characteristics commonly used in landscape design.

- Sequence: concerns a series of ordered objects which directs the visual experience along movements (e.g. serial vision, alternate enclosure, vista).
- Orientation: indicates the sense of physical movement and visual access within landscapes to aid wayfinding (e.g. a sense of direction, prospect and refuge).
- Continuity: states the relative degree of connectivity of some layouts to each other, which causes adjacent spaces to be a group in a composition (e.g. continuous surfaces or edges, visual and physical accessibility).
- Complexity: suggests richness of spatial and visual elements contained in a landscape scene (e.g. richness/diversity of the view).

3.3 Pilot Study and Data Sources

3.3.1 Pilot Study – Vondelpark, Amsterdam

To showcase the potential of mapping methods for visual landscape research, Vondelpark (Amsterdam, the Netherlands) is used as an example (Figure 3.2). Vondelpark an urban park, designed in the 19th century, employed the spatial principles of English landscape design. This included important hallmarks such as the concealment of boundaries, the illusion of endless water bodies, spatial sequences, and continuous views (Pevsner, 1956; Hirschfeld, 2001; Steenbergen & Reh, 2003, 2011). The emphasis was on creating an internal-oriented spatial experience with little spatial-visual relationships to the surrounding urban context. As a result, the park is an important learning opportunity for spatial-visual design. Moreover, as an important urban park in the Netherlands, adequate data accessibility and physical accessibility (i.e. fieldwork) helped to evaluate and refine the results of the mapping study.

FIG. 3.2 Top: Orthogonal Aerial photograph of Vondelpark (Google Maps, September 2019); Bottom: Digital Terrain Model with heights in metres (Actueel Hoogtebestand Nederland, 2019).

3.3.2 Mapping Tools and Data Sources

As mentioned above, six potential mapping methods of spatial-visual landscapes are used to explore the primary spatial design characteristics in such a way that the feasibility and peculiarity of different mapping methods can be compared. Considering that each method has its specific characteristics, a variety of tools and data are needed (Table 3.1).

TABLE 3.1 Tools, platforms, and data for different mapping methods.

Mapping methods	Compartment analysis	3D landscapes	Grid-cell analysis	Visibility analysis	Landscape metrics	Eye-tracking analysis
Tools & platforms	Pen & sketchbook; Depthmap	Pen & sketchbook; Camera; 3D modelling software (SketchUp, Rhino etc.)	SegNet & Excel; GIS	GIS & Excel	GIS & Fragstats	Eye-tracking hardware & software
Data	Field survey; Axia map (CAD)	Field survey; Photograph; Photomontage; 3D model	Photograph; Field survey & GIS data (vector)	GIS data (raster)	GIS data (raster)	Photograph or video

3.4 Applications of Spatial-visual Landscape Mapping Methods

In order to explore the possibilities of mapping spatial-visual characteristics, the six mapping methods are applied to evaluate and describe the previously mentioned categories of design vocabulary, addressing space from qualitative and quantitative perspectives. The tools are used in a rather intuitive way to address the form and function of three-dimensional landscape spaces. They are selected based on their potential to explore particular spatial-visual phenomena common in landscape design, such as the framing of views, serial vision along a route, the identification of dominant visual landscape elements etc.

3.4.1 Compartment Analysis

In compartment analysis, the visible landscape is considered as a set of concave compartments that can be characterised by size, shape, border type, and their content (De Veer & Burrough, 1978; Nijhuis et al., 2011). Compartment analysis always utilises maps to distinguish the relationship between space and mass in qualitative or quantitative terms and understands landscape architectonic compositions from a vertical perspective. Conventional schematic diagrams include hand drawings, graphic illustrations, topographic maps, and aerial photographs. These are often used to show landscape morphology in the design process (see, for applications, Simonds, 1997; Motloch, 2000; Dee, 2004; McEwan, 2018; Koh, 2019). Spatial network analysis, as a specific form of compartment analysis, represents and quantifies physical configurations as a whole at different scales (e.g. Kofi, 2010; van Nes, 2011; Telega, 2016; Wernke et al., 2017; Boeing, 2018).

Sequence: Sequential experience follows what people see and perceive when moving along a certain trajectory. Figure 3.3a shows the mapping of a sequence, revealing the variation of the water body shapes. Linkages among spaces, foci, and thresholds create spatial sequences that have a certain rhythm (as an example see Figure 3.3b).

Orientation: The circulation pattern has a direct influence on the orientation of space, the winding patterns of the route convey the spaces themselves and reveal different perspectives (Figure 3.3c). The resulting oval-shaped spaces have an elongated orientation along the long side (Figure 3.3d).

Continuity and complexity: Figure 3.3e evaluates the degree of openness of the edges of each spatial unit and their relationships in terms of visual and physical continuity. The shape of the spaces address aspects of spatial complexity. Figure 3.3f shows the form of spaces ranging from curving edges and geometric internal structures, while others are only characterised by curving shapes.

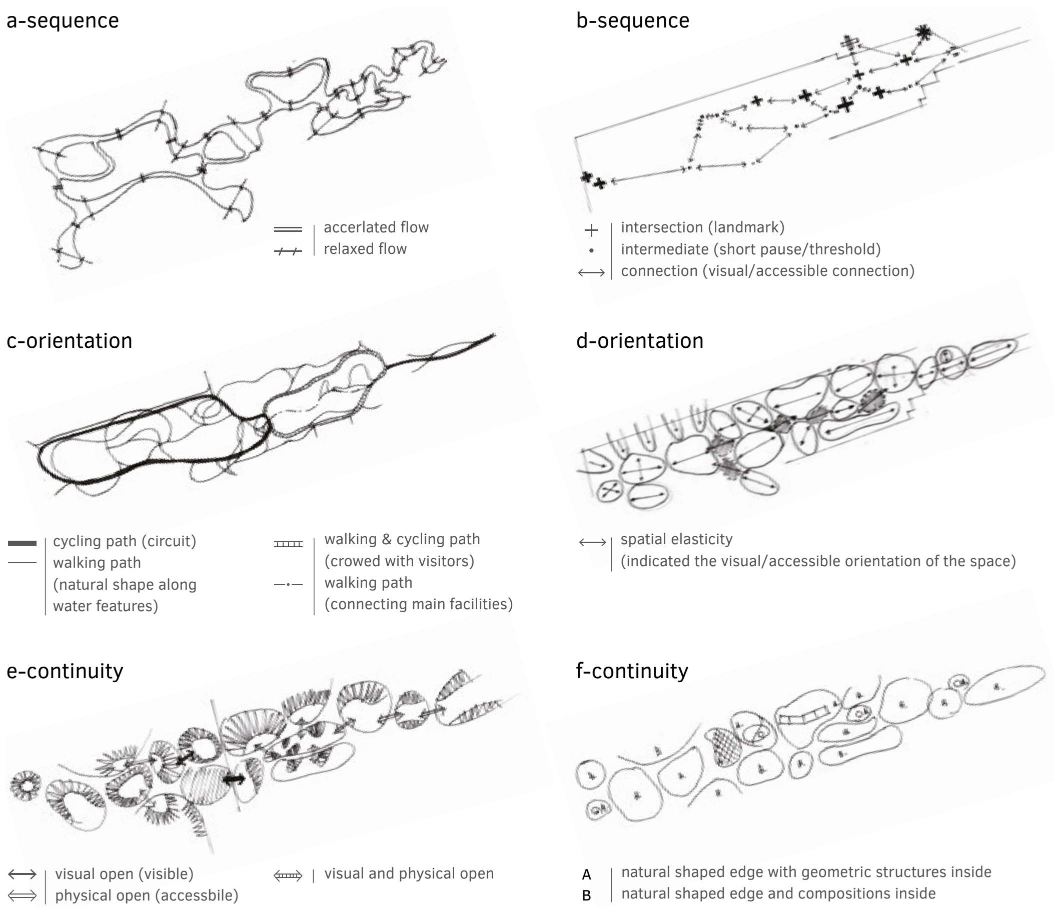


FIG. 3.3 A series of hand-drawn maps employing compartment analysis to describe the spatial-visual organisation of Vondelpark (Field survey, January 2019).

Orientation: Although hand-drawn diagrams help to map the spatial-visual organisation of landscape directly and efficiently, it lacks scientific evidence which can demonstrate findings. In this case, indicators, such as integration and connectivity from space syntax, can provide complementary and verifiable clues in a quantitative manner. To view landscape space as a whole, integration describes the average depth of a space compared to all other spaces. It calculates how close the origin space is to all other spaces and shows its relative position in the open space system. If the origin space is highly integrated with other spaces, it is possible that people will enter and experience that space (Klarqvist, 1993; Montello, 2007). In Figure 3.4, the values of the two entrances along the Van Baerlestraat are the highest, which implies that these spaces have the highest degree of accessibility and connectedness. Important scenic spots and open views of the park

TOC

are located here to draw attention and pull people into the park. In addition, the value of the Stadhouderskade entrance (1.432), in the Northeast, is higher than the Amstelveenseweg entrance (1.323) in the Southwest, which indicates that the direction of flow in the park is more likely to be from Northeast to Southwest.

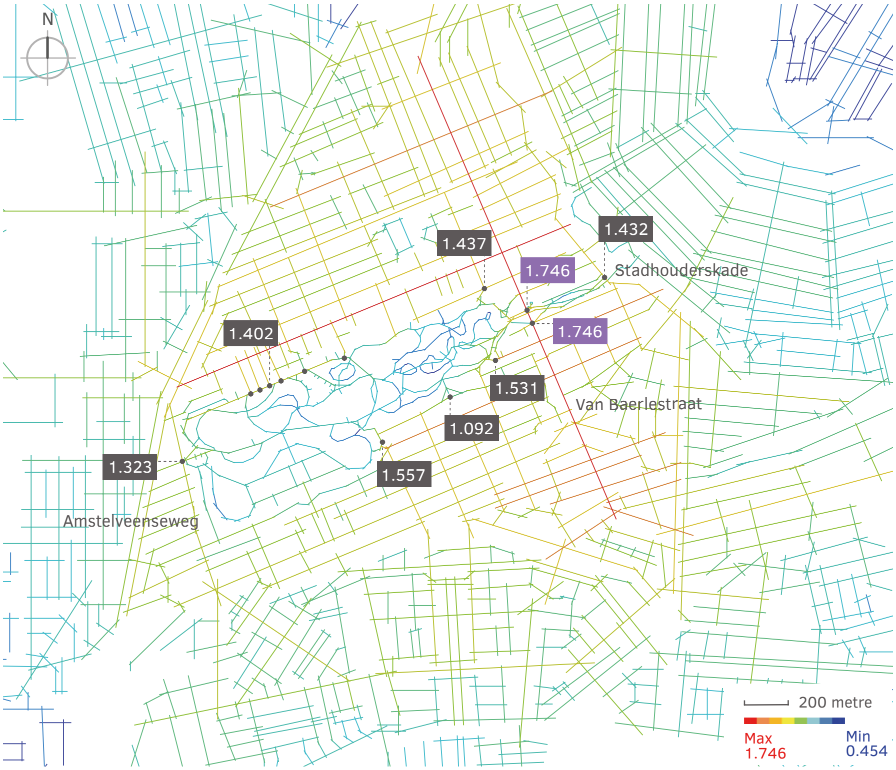


FIG. 3.4 Axial analyses provides a means to understand the movement flow through and in Vondelpark (Axial map based on Open Street Map data, 2019).

Continuity and Complexity: The continuity of spaces can also be analysed using an axial map which helps to evaluate the position of a certain space in the whole spatial system. The red lines in Figure 3.5 indicate paths with a high level of integration. The spaces here are mainly used for service functions connected to key facilities in the park (e.g. monument, pavilion, stage, and cafés). Some segments have a similar integration index (0.730 and 0.732) but represent a different spatial organisation. The north section consists of a dense and visually enclosed edge condition resulting in an enclosed atmosphere, while the diverse and visual open edges of the south section are open and accessible. This contrasting spatial character strengthens the variation in spatial experience.

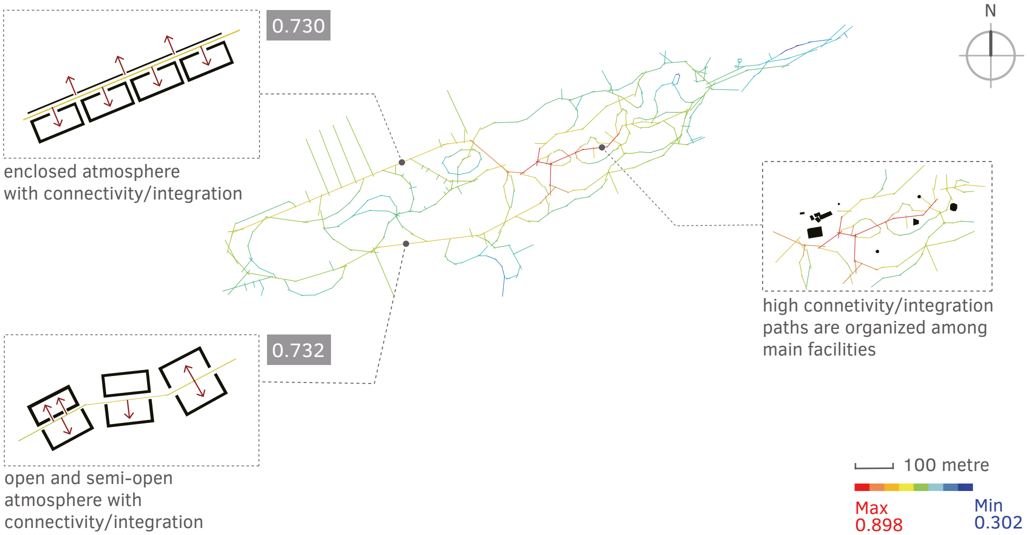


FIG. 3.5 Analysing the visual and spatial composition along the path (Axial map based on Open Street Map data, 2019).

In general, compartment analysis provides important clues for understanding the relationship between space and mass. Traditional descriptive maps drawn by hand are used to present landscape characteristics in relation to the spatial-visual organisations of the landscape. Quantitative mapping methods like space syntax help to understand inner mechanisms in the landscape compositions and configurations, which enables spatial designers to address landscape qualities in a more objective way. Compartment analysis mainly focuses on mapping spatial attributes from a vertical perspective and neglects the visual properties of the landscape from a horizontal perspective.

3.4.2 3D Landscapes

3D landscapes identify landscape spaces from an observer's point of view, utilising three-dimensional visualisations and addresses spatial-visual characteristics from a horizontal perspective. 3D landscapes are often represented with sketches, photographs, photomontages, and virtual landscape techniques, such as landscape modelling, virtual reality, and 3D displays based on GIS (e.g. Ervin, 2001; Punia & Pandey, 2006; Bianchetti, 2017; Lin et al., 2018; Bruns & Chamberlain, 2019). These eye-level landscape evaluation tools not only provide spatial attributes and visual organisations of static landscapes (e.g. Simonds, 1997; Bell, 1999), but can also

TOC

reveal dynamic properties via the movement through landscape and the movement of landscape (Ervin, 2001; Nijhuis, 2015). Serial visions via a series of 3D landscape representations are widely used to show a users' spatial-visual experience within a certain time interval (e.g. Cullen, 1961; Ţălu et al., 2016). While multiple time-sliced snapshots, based on photographs or deductive landscape scenarios, are crucial for exploring the spatial transformation over time or demonstrating a proposed development of landscape space, for example Lewis & Sheppard (2006) and Liu & Schroth (2019). Moreover, 3D landscapes are also often used for visual landscape assessment studies (for elaboration, see Lange, 2001; Tveit et al. 2006; Cureton, 2016; Lindquist et al., 2016; Liu & Schroth, 2019).

Sequence: Cullen (1961) proposes the concept of a serial vision, which is revealed in a series of scenes, jerks, and revelations to present the sequence of space. Figure 3.6 shows eight scenes at equal distance along a primary route in Vondelpark. The analysis reveals that the landscape architect employed a wide variation of spatial-visual features (e.g. permeability of the edge, landmark, orientation of the path) to create a sequential experience that arouses the eye of the visitor and affords continuous movement.

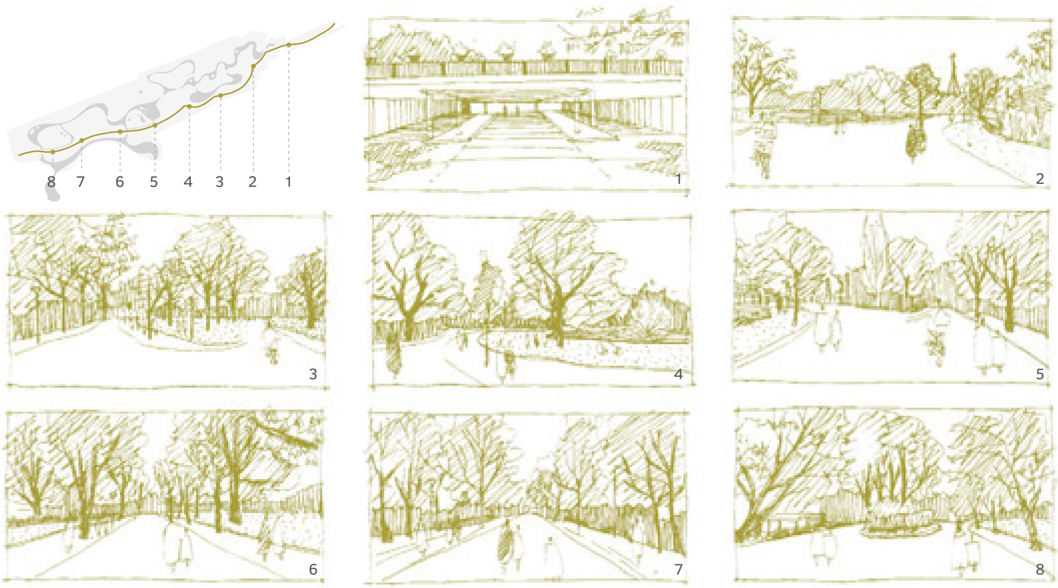
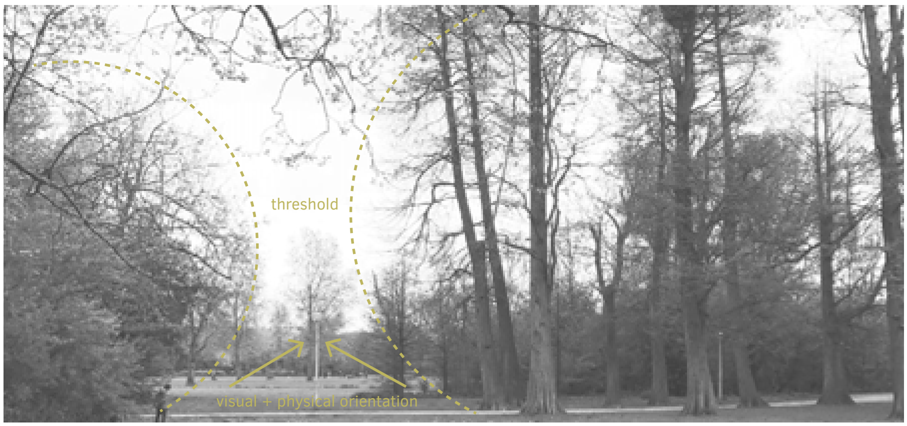


FIG. 3.6 Mapping serial vision analysing a spatial sequence in Vondelpark (Hand drawings in the field, May 2019).

Orientation and continuity: Instead of hand-drawn sketches, photographs are also an effective medium to grasp spatial-visual three-dimensional effects. For example, in Figure 3.7 two vegetation-shaped thresholds within Vondelpark are indicated. The left one is an open gateway affording continuous physical movement, but a fountain in another direction attracts more visual attention and makes the observer pause for a moment. The right scene shows a visual threshold that combines physical and visual directions.

Vegetation shaped threshold affording physical movement, while a foundtain in another direction attracting visual attention



Vegetation shaped threshold providing both visual and physical orientation

FIG. 3.7 Mapping the connection of Vondelpark by photographs and illustration (Photos taken May 2019).

Orientation, Continuity, and Complexity: Architectonic features like bridges, monuments, gateways, or natural elements like a hill or a water feature are an important type of point-reference in landscape spaces that direct the eye of the observer. They are often used to attract attention in order to guide users through the landscape. For instance, a series of landmarks can visually 'pull' the visitor along a route. Once you arrive at a landmark, another one becomes visible and indicates the next destination. Figure 3.8 shows 3D models of crucial architectonic structures in the park, and are grouped by specific categories, which are threshold/gateway, threshold/transition, and landmark/attraction.

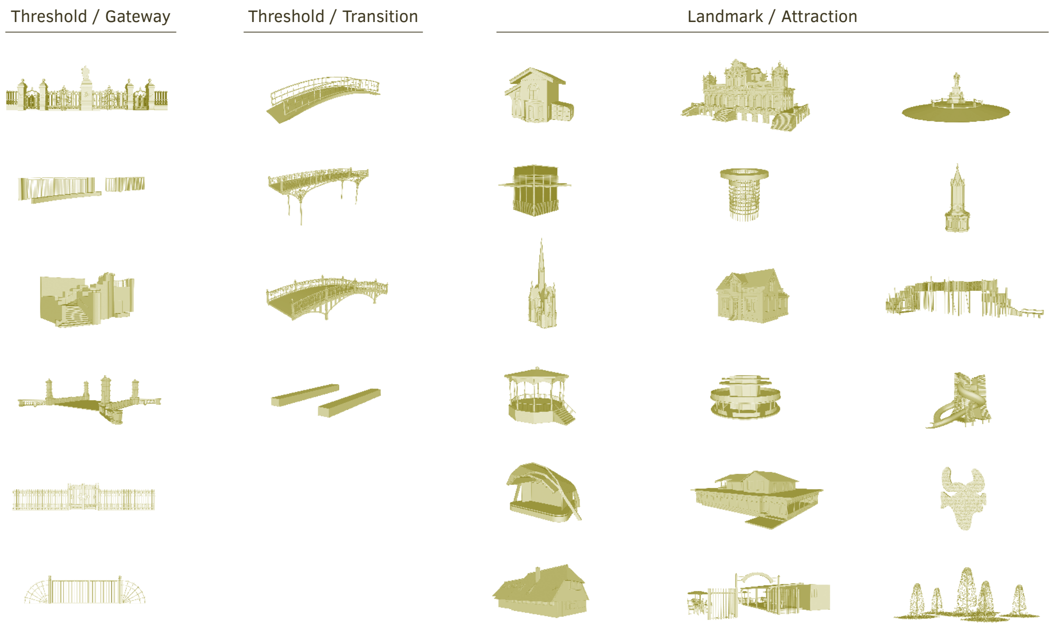


FIG. 3.8 3D models of architectonic elements in Vondelpark with different types of functions.

Compared to compartment analysis, 3D landscapes provide the possibility to address landscape space from a horizontal perspective. Both sketches and advanced visualisation technologies have their advantages and difficulties in analysing spatial-visual aspects of landscape space. For example, while sketches can be made quickly, they often have a subjective connotation; the use of digital technology is time-consuming but is usually regarded to be more objective.

3.4.3 Grid-cell Analysis

In grid-cell analysis, the landscape is analysed by subdividing spatial features into raster cells or grid-shaped polygons. Each feature is described by one or more variables and can be integrated in each cell (Nijhuis et al., 2011). The calculations are often based on selected landscape features derived from digitised historical maps, topographical maps, or orthogonal aerial photographs, or acquired by field surveys. For each grid-cell, variables like the number of patches, patch density, and land type diversity are calculated to show the composition and configuration of landscapes (e.g. Dijkstra & van Lith-Kranendonk, 2000; van Eetvelde & Antrop, 2009; Stokes & Seto, 2018). In addition, video and photographs can be used to compute landscape characteristics via coding landscape objects in scenes and panoramas (for example see, Palmer & Lankhorst, 1998; Bishop et al., 2000; Badrinarayanan et al., 2017; Dong, Zhang, & Zhao, 2018).

Sequence: SegNet is a scene analysis tool that uses pixel-wise semantic segmentation and can be a useful tool to interpret spatial-visual landscape characteristics. It was developed to model the appearance of architectonic structures, and to understand the spatial-relationship within images (Badrinarayanan et al., 2017). Through deep learning, SegNet provides accurate encoding and decoding for multi-class landscape scenes. It identifies different landscape elements by colours, and automatically performs a composition analysis (Figure 3.9). Here, SegNet is used to map sequential experiences based on the degree of openness. Landscape photographs are collected from 20 viewpoints along Path 1 with 100 metres equidistance. In the analysis of the photographs, landscape components such as trees, buildings, and streetlamps are regarded to be visually enclosed, while elements like water, grassland, sky, road, and pavement, are regarded as visually open. In Figure 3.10, measurements on the proportion of open-enclosed views are visualised and show the degree of openness change along movements. From viewpoint 1 to 7, open and enclosed scenes along the two paths alternate. After that, scenes on Path 1 are more visually enclosed, and the overall trend is relatively stable. Applying the same mapping method on Path 2, scenes appear to be more enclosed, but with sudden changes. For this type of grid-cell analysis via SegNet it is important to mention that how the shorter distance between each viewpoint (the more precise the variation of openness) can be calculated.

Viewpoint 1-21

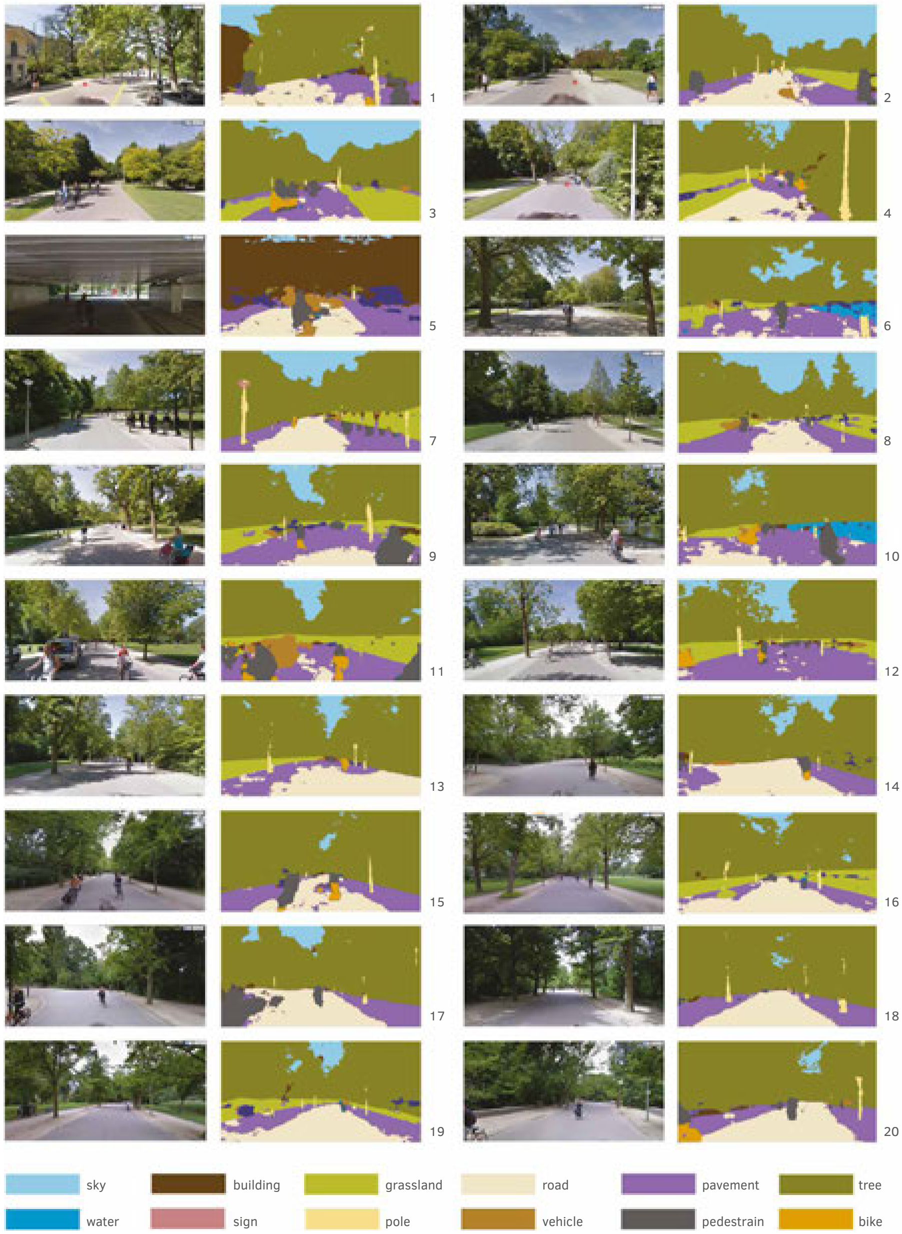


FIG. 3.9 SegNet analysis of 20 Scenes along Path 1 with an equidistance (100m) (Photos derived from Google Maps Street View, February 2019).

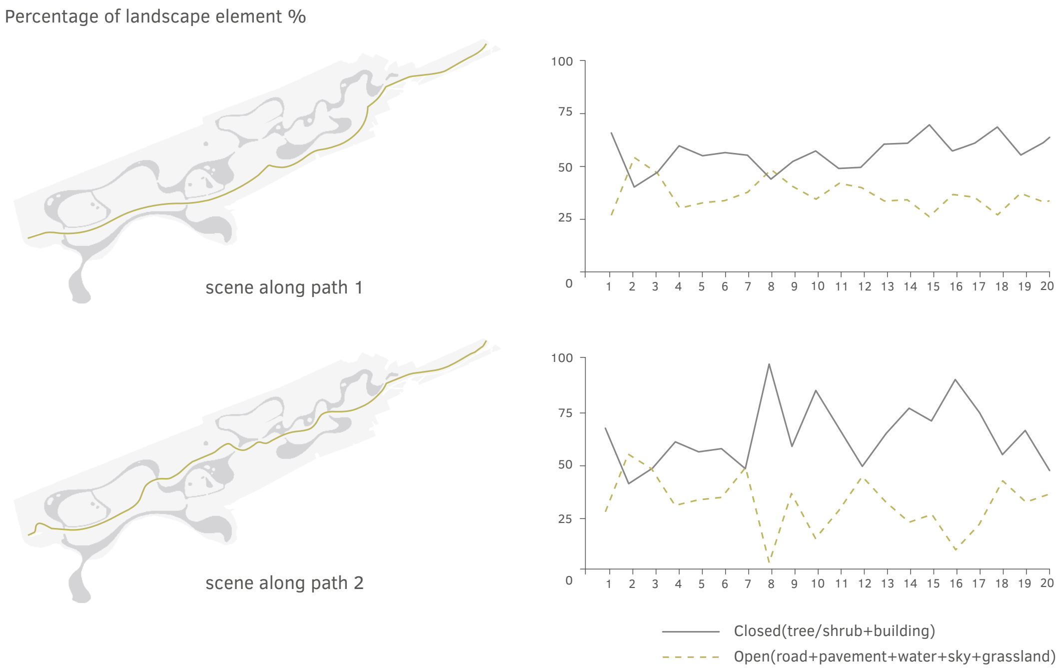


FIG. 3.10 Line charts showing the sequence of scene's degree of openness along Path 1 and Path 2 at eye level based on the SegNet results.

Continuity: Grid-cell analysis can also derive multi-dimensional clues from a vertical perspective. For instance, Robinson (2004) defines the permeability of an enclosure and states that every scene can be characterised by a visual and a physical enclosure. Edges of a space above eye-level with solid structures are perceived as visually enclosed. Open or low edges are visually open. Edges that stop movement via structures (e.g. big shrubs, ground cover) at/above knee height are regarded as physically enclosed, otherwise physically open. Figure 3.11 shows visually and physically open viewpoints along the path system in Vondelpark and calculates point density based on a grid-cell analysis through ArcGIS. Merging the two layers, a map is drawn showing the permeability of an enclosure, which indicates the continuity of space along the route system in the park. It shows that compared with the East, the Western part of the park has hardly any visual and physical connection with the surrounding neighbourhoods, which might reflect the intention of the designer to conceal the boundaries of the park.

FIG. 3.11 GIS-based analysis of visual and physical densities of spatial thresholds indicating the continuity of space in Vondelpark in 2019.

The grid-cell analysis can be helpful to analyse spatial-visual characteristics from both vertical and horizontal perspectives, while combining qualitative and quantitative approaches. Different forms of data and sources, such as photography and fieldwork, can be employed for measurements that enable more objective knowledge acquisition and communication.

3.4.4 Visibility Analysis

Visibility analysis is basically a three-dimensional calculation based on raster, which shows the geographical area visible from a given position (Nijhuis et al., 2011). From the observer's perspective, it maps all the points within the horizon and excludes the points that are obstructed. It also maps the visibility of features that refers to the area of an object that can be seen (Federal Highway Administration, 1988). This commonly used tool is the GIS-based viewshed analysis in ArcGIS or 3D analyst. Visibility analysis plays a crucial role in exploring visual expression and consequences of landscape architectonic compositions, mainly for assessing landscape characterisation and investigating landscape preference (see, for example, Fisher, 1996; Llobera, 2003; Möller, 2006; Brabyn & Mark, 2011; Krøgli et al., 2015; Cuckovic, 2016; Kamalipour & Dovey, 2019). In addition, as a process of spatial-visual organisation, the landscape alters over various time scales, such as diurnal, seasonal, and geological changes (Nijhuis, 2015). Visibility analysis serves as a potential mapping method is useful to capture these spatial and temporal properties (see examples, Mouflis et al., 2008; Qiu et al., 2011; Crawford et al., 2014).

Nijhuis (2015) proposes the accumulative viewshed analysis as a way to analyse spatial-visual characteristics at eye-level along specific routes. Through people's eyes, each person experiences the environment by a moving sensory system, which refers to a viewers' head and body behaviour (Felleman, 1979). Moving speed, direction, and transportation modes will influence the visibility of spaces (Daniel & Boster, 1976; Sanoff, 1991; Weitkamp, 2010; Nijhuis, 2011). Pedestrian activities can be approximated by a 360 degree horizontal viewing range. The visual angle of walking straightforward or jogging is defined as 124 degrees and cycling is about 60 degrees (Panero & Zelnik, 1979; U.S. Department of Transportation, 2015) (Figure 3.12). Moreover, parameters for controlling the viewshed analysis also includes various factors, such as observation point elevation values, vertical offset (eye level height) and scanning distances (Esri, 2016).

A precise raster Digital Terrain Model (DTM) is constructed as a basis for the GIS-based viewshed analyses as presented in this paper. The DTM is based on the LiDAR scanned Digital Elevation Model (Actueel Hoogtebestand Nederland, accessed June 2018) and complemented with vegetation canopies and buildings derived from detailed field surveys. Two types of vegetation are included, above and below eye-level. Canopies above eye-level without sight block are neglected where only the area and height of trunks are included in the DTM. Vegetation such as shrubs with dense canopies are included as solid mass.

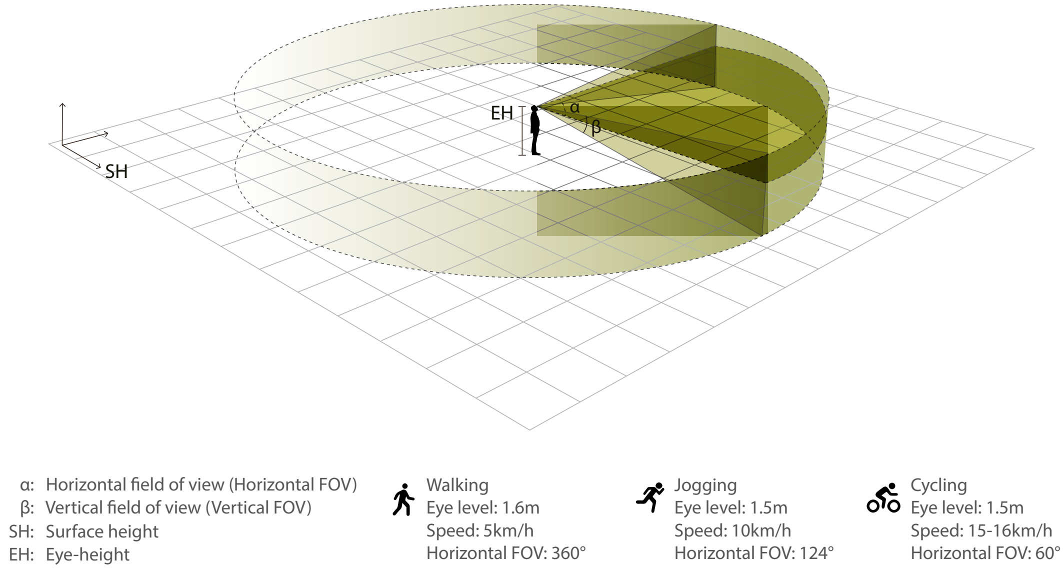


FIG. 3.12 Parameters for controlling the visibility analysis (Data derived from Panero & Zelnik, 1979; U.S. Department of Transportation, 2015).

Orientation: The skeleton of the park is determined by a series of spaces that follow a linear configuration. The path system connects the spaces. Three important routes are used to perform a cumulative visibility analysis. As visible in Figure 3.13, different transportation modes show clear differences in visible space, when the moving speed increases, the visual angle and the visibility diminishes. Directions of movement also influence the visible field. Analysis of Path 1 and Path 2 point out that the route along a Northeast to Southwest direction provides more visible space than the Southwest to Northeast direction. Visible areas along Path 1 from Northeast to Southwest entails 13.72% of the total park area. The Southwest to Northeast direction only accounts for 5.72%. Along Path 3, there is more visible space by moving in a clockwise direction than counterclockwise. The main entrance in the Northeast side of the park, the Stadhouderskade-gate, takes full advantage of this effect, offering a spacious and grandiose glimpse into the park, drawing the attention of pedestrians and pulling them into the park (see also section 4.1).

Path 1

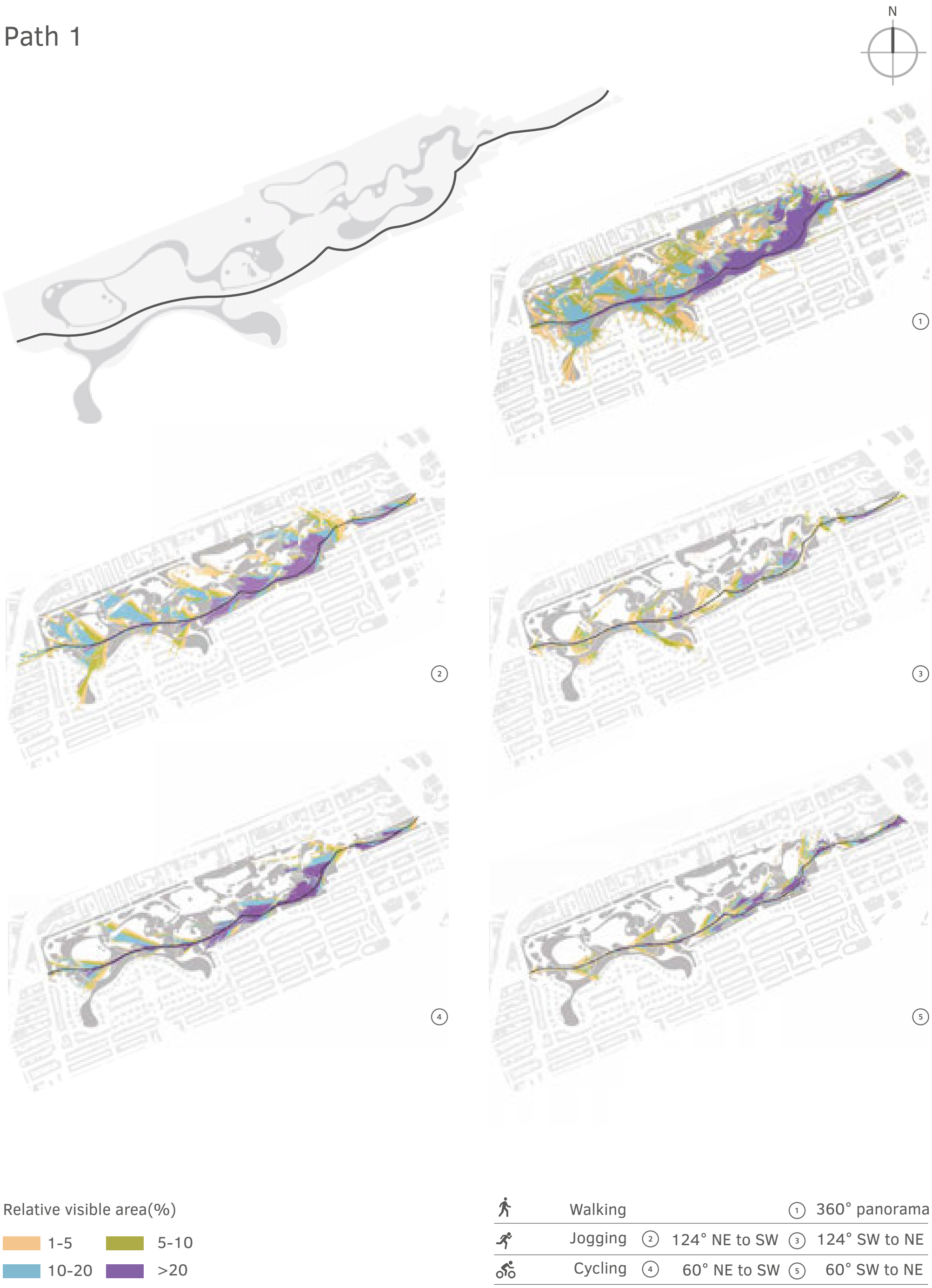
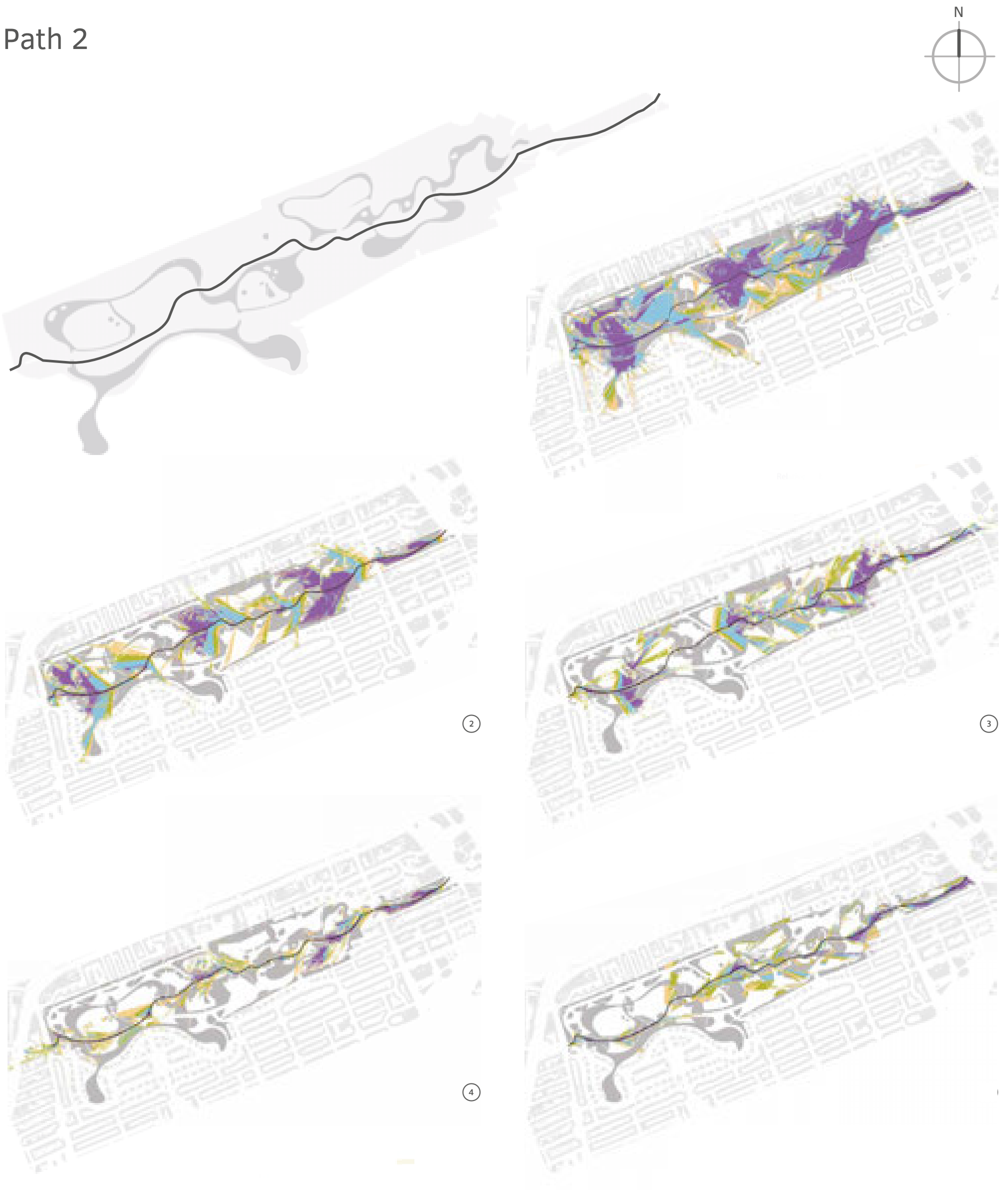


FIG. 3.13 A Visibility analyses of Path 1 simulating different transportation modes, speeds, viewing angles, and directions.

Path 2



Relative visible area(%)

1-5 5-10
10-20 >20

Walking		① 360° panorama	
Jogging	② 124° NE to SW	③ 124° SW to NE	
Cycling	④ 60° NE to SW	⑤ 60° SW to NE	

FIG. 3.13 B Visibility analyses of Path 2 simulating different transportation modes, speeds, viewing angles, and directions.

Path 3

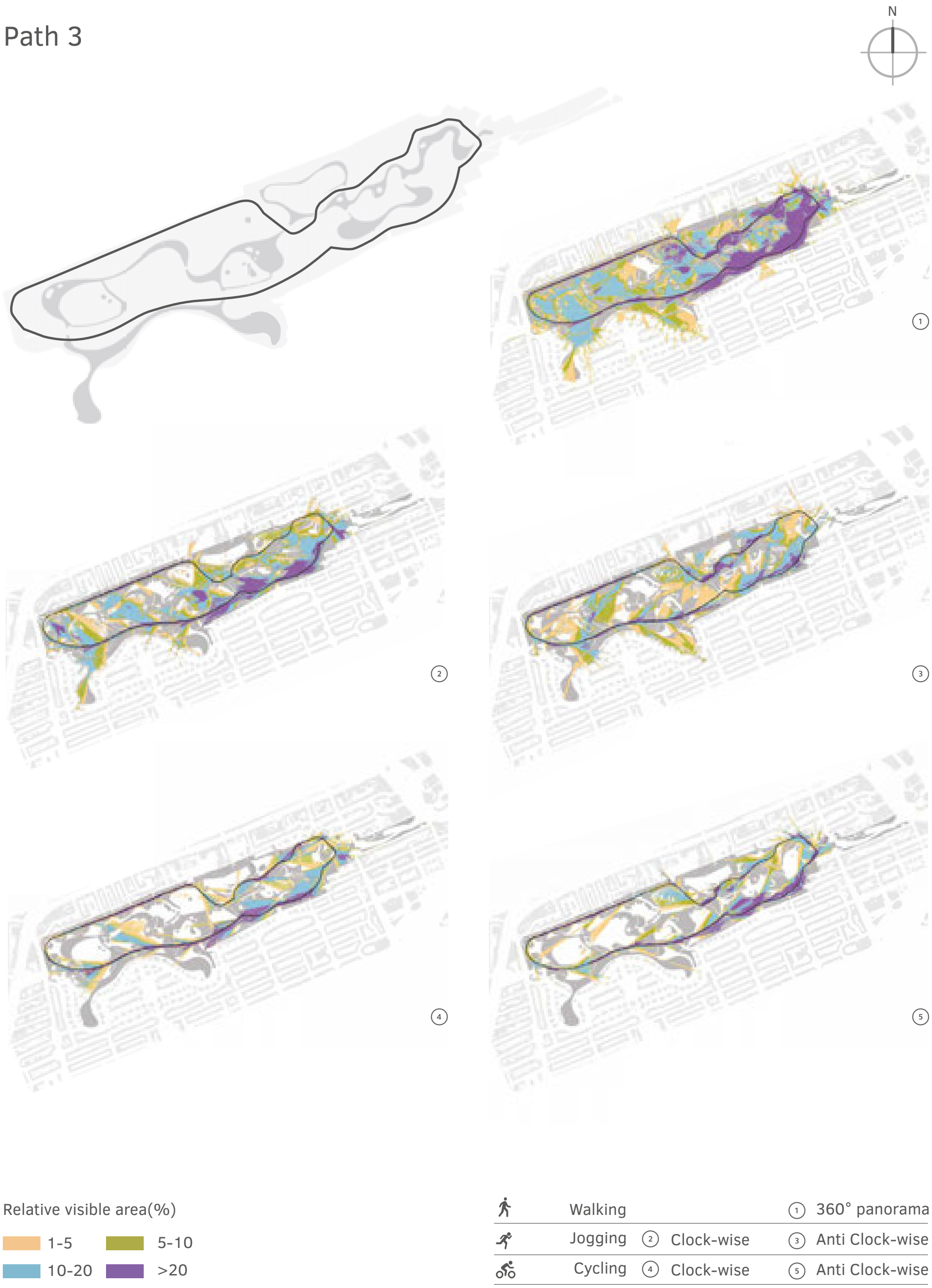


FIG. 3.13 C Visibility analyses of Path 3 simulating different transportation modes, speeds, viewing angles, and directions.

Yahner et al. (1995) argue that the direction of open views can give insight into the sense of spatial-visual orientation. An example is shown in Figure 3.14. Here, the sense of visual orientation by walking or jogging with a 124-degree horizontal vision from the Northeast to the Southeast is evaluated. The spatial structure along the first half of Path 1 can be characterised as a series of open spaces with water features and grasslands along the north side of the route, while the visual orientation of the second half addresses both sides. Path 2 links most of the important facilities in the park (i.e. sculpture, stage, café, and pavilion), and requires good accessibility and visibility. The spatial structure along this path is visually open and the entire route is part of the space it goes through. Path 3 is a circular beltway. The Northeast part of the route has an inward visual orientation. The views look towards open areas with most of the ornamental and functional elements in the park. Due to the tall trees along the Northwest part of the loop, there is tunnel-effect with a clear linear visual guidance.

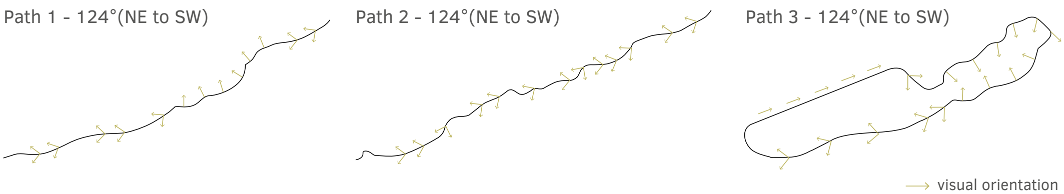


FIG. 3.14 Analysis of the inward-outward visual orientation along the three paths.

In addition to the measurements along paths, a visibility analysis is applied on individual viewpoints to provide insights in their specific spatial function. For example, bridges play an important function in the spatial composition of the park. Four viewpoints were set up on each of the bridges and the visibility analysis reveals a particular spatial principle. When people cross or stand on the bridge, the visual orientation follows the direction of the water which is perpendicular to the orientation of the physical direction of the route across the bridge (Figure 3.15).

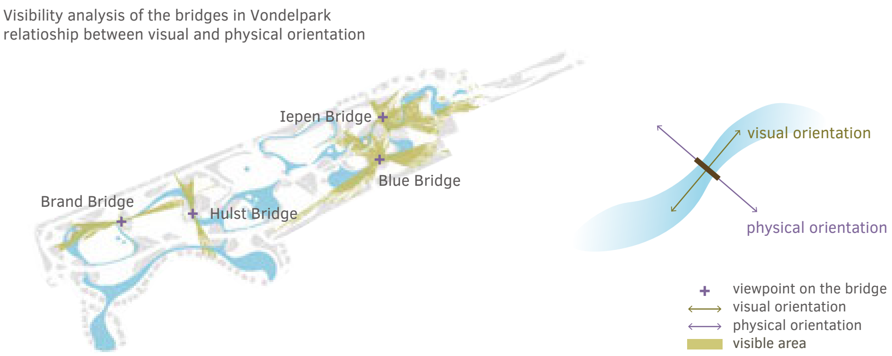


FIG. 3.15 GIS-based visibility analysis showing the relationship between the visual and physical orientation in Vondelpark.

Sequence: The accumulative visibility analysis can also provide insight into the duration of visibility for certain spaces (Figure 3.16). The first half of Path 1 shows relatively open views compared to the other half. Bar charts are used to show changes in duration of the visibility of each viewpoint, which indicates distinct flows of visual enclosure. The perception of sequence along Path 1 changes gradually from open to semi-open, while the sequential experience along Path 2 varies from open/ semi-open to enclosed sharply and repeatedly.

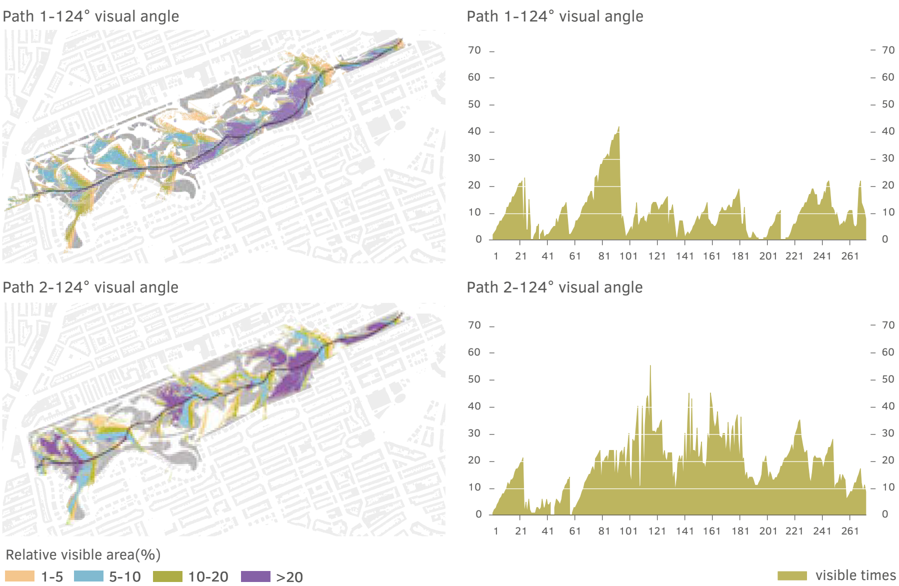


FIG. 3.16 Duration of the visibility of the spaces along paths 1 and 2 from east to west.

TOC

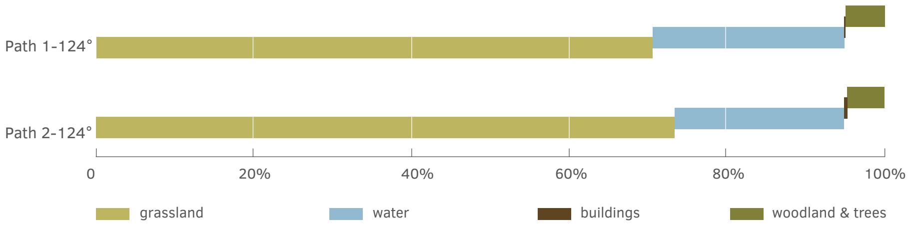


FIG. 3.17 Comparison of visual dominance at eye level from Path 1 and Path 2.

The visibility analysis can also provide insight into the visual dominance of different forms of land-use (Nijhuis, 2015). Along the two paths, grassland and water are visually dominant (Figure 3.17). There are more buildings visible from Path 2 (0.30%) than from Path 1 (0.22%), while the visibility of water from Path 2 (21.65%) is less than from Path 1 (24.31%). To sum up, the visual landscape from Path 2 is more related to architectural features and offers a high degree of variation in openness. Path 1 provides more distinct open views dominated by natural features.

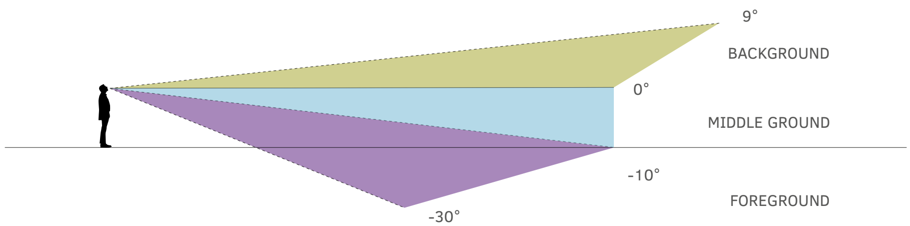


FIG. 3.18 Angles of elevation and sense of visual nearness in an open view (Data adapted from Maertens, 1877; Higuchi, 1988).

As mentioned before, the horizontal visual range corresponds to how much can be seen, while vertical viewing angels are crucial for a sense of distance and appearance of objects in terms of spatial-position relationships (Nijhuis, 2015; Maertens, 1877; Higuchi, 1988) (Figure 3.18). The foreground, middle ground, and background are mainly determined by vertical visual angles and the length of the sightline (Tveit, 2009). Higuchi (1988) proposes that the foreground range from 10 to 30 degrees facing downward. Except when one is standing on a high building or elevation, then the sense of foreground and the middle ground becomes a matter of vertical distance. Views between 0 and 10 degrees below the horizon are defined as middle ground, whereas the area from 0 to 9 degrees facing upward are considered, visually, as the background. People's typical range of sight sits mostly within the middle ground range. Also, the sense of pictorial view (multi-layers of the scene) relates to the distance between the viewpoint and the spatial structures (Lange, 2001), which is elaborated as a background scene (more than 5 km), middle ground scene (between 400 m to ca. 5-8 km), and foreground scene (0 to 500-800 m).

Complexity: Including vertical angles in a visibility analysis demonstrates the complexity of spatial-visual landscape compositions. In an open space, when a viewer looks at a specific object from different locations, this could provide various visual effects and perceptions. For example, a particular statue in Vondelpark (Joost Van Den Vondel) has round-shaped flowerbeds higher than ground level and is one of the most popular foci in the park (Figure 3.19).

FIG. 3.19 Visibility analysis showing the diversity (complexity) of scenes with the composition of different foregrounds, middle grounds, and backgrounds in Vondelpark (Photos collected from Google Maps Street View, February 2019).

When looking at the statue from Viewpoint 1, the foreground has an open and undulating grassland. A church outside the park (Vondelkerk) and the vegetation edges are the background in this scene. In Viewpoint 2, the foreground is determined by grassland and the path itself. Water bodies play an important role as the middle ground reflecting the features from the background. The sculpture, the flowerbeds, and the vegetation skyline are now in the background. This example points out that the position of the observer to the landscape space (and featuring elements) is of crucial importance and that changes in position greatly impact the perception of spatial diversity.

Visibility is an integrated three-dimensional mapping method that considers various relevant factors from an eye-level perspective, in order to extract people's visual perception of the landscape. This measurement can easily show different visual clues of spatial compositions and configurations, such as sequence, visual orientation, and complexity. These are crucial for interpreting and evaluating all kinds of spatial-visual landscape design intentions.

3.4.5 Landscape Metrics

Landscape metrics are important methods for characterising landscape structures (Uuemaa et al., 2009). They were originally developed for the spatial analysis of land-use patches in landscape ecology, in which landscapes are modelled into patches, corridors, matrix and mosaics (Nijhuis, van Lammeren, & van der Hoeven, 2011). Landscape metrics are two-dimensional measurements by raster or vector. Software packages like Fragstats developed by McGarigal & Marks (1995) and GIS-based toolboxes (e.g. Patch Analyst and module Pattern) are widely used to quantify potential metrics for landscape compositions and configurations. Applications in visual landscape research mainly refers to the spatiotemporal aspects of landscape, which discover relationships between landscape metrics and visual landscape perception/preference during landscape change (see examples, Palmer, 2004; Sang et al., 2008; Uuemaa et al., 2009, Lausch et al., 2015; Zhang et al., 2019).

TABLE 3.2 Landscape metrics related to spatial continuity (McGarigal & Marks, 1995).

Indicator	Abb.	Scale	Spatial Description	Formula	Variable
Radius of gyration/ Correlation length	GYRATE	Patch	Elongated and less compact extensive patches have a greater radius of gyration, which indicates the connectivity of space.	GYRATE= $\sum_{r=1}^{z} \frac{h_{ijr}}{z}$	h = distance (m) between cell ijr [located within patch ij] and the centroid of patch ij (the average location), based on cell centre-to-cell centre distance. z = number of cells in patch ij.
Proximity	PROX	Patch	Patches in relation to its neighbours of the same class. The larger the index value, the more contiguous and higher the potential to connect.	PROX= $\sum_{s=1}^{n} \frac{a_{ijs}}{h_{ijs}^2}$	a = area (m^2) of patch ijs within specified neighbourhood (m) of patch ij. h = distance (m) between patch ijs and patch ijs, based on patch edge-to-edge distance, computed from cell centre to cell centre.

Landscape metrics such as Radius of gyration/Correlation length (GYRATE) and Proximity (PROX) (Table 3.2) are regarded as useful to analyse the continuity of landscape space (McGarigal & Marks, 1995). Radius of gyration is a measure of patch environment, presenting how far across the landscape a patch can extend. With this in mind, elongated and less compact extensive patches have a greater radius of gyration, which indicates the connectivity of spaces. In the design context, continuous spaces that are well connected show strong continuity and have a high radius of gyration value. The proximity index quantifies the spatial context of a patch in relation to its neighbours of the same class. A larger proximity index shows compacted groups of spaces, which have the potential to connect to create physical and visual connectivity.

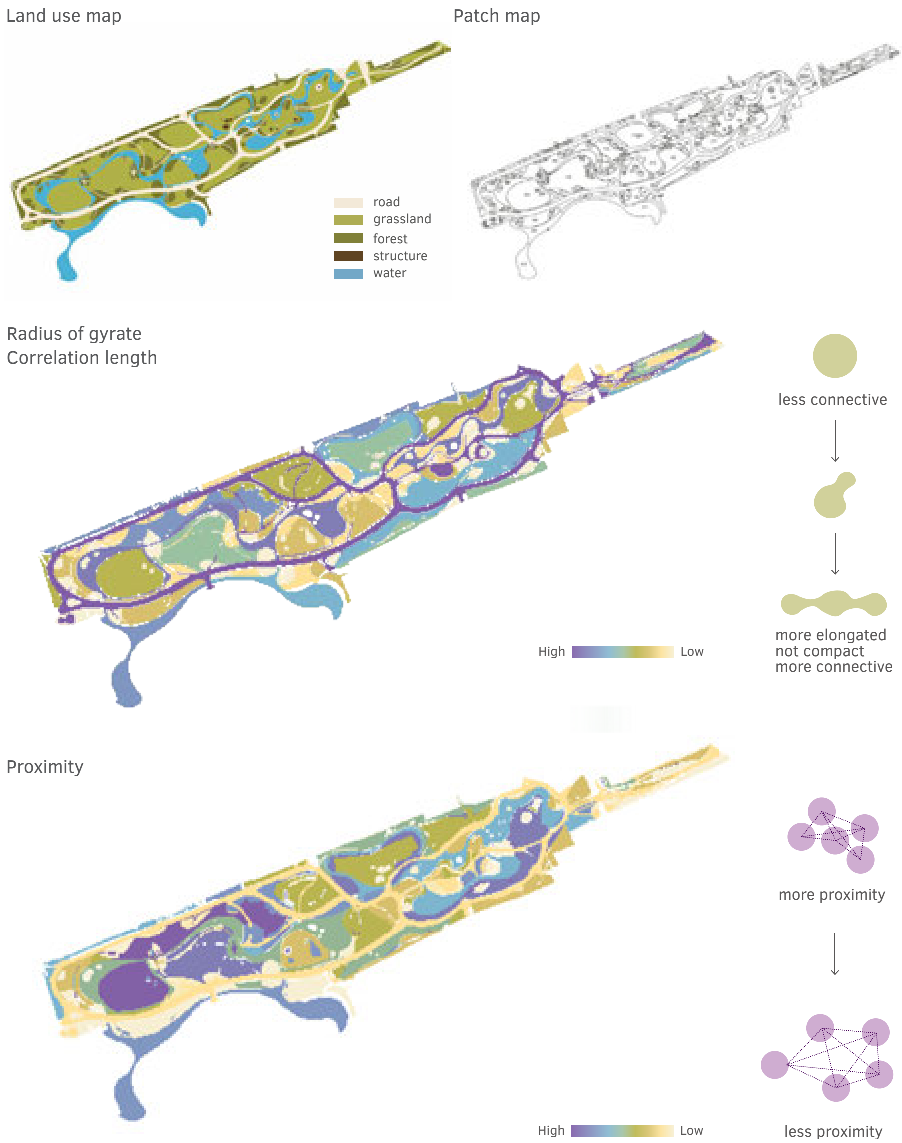


FIG. 3.20 Top: (left) Land-use map; (right) Patch map of Vondelpark; Middle and bottom: Analyses of space using Fragstats indicators: Radius of Gyrate and Proximity at the patch scale.

Continuity: For Vondelpark, landscape metrics are calculated using Fragstats software (McGarigal & Marks, 1995) in combination with GIS (Figure 3.20). For the calculation, the land-use map is transformed into a patch map. The analysis points out that individual, but connected spaces have a high value of radius of gyration, which indicates strong continuity. Compared to compact but discrete spaces, continuous and elongated spaces are more connected. At the same time, the proximity analysis indicates that enclosed spaces have larger values. This means that even though they are not visually connected, they are nearby and closely connected in structural terms. Landscape architects can use these clues as a basis to create continuity, such as providing transitional spaces or thresholds between contiguous spaces.

To summarise, landscape metrics are used here to analyse spatial-visual configurations relevant to spatial design. Indices to analyse patch, class, and landscape elements prove to be useful in analysing and representing specific spatial-visual characteristics of landscapes. As such, landscape metrics offer a means to address specific aspects of landscape space from a vertical perspective and are complementary to the other discussed methods.

3.4.6 Eye-tracking Analysis

Eye-tracking is used to record eye movements and fixations when people are observing scenes. Eye-tracking has been broadly used in visual perception research in the recent years (e.g. Dupont et al., 2017; Junker & Nollen, 2018). Compared to common landscape perception research methods such as in-situ or photograph observations, in combination with questionnaires, or in-depth interviews, eye-tracking analysis measures people's eye behaviours and the observation of landscapes more objectively (Dupont et al., 2014). Stationary eye-tracking within the laboratory is used to assess people's gaze distribution on photographs or videos in order to investigate human's visual engagement and behaviour. While mobile eye-tracking in the real-world provides researchers the potential to explore and understand what people are looking at in real time, and how they interact with the environment when they move freely in the outdoor settings (Uttley et al., 2018; Tobbipro, 2020). Both of them have been widely used in various research fields, such as environmental psychology, landscape or urban research, sports, medicine, and marketing etc. (Simpson et al., 2019). There are two main types of maps that cam potentially be used for indicating people's attention in the landscape, which are heat maps or fixation maps. A heat map (or dynamic heat map video) displays focus points of observation and indicates dominant visual elements in the field. A fixation map (or eye-tracking video) catches and records eye movements which can visualise the visual queue and affordances for wayfinding in a landscape scene (de Lucio et al., 1996; Massaro et al., 2012; Popelka & Brychtova, 2013; Ren & Kang, 2015; Junker & Nollen, 2018; Wissen Hayek et al., 2019).

Complexity and Continuity: In Vondelpark, three of the most important scenes are selected for eye-tracking analysis. The eye-tracking experiment involved a sample of fifteen people that observed photos of the scenes that were displayed at a one-to-one scale display. The results are accumulated and visualised in Figure 3.21. The analyses reveal that monuments, water edges, the church tower, and certain species of trees (different colour or texture) are important visual elements that attract attention. The fixation maps give a more detailed view on the common visual logic of the scenes. The experiment results show that the relatively bright, contrasting, and distinctive elements (e.g. landmark, open space, or specimen trees) raise attention first. Then the eye gradually follows the contour lines of the foreground, middle ground, and background (skyline). To conclude, by having an overview of the landscape, people tend to discover and predict where to go next. The brightest and most distinctive elements in the landscape are considered to be the most visually attractive, hence their potential to facilitate orientation and afford further action.

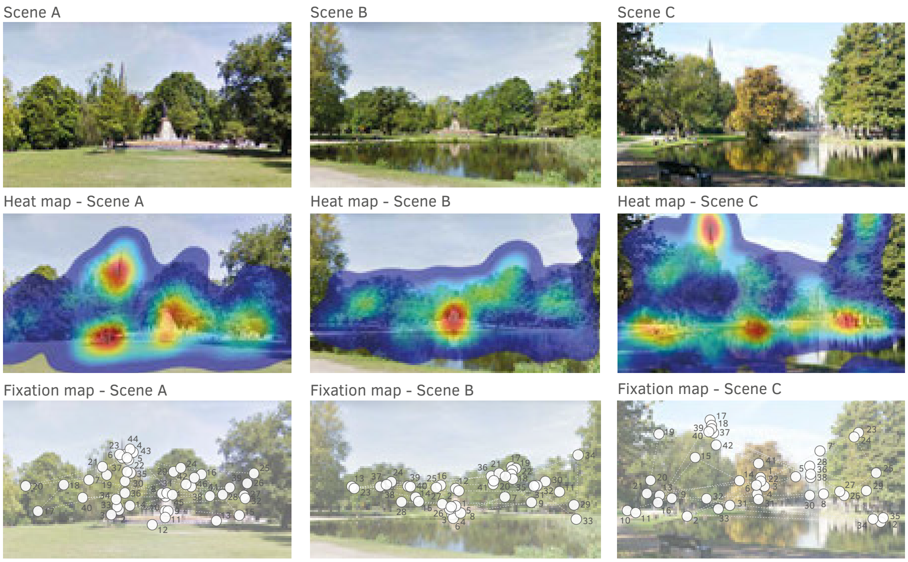


FIG. 3.21 Eye-tracking results visualised as heat and fixation maps for the analyses of static scenes (Photos collected from Google Maps Street View, March 2019).

Serial vision
along the Path 1 in the current Vondelpark

Heat map from the eye-tracking analysis
indicating visual dominance
elements and compositions

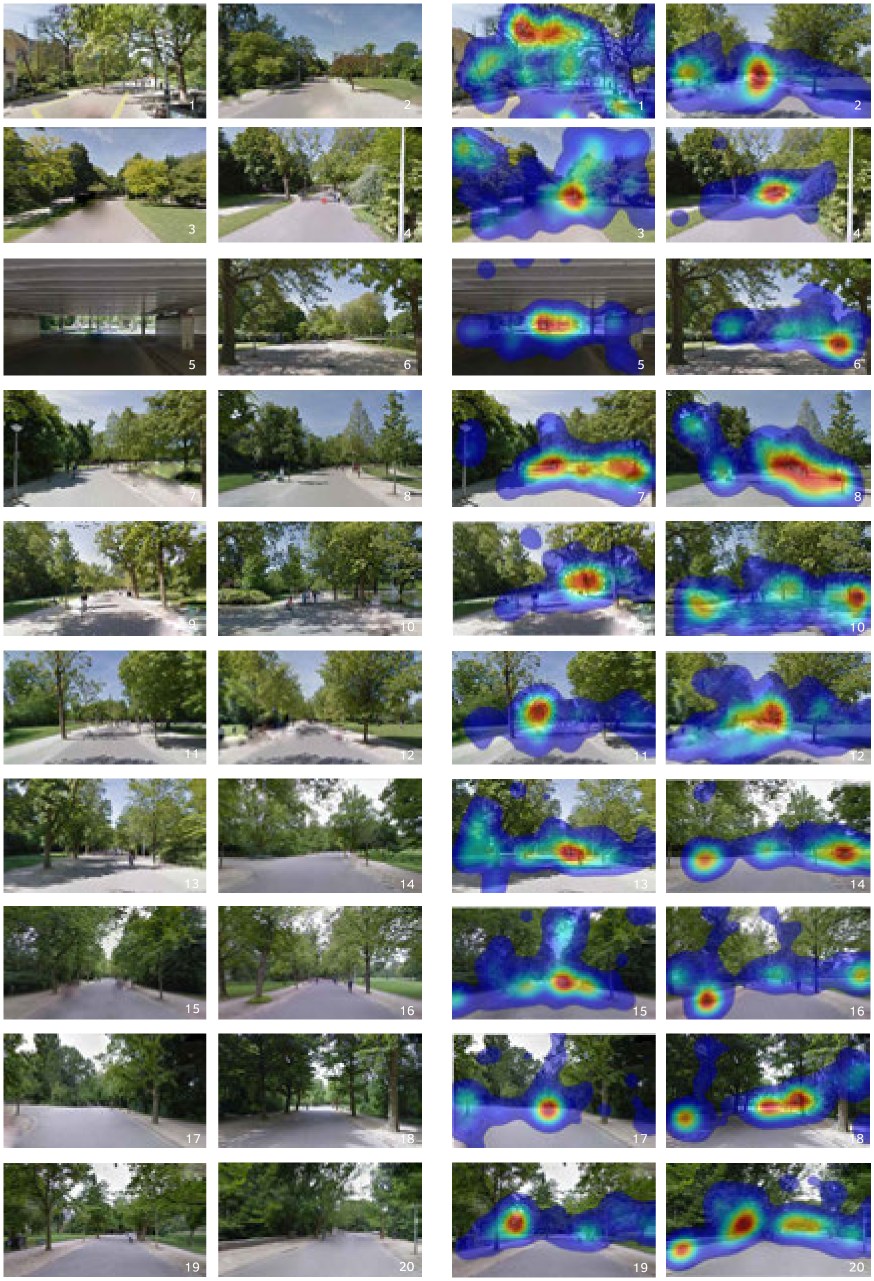


FIG. 3.22 Eye-tracking analysis of the spatial sequence along Path 1 in Vondelpark, accumulated results visualised as heat maps (right) (Photos collected from Google Maps Street View, March 2019).

Sequence, Complexity, and Orientation: Eye-tracking analysis was also applied to a sequence, a set of eye-level photographs taken at viewpoints with an equal distance of 50 meters along Path 1 (Figure 3.22). The accumulated results shown in the heat maps reveal that elements along the path, like streetlamps, benches, and different textures of vegetation are the main focal points. However, open views with water, grassland etc., and thresholds, such as branches of the path structure, gateways etc., and water features, are visually the most important in the sequences. This is logical because a person's line of vision mainly concentrates on the continuation of the route. Also, the borders are scanned to provide more information and when there are distinct features like a landform or a different texture in vegetation, the eye fixates a little longer.

Eye-tracking analysis is a powerful mapping method that provides opportunities to understand the correlations between the spatial intentions of the designer (conscious/unconscious) and reception by its users. It helps to reveal the perception of landscape architecture compositions and helps designers to be more conscious about the functioning of space, wayfinding, and affordances.

3.5 Discussion

3.5.1 Mapping Methods for Understanding Spatial-visual Characteristics

As exemplified by this paper, mapping landscape spaces combines landscape architecture concepts, landscape perception approaches, and mapping methods. Applications of different methods enable landscape architects to explore and visualise different spatial-visual characteristics of the designed landscape (Table 3.3). Horizontal three-dimensional mapping methods (i.e. 3D landscapes, visibility analysis, and eye-tracking analysis) provide com plementary interpretations of visual properties to vertically oriented two-dimensional methods (i.e. complement analysis and landscape metrics) which mainly concentrate on spatial attributes. Furthermore, mapping methods based on measurements, such as grid-cell analysis, visibility analysis, landscape metrics, and eye-tracking analysis offer more precise spatial-visual clues of landscape compositions than qualitative conventional mapping methods, like hand-drawn compartment analysis and 3D landscape visualisations. Considering that each mapping method has its own merits, it is crucial to combine horizontal-vertical, qualitative-quantitative methods to gain a more comprehensive understanding of landscape spaces.

TABLE 3.3 The application of mapping different methods and tools on the interpretation of spatial-visual organisation of landscape.

Mapping methods	Spatial-visual characteristics	Mapping tools	QUANT	QUALI	HORI	VERTI
3D landscapes	Sequence: Serial vision	Hand-drawn sketches		○	○	
	Sequence: Proportion of enclosure of a series of scenes	Photographs & SegNet (grid-cell analysis)	○	○	○	
	Orientation: Visual/physical direction	Photographs		○	○	
	Complexity: Shape of space	Photographs		○	○	
	Complexity: Form of architectonic structures	3d models		○	○	
	Complexity: Vertical view angles, the foreground, middle ground, and background of the scenes	ArcGIS (visibility analysis) & Photographs	○	○	○	
Compartment analysis	Sequence: Width variation of the watercourse; Space, foci, threshold, and the corresponding physical/visual relationships	Hand-drawn maps		○		○
	Orientation: Variation of the path shape; elastic direction of spaces	Hand-drawn maps		○		○
	Orientation: Connectivity/integration of paths (urban scale)	Axial maps (space syntax – Depth map)	○			○
	Continuity: Visual/physical openness of edge/space; integration of multiple spaces	Hand-drawn maps		○	○	○
	Continuity: Connectivity/integration of paths (local scale)	Axial maps (space syntax – Depth map)	○	○		○
	Complexity: Shape of the edge/space	Hand-drawn maps		○		○
Grid-cell analysis	Sequence: Proportion of enclosure of a series of scenes	Photographs (3D landscapes) & SegNet	○	○	○	
	Continuity: Density of visual/physical accessible points along path	ArcGIS	○	○	○	○
Visibility analysis	Sequence: Visible times of viewpoints on the path	ArcGIS & Excel	○		○	○
	Orientation: Visual direction	ArcGIS	○	○	○	
	Orientation: Relationship between visual and physical direction	ArcGIS	○		○	
	Complexity: Vertical view angles, the foreground, middle ground, and background of the scenes	ArcGIS & Photographs (3D landscapes)	○	○	○	
Landscape metrics	Continuity: Gyration of radius; proximity (patch scale)	ArcGIS & FRAGSTATS	○			○

>>>

TABLE 3.3 The application of mapping different methods and tools on the interpretation of spatial-visual organisation of landscape.

Mapping methods	Spatial-visual characteristics	Mapping tools	QUANT	QUALI	HORI	VERTI
Eye-tracking analysis	Sequence: Open space (water and grassland), volume (dominant element), and threshold	Eye-tracking software and hardware, photographs	○	○	○	
	Orientation: Open views and thresholds; characteristics of the path	Eye-tracking software and hardware. photographs	○	○	○	
	Continuity: Open/bright points; Visual depth (foreground, middle ground, background)	Eye-tracking software and hardware, photographs	○	○	○	
	Complexity: Dominant elements; visual depth (foreground, middle ground, background)	Eye-tracking software and hardware, photographs	○	○	○	

**QUALI=qualitative; QUANTI=quantitative; HORI=horizontal; VERTI=vertical*

3.5.2 Potential Application

Mapping landscape spaces combines creative and rational analysis methods while synergising with different fields of knowledge. The mapping methods and tools shown in this paper enable landscape architects to understand and visualise landscape space from a horizontal and vertical perspective, which promotes an improved understanding of spatial-visual landscape features in design. There is a vast array of possibilities available to map landscape spaces that can be used in different circumstances.

Compartment analysis can be easily generated through field surveys in order to understand contextual situations in renovation projects, such as the current spatial compositions and organisation, transportation network, and site restrictions etc. It is not only an analysis tool, but can also help designers present spatial layouts intuitively and instantly, and then form design proposals in the design stage. Furthermore, compartment analysis represented by axial maps reveals invisible spatial information from a holistic point of view. It can be used to evaluate and validate the connectivity of the road network and indicate the rationality of the spatial design.

3D landscapes are useful to simulate eye-level visual perspectives to interpret landscape spaces, incorporating different media and tools. Hand-drawn sketches and photographs can be conveniently implemented for site analysis in order to show visual perception of the space. 3D landscape modelling is a strong visualisation tool which can help explore possibilities of the relationship between content and forms through design experiments. Also, 3D visual representations depicting the status quo and landscape scenarios are effective for capturing the spatial and temporal dynamics of a landscape. The synthesised multitude of time-slice snapshots, based on geological and deductive constructional models, could perform changes of landscape patterns and spatial effects over time which is helpful to demonstrate or evaluate design modifications (Nijhuis, 2015).

The grid-cell analysis is suitable for calculating indicators like density and complexity, as well as the proportion of different landscape elements from both a vertical and horizontal perspective. Such interpretation of landscape features could provide further applications in the research of landscape planning issues, EIA, and LCA. Moreover, as developed in this research, the GIS-based mapping approach supports designers to understand spatial connectivity (visual/physical accessibility) of landscape spaces, which can be used during the prophase analysis of the design assignment or can be used to show the spatial effects of certain design schemes. SegNet is specifically used for analysing components of streetscapes. After adapting and applying this method to interpret spatial-visual landscape characteristics, it presents opportunities to express dynamic sequential experiences through movements either in the analytical or evaluation stage.

Visibility analysis can provide both dynamic and static visual information which enables the researcher to calculate either how many spatial elements you can see from a viewpoint or from where in the landscape you can see the viewpoint itself. The improved GIS-based viewshed analysis is to measure visible areas and describe sequential experiences through movements in the landscape, which is valuable to validate the visual performance of design plans. Moreover, considering vertical visual angles, visibility analysis can also be used to interpret static spatial-visual characteristics, such as the pictorial effects of landscape scenes. Moreover, landscape is a living system, in which both natural and artificial elements show distinctive visual phenomenon over time, such as seasonal variation and landscape transformation. Visibility analysis based on adaptable digital terrain models, has the potential to simulate spatial-visual consequences and show a dynamic of change.

Landscape metrics is applicable to calculate and map spatial compositions and configurations from an ecological perspective via a combination of Fragstats and GIS platform. Only land-use data (water, grasslands, roads, structures, forests) need to be considered so as to build up and visualise the relationship between spatial patterns and ecological effects during the design process. To show the transformation dynamics of landscape patterns, landscape metrics is a valuable method and helps to reveal and understand the heterogeneity of landscape compositions over time.

Eye-tracking analysis can be done by viewing photographs, models, or landscape scenes on-site, which aims to reveal how people perceive and observe landscapes. Either when people stop and perceive the landscape statically or move through the landscape, eye-tracking analysis can help capture typical, affordance, interesting, unique spot views, which is an effective mapping method that explores whether subconscious visual behaviours fit descriptive design intentions.

3.5.3 Limitations

In order to understand and communicate about the spatial-visual characteristics of landscape architectonic compositions, mapping methods and tools addressing the arrangement of a variety of structural elements are of fundamental importance for landscape architecture. However, landscape design not only deals with form, but also with functional use and aims to achieve social, cultural, and ecological outcomes (Vroom, 2006). The mapping approaches, as presented, mainly focus on the spatial-visual aspects in designed landscapes, but do not take into consideration the meaning and symbolic or functional aspects of landscape space.

These mapping methods also have limitations in terms of data processing, and the results are dependent on the quality of the data. For instance, even though the Digital Terrain Model is a very precise raster dataset that includes all topographic elements (e.g. landform, built structures, vegetation etc.), it has major restrictions in the visibility analysis from eye-level, especially because it is hard to distinguish if vegetation canopies block sights or not. In that respect, using 3D-point cloud technology provides promising clues to achieve more accurate results. However, 3D-point cloud data processing and analysis requires high levels of processing capacity, which is not always possible in practical terms. The grid-cell analysis produced via the SegNet platform also shows an inexact identification of spatial components from photographs, which causes a certain deviation for further analysis. In addition, the results of the eye-tracking analysis depend on the size of the sample, in this case, only fifteen respondents, which is statistically not significant. The sample size will not only affect the accuracy of the findings, but also have an effect on practical and organisational aspects, like how many eye-tracking devices one needs, processing of huge amounts of data. The next step would also be to include the dynamic aspects of spatial-visual perception using videos instead of static photographs.

3.6 Conclusion

This chapter sought to give an overview of methods used for mapping landscape spaces and their spatial-visual characteristics, which explores combinatory ways for understanding designed landscapes in a more comprehensive and inter-subjective way. Through the pilot study, six mapping approaches (compartment analysis, 3D landscapes, grid-cell analysis, landscape metrics, visibility analysis, and eye-tracking analysis) are used and adapted to describe four spatial-visual organisations (sequence, orientation, continuity, complexity) from both qualitative and quantitative dimensions. The overview showcases mapping methods that have a great potential to become part of the standard toolset available to landscape architects and related disciplines and provides new horizons to interpret landscape space from a designer's perspective.

To sum up, studies on mapping spatial-visual characteristics contribute not only to an increased understanding of landscape space in the framework of design, but also offers clues for the development of the discipline by:

- *Supplementing the body of knowledge of spatial-visual aspects of landscape.* Mapping landscape spaces through advanced methods enables landscape architects to gain insight in the form and functioning of landscape spaces in order to become more conscious about fundamental spatial-visual aspects relevant to landscape design.

- *Developing a toolbox for the interpretation of landscape spaces.* The overview showcases different mapping methods that address landscape space from horizontal and vertical perspectives and that, in combination, offer a wide range of possibilities to explore spatial features and visualise them. Measurements reveal inner mechanisms of spatial relationships and the visual organisation of landscape compositions. The quantitative mapping methods show great potential to understand, describe, and communicate landscape spaces in a more inter-subjective way.

- *Adapting existing theories and techniques to investigate new perspectives for landscape design.* The mapping methods as presented in this chapter integrate knowledge as developed in other fields, such as urban morphology and landscape ecology, and make them operational for landscape design.

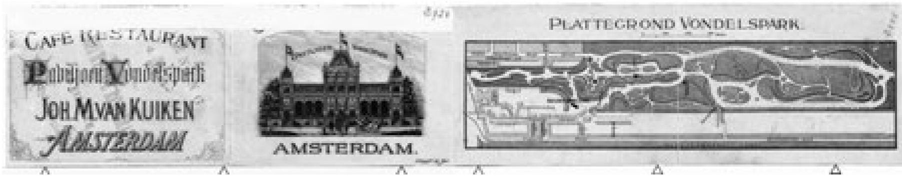
As exemplified by this chapter, there is not one method or tool that can do it all or can be regarded as a panacea. The power is in their combination. Each method has its own strengths and weaknesses and using them together enables researchers and designers to explore different aspects of landscape space in complementary ways. It is not only important to increase awareness on the potential of their use and the multitude of possible applications, but also to train future generations through educational programmes. This will help landscape architects remain at the forefront of landscape development, transformation, and preservation while making use of new technologies, as well as traditional means for knowledge-based design interventions and policy development that take spatial-visual aspects as a starting point.

Paviljoenvijver (Pavilion pond), ca. 1908. Publisher: Rommler & Jonas, Dresden. 4023Pg.
(www.inhetvondelpark.nl / John de Kok / Hans Homburg, 2015)

Pavijoen Vondelpark Met Drinkfontein (Pavijoen Vondelpark With Drinking Fountain). Publisher: Dr. Trenkler Co., Leipzig. 20713. (www.inhetvondelpark.nl / John de Kok / Hans Homburg, 2015)

A threshold and water body in Vondelpark, 1944 ca. (Produced by Begheyn, PTIM; Amsterdam City Archives)

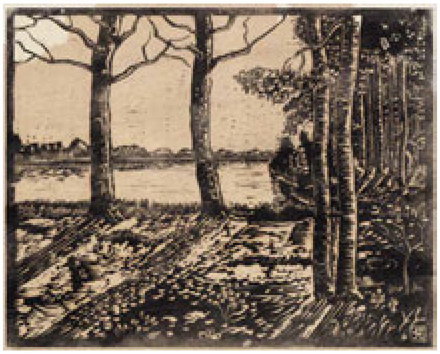
A bridge and bandstand in Vondelpark, 1999. (Produced by Rijn, Ton Van; Amsterdam City Archives)



Front: plan Vondelpark; rear: facade Pavilion in Vondelpark on invitation card, blueprint. (Amsterdam City Archives)

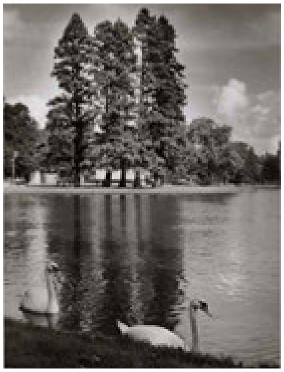
Views of Vondelpark from Vondelbrug; Archives of the Spatial Planning Department. (Amsterdam City Archives)

A water feature of the new Vondelpark, 1868. Produced by Oosterhuis, Pieter. (Amsterdam City Archives)



Trees on the edge of a pond in Vondelpark, linocut, 1880 ca. (Produced by Deventer, JF van; Amsterdam City Archives)

Open air theater in Vondelpark. (Amsterdam City Archives)



Pond of the Vondelpark, 1956. (Archives of the Spatial Planning Department; Amsterdam City Archives)

Views over the water of the pavilion demolished in 1878. (Produced by Oosterhuis, Pieter; Amsterdam City Archives)

Vondelpark, Amsterdam (Photo by Mei Liu, 2020)

4 Designing Landscape Spaces

Implementation of Mapping Spatial-Visual Characteristics in Landscape Design

Part of this chapter is based on a published article:

Liu, M., & Nijhuis, S. (2020), Digital Methods for Mapping Landscape Spaces in Landscape Design. Journal of Digital Landscape Architecture, 5-2020, © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-690-1, ISSN 2367-4253, doi:10.14627/537690065.

In order to break down the barriers of using multidisciplinary mapping technology in the practice of landscape design, it is essential to develop applications that show their potential and added value in a practical design context. Chapter four evaluates the feasibility and effectiveness of spatial-visual mapping methods via two hypothetical design assignments of Vondelpark to show how to apply spatial-visual mapping methods and tools into the landscape design process. An iterative design process is employed to demonstrate the analytical, generative, and evaluative capacities of the mapping toolbox, which will help designers think about and visualise landscape space in a qualitative and quantitative way.

4.1 Introduction

In the field of landscape architecture, landscape design is an essential area of knowledge (Evert et al., 2010). Landscape design is about the construction and articulation of outdoor space and results in landscape architectonic compositions. Landscape architectonic compositions deal with form and meaning and provide a physical, functional, and aesthetically pleasing arrangement of a variety of structural elements to achieve desired social, cultural, and ecological outcomes (Vroom, 2006). Landscape architects have always been eager to develop and employ manual and digital media that can support thinking and communicating about the spatial-visual characteristics of landscape spaces. Despite its importance, there are only a few attempts to implement and develop digital tools that help to understand and describe the visual manifestation of landscape space, how space is organised, and what ordering principles play a role, from both qualitative and quantitative perspectives.

With the growth of visual landscape research and modern technology, more digital ways for understanding and representing landscape space are invented, such as photomontages, computer models, 2D and 3D photorealistic visualisations, and virtual reality (VR) environments (e.g., Cantrell & Michaels, 2010; Cureton, 2016; Walliss & Rahmann, 2016; Bianchetti, 2017; Lin et al., 2018; Bruns & Chamberlain, 2019). They are essential means to present three-dimensional spatial characteristics of the landscape and mimic the existing, or future landscape scenarios in the design process.

Beyond these visual representation tools, there are also some quantitative mapping methods that use algorithms and indicators to gather knowledge of the spatial-visual characteristics of landscape. For example, GIS-based approaches, space syntax, and landscape metrics etc. (e.g. Weitkamp, 2010; Tudor, 2014; Warnock & Griffiths, 2015; Swetnam & Tweed, 2018; Wang, 2019). These methods open alternative ways to understand landscape spaces. However, given the vast range of possibilities, selecting and applying augmented digital methods for thinking about landscape space in the design process remains problematic because the emphasis is often on the digital tools themselves, or on the design process.

This chapter replies to research question 3: How to apply spatial-visual mapping methods in landscape design? It explores advanced methods for mapping landscape space in the design process, as a means for thinking and communicating about the spatial-visual characteristics of landscape. Central to this is a hypothetical design experiment to illustrate practical applications of spatial-visual mapping methods and tools in each stage of landscape design while exploiting their powerful integrating, analytical, and graphical capacities.

4.2 Methods

4.2.1 Research through Design

Design is a core activity of landscape architecture and is also regarded as a research strategy, often referred to as 'research through design' (Deming & Swaffield, 2011; Nijhuis & De Vries, 2020). Research through design enables researchers to explore possibilities in a spatial and design-oriented way and generates specific knowledge for design in the form of guidelines and design principles through design experiments and their evaluation (Nijhuis & De Vries, 2020). Steinitz (1994) identifies six steps typical for the design process. As an essential part of the process of design, mapping media, such as drawings, models, and computational techniques are seen as an indispensable means for understanding landscape space from multiple levels of scale. This research conducts a design experiment while using multiple digital mapping methods and tools for gaining an understanding of landscape space in the design process (Figure 4.1):

- Step 1: Defining the problem, challenge and/or programme;
- Step 2: Understand the context and identify the spatial-visual characteristics which are most likely to be addressed;
- Step 3: Review and extract successful and appropriate design principles as references;
- Step 4: Develop design principles into rational interventions and putting forward the design;
- Step 5: Test and measure the differences which the design/changes might cause. If the results are good, then go to the next step, otherwise back to the design stage;
- Step 6: Go through the above steps iteratively until getting the final design decision.

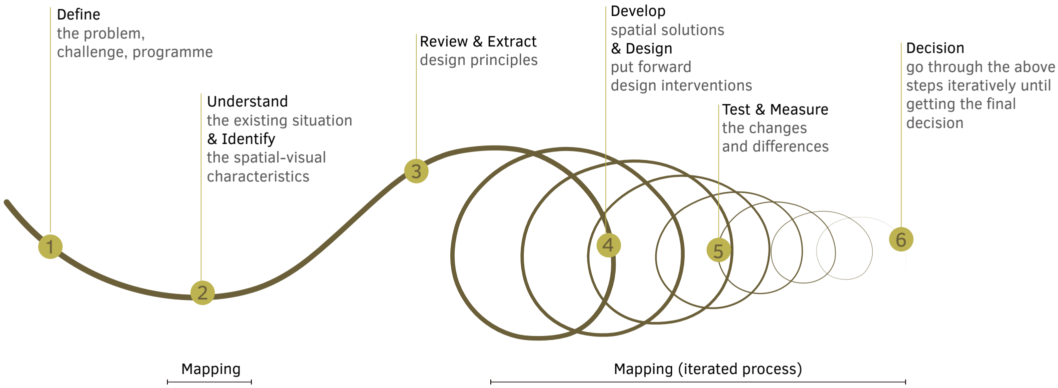


FIG. 4.1 The landscape design process in six steps.

4.2.2 The Hypothetical Design Assignment

In order to showcase the potential of mapping methods in the design process, Vondelpark in Amsterdam is used as an experimentation site. Vondelpark is a public urban park initially designed by the architect Jan David Zocher in 1865. Since 1996 the park has been designated as a National Monument, which nowadays welcomes more than 10 million visitors every year. Vondelpark effectively employs design principles of English landscape gardens, such as the concealment of boundaries, the illusion of endless water bodies, spatial sequences, and continuous views (Pevsner, 1956; Hirschfeld, 2001; Steenbergen & Reh, 2003, 2011). Thus, Vondelpark is a vital learning case for spatial-visual-oriented landscape design. Moreover, all relevant geo-data and topographic datasets of the park are available as a basis for the construction of the Digital Landscape Model (DLM) of Vondelpark (and its hypothetical changes) that serves as a basis for the computational analysis.

As cultural heritage, Vondelpark suffers from problems related to climate change and the popularity of the park. Four main spatial challenges urgently need to be addressed. These are: A) ever-increasing subsidence of the ground surface by drainage; B) increasing flood risk by heavy rainstorms; C) lack of visual connectivity with the surrounding neighbourhoods; and D) overcrowding and traversing cyclists. These challenges are addressed in a hypothetical design exercise which is used to display the potential of advanced mapping methods and tools in the design process. The main constraints of the design assignment are to maintain and emphasize the spatial-visual character and organisation of the park.

4.3 Results

4.3.1 Spatial-visual Design Solution

In Amsterdam, changing lifestyles, growth, overcrowding, and climate change call for new approaches to green space in the city. As Vondelpark is the most popular urban park in Amsterdam, arguably in the Netherlands, it also faces these problems. Together, with previous studies on mapping the spatial-visual characteristics of the current state of Vondelpark, for its preservation and renovation, some issues must be addressed:

A **Considering the ever-increasing subsidence issue in Amsterdam**
Vondelpark is located in the Southwest part of Amsterdam, where there is a low area covered with peaty soil. The ground level in Vondelpark is declining due to the subsidence of the substrate. In the summer, it can subside quickly because the peat becomes dry which causes oxidation of the soil. Thus, flooding is a persistent problem in Vondelpark.

B **Dealing with climate change (flood risk)**
Subsidence is not the only reason for flooding in Vondelpark. Concerning climate change, constant rainfall also leads to pluvial (rain-related) flooding in urban green space. Also, due to the limited infiltration of rainwater and intensive use of the park, the growing conditions of many trees and lawns in the park are not optimal.

C **Lack of connection between Vondelpark and the neighbourhoods**
According to the previous analysis of Vondelpark, its current spatial-visual organisation lacks a connection in the north-south direction. There are adequate entrances along the north and south sides of the park but untrimmed vegetation blocks views and accessibility.

D **Capacity difficulties and safety problems caused by an increasing number of users**
Vondelpark is the most famous urban green space in Amsterdam, where people like walking, jogging, cycling, and doing different activities. However, the number of people visiting parks has intensively increased in the recent years. Safety problems caused by the mix between bikes and people cannot be neglected.

To deal with these challenges, lessons from successful projects and relevant research findings are reviewed and learnt. For each aim, there are design principles that can be extracted as references for the renewal and transformation of the landscape (Table 4.1).

TABLE 4.1 Spatial-visual design principles for the challenges in Vondelpark.

Program/Need/ Challenge	Design principles (spatial-visual related solutions)
A Ever-increasing subsidence	Creating landforms;
	Replacing the vegetation type (e.g. wet forest etc.)
B Flood risk	Expanding the water areas, for example creating more ponds, expanding the size of watercourses;
	Creating new structures to collect and store water;
	Flexible sunken open spaces (grasslands).
C Lack of connections	Creating passable routes and vistas;
	Combining more integrated space with specific direction.
D Capacity difficulties and safety problems	Separating the bike routes;
	Expanding more open spaces for example by cutting vegetation that blocks sightlines.

4.3.2 Hypothetical Design Assignment 1

4.3.2.1 Maintain the Current Spatial-visual Organisation of Vondelpark

In order to address these challenges, the following interventions are proposed: 1) Create landforms in open spaces to alleviate landscape subsidence (Challenge A); 2) Expand water bodies to increase storage capacity, as well as to enhance the perception of open and closed spaces (Challenge B); 3) Creation of a new retention pond connected to the main water system (Challenge B); 4) Re-establish the visual connection between Vondelpark and neighbourhoods by removing some vegetation to create vistas and accommodate wayfinding (Challenge C);

TOC

5) A new cycle route from north to south as a way to divide pedestrians and cyclists (Challenge D); 6) Open spaces along the cycle path to accommodate the distribution of visitors, but also to improve the perception of safety (Challenge D). Figure 4.2 shows the renovation plan of Vondelpark compared with the original one.

The original plan of Vondelpark

Renovation plan (hypothetical design assignment)

FIG. 4.2 The original plan and the renovation plan of Vondelpark.

4.3.2.2 Mapping Spatial-visual Characteristics of the Space

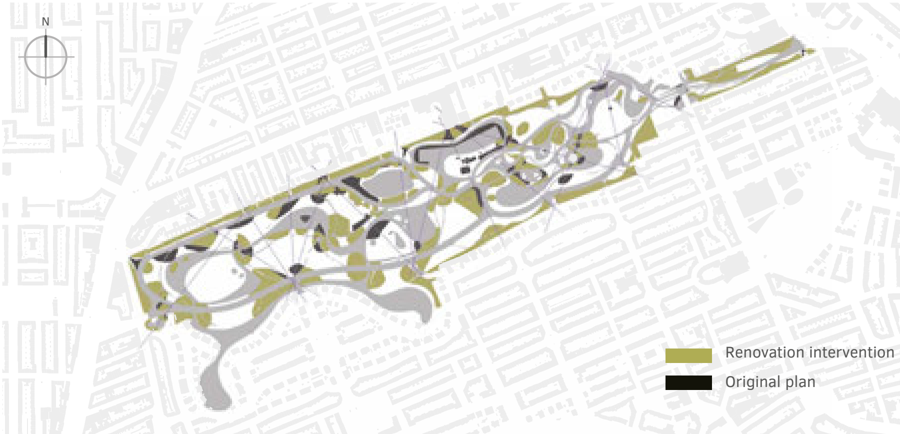
As presented by Figure 4.3 the proposed interventions are translated into a spatial design. In order to identify the spatial-visual consequences of the interventions in Vondelpark, selected mapping methods and tools are employed to analyse, measure, and evaluate spatial properties such us the framing of a view, the construction of a spatial series along a route, making a pictorial landscape composition, and identifying dominant visual landscape elements etc.

Challenge A: subsidence
Saptial-visual solution: creating landforms

Challenge B: flood risk
Spatical-visual solution: expanding water areas

FIG. 4.3 A The renovation plan of Vondelpark following design assignment 1: keep the current spatial-visual situation but address challenges A, B, C, and D.

Challenge C: lack of connection
Spatial-visual solution: opening passable routes and vistas



Challenge D: capacitiy difficulties
Spatial-visual solution: seperating bike routes; creating more open spaces

FIG. 4.3 B The renovation plan of Vondelpark following design assignment 1: keep the current spatial-visual situation but address challenges A, B, C, and D.

Compartment analysis and landscape metrics (Challenge A & B)

To evaluate the impact of topographic changes through the addition of landforms, compartment analysis is applied, which is helpful to represent the relationship between space and mass and concludes with landscape architectonic compositions from a vertical dimension. The new landforms are integrated in the DLM and processed in ArcGIS.

The average height of the new plan's terrain rises from -1.71 to -1.53 metres ASL. Figure 4.4 shows the cross-section elevations of the terrain elevation in the original and renovation situation.

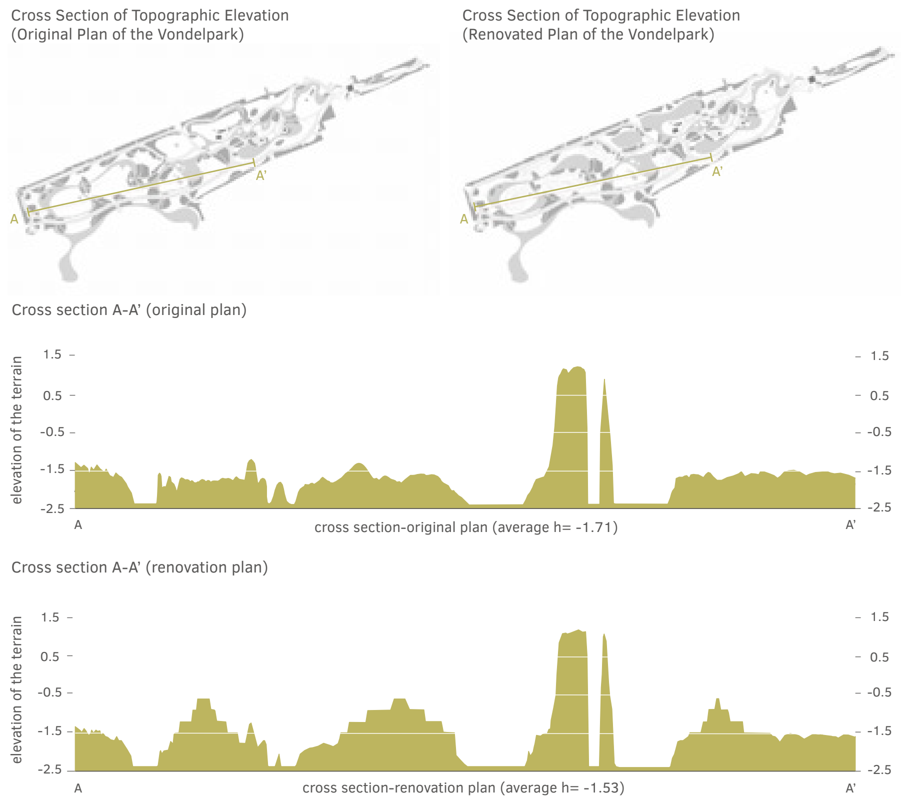


FIG. 4.4 Cross-section elevations A-A' in the original plan and the renovation plan.

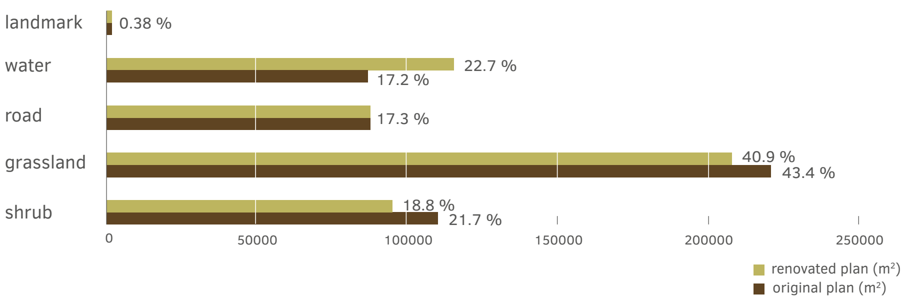
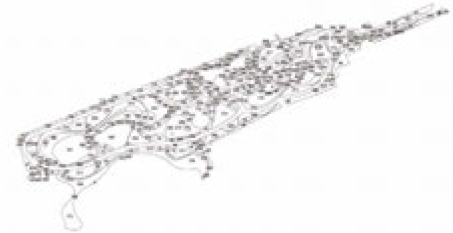


FIG. 4.5 Bar chart comparing the proportion of land-use in the original and renovation situations.

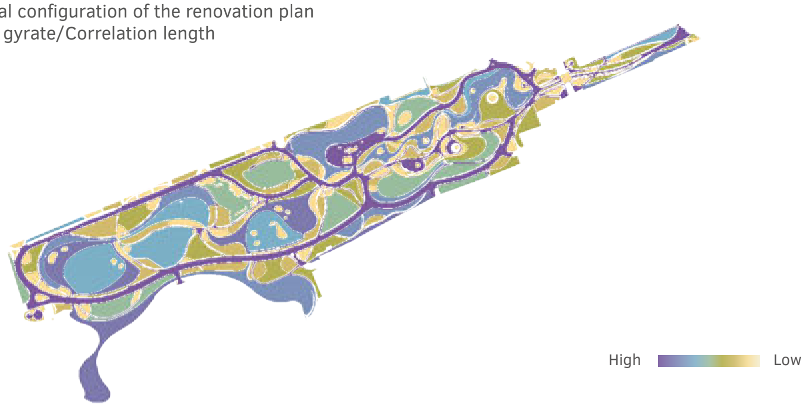
After calculating the proportion of land-use in both plans, surface water in the park increases from 17.2% to 22.7%, which indicates the need for greater rainwater storage capacity (Figure 4.5). In terms of spatial composition, the open-enclosed variation along the water flow is emphasised.

Land use map

Patch map



The spatial configuration of the renovation plan
Radius of gyrate/Correlation length



The spatial configuration of the renovation plan
Proximity

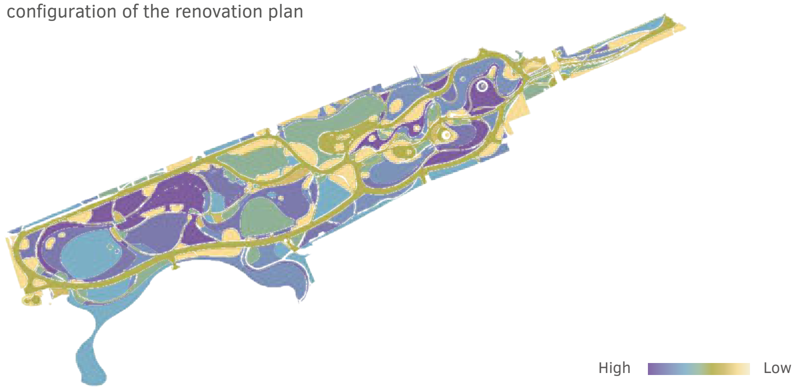


FIG. 4.6 Top: (left) Land-use map; (right) Patch map of Vondelpark; Middle and bottom: Measurement of landscape ecological indicators via Fragstats and ArcGIS, Radius of gyrate and Proximity at the patch scale of the renovation plan of Vondelpark.

To evaluate changes in the spatial pattern, landscape metrics are utilised. Radius of gyration (GYRATE) and Proximity (PROX) (McGarigal & Marks, 1995) are used to provide information on the spatial composition of the park. Fragstats is applied to measure the indicators based on the land-use grid map and transferred to ArcGIS for visualisation. Figure 4.6 shows individual spaces that are connected and demonstrate a significant Radius of gyration value, which indicates visual continuity. Compared to the compact but discrete spaces, continuous and elongated spaces are joined. At the same time, the proximity analysis shows that closed spaces from the same class express larger values. Even though they are not physically connected, they show structural adjacency. Spatial designers can use these clues as a basis to create visual continuity by providing transitional spaces or thresholds between contiguous spaces.

Grid-cell analysis, vertical visibility analysis, and 3D landscapes (Challenge C)

To strengthen visual connections between Vondelpark and its urban context some vegetation is removed (see previous Figure 4.3). Grid-cell analysis is used to evaluate the changes by calculating different spatial properties by means of grid-shaped polygons or raster cells. Spatial features are described by one or more variables for each grid-cell. Permeability is a useful indicator. Robinson (2004) defines the permeability of an enclosure and states that a visual and physical enclosure can characterise every scene. Figure 4.7 shows open viewpoints along the path system and calculates point density based on the grid-cell analysis. Compared with the original situation, the renovation situation shows more integrated connectivity in all directions.

The new vistas improve the complexity/diversity of open views and eye-catching landmarks from different perspectives. Visibility analysis, and 3D landscape visualisation are used to analyse the spatial-visual relationships of the scenery. Altering vertical angles within the visibility analysis help to understand the foreground, middle ground, and background of a scene (Higuchi, 1988). According to Higuchi (1988), the normal sightline of observers is mostly within the middle ground range.

For example, to build up the visual connectivity and strengthen wayfinding, the music hall on the north side of the park is borrowed as a visible and attractive background element of various scenes from different viewpoints. When looking from viewpoints 1 and 3 (Figure 4.8), it is a part of the background, while in the foreground and middle ground, open grasslands and water features prevail. Changing to viewpoints 2 and 4 along the main path, vegetation edges (shrubs and avenue trees) are framing scenes, where the music hall is located at the end of a sightline.

FIG. 4.7 Grid-cell analysis through the use of GIS-based measurements indicating the continuity (visual and physical connections) in Vondelpark.

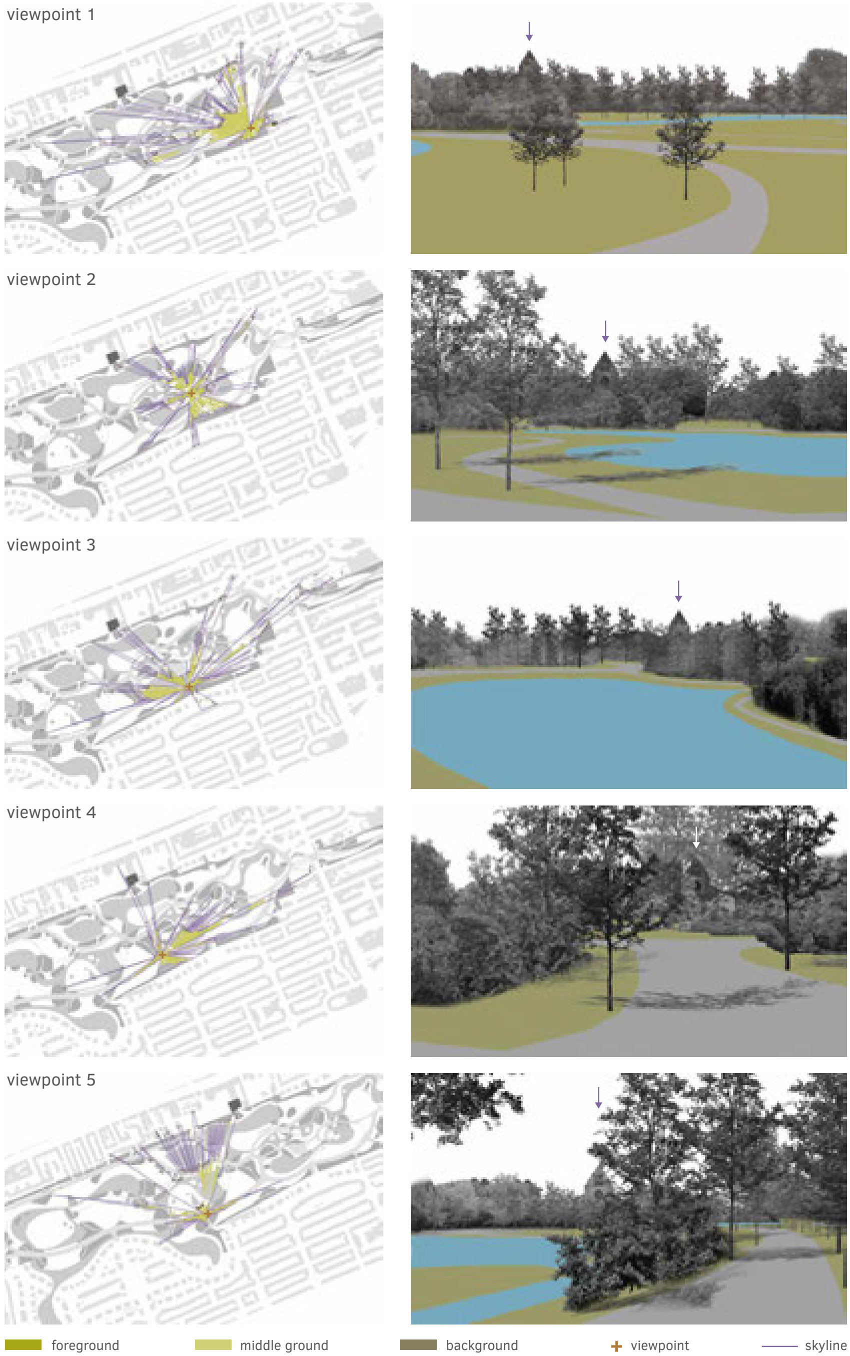


FIG. 4.8 Vertical visibility analysis combined with 3D landscapes to show the complexity/diversity scenes in the renovation plan of Vondelpark.

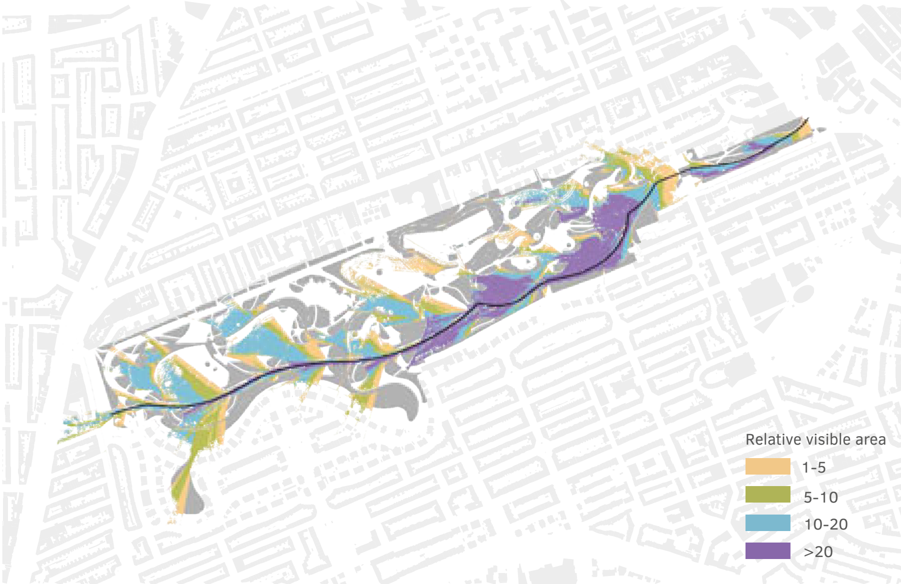
Horizontal visibility analysis and 3D landscapes (Challenge D)

Spatial sequences (e.g. serial vision, alternating enclosures) are an important visual feature of the park and concerns a series of spaces that direct movement and determines the visual experience. To explore the spatial sequence, visibility analysis is employed to show the geographical area visible from different viewpoints along the route. Moving speed, direction, transportation modes will influence the visibility of spaces (Weitkamp, 2010) (Figure 4.9, 4.10, 4.11, 4.12).

Taking Path 1 as an example, Figure 4.9 and the line chart in Figure 4.10 show the visual character of sequential experience, with a horizontal visual angle of 124 degrees, moving forward from east to west. The indicator used here is the amount of overlapping open space seen along the path in the original and renovation situation ('how often is the space seen'). The analysis points out that the spatial sequence remains the same, only with small differences at viewpoints 114, 170-180, and 213. 3D landscapes are used to show the changes from a horizontal point of view. Vegetation is removed to create more open spaces and to reveal the landmarks (e.g., café, pavilion, bridges). Spatial thresholds are created to enforce visual orientation.

The case, as presented, showcases that a combination of different mapping methods, such as grid-cell analysis, eye-tracking analysis and visibility analysis, effectively contribute to a more comprehensive understanding of the restrictions, problems, and potentials of the site from a spatial-visual point of view. They help to understand the landscape space and provide valuable spatial-visual clues for the design stage. Mapping approaches like compartment analysis, landscape metrics, and 3D landscapes, play an important role in evaluating the effects of a renovated spatial-visual organisation in order to explore whether the challenge and/or problem is achieved or not.

Visbility analysis along Path 1 in the original plan of Vondelpark



Visbility analysis along Path 1 in the renovation plan of Vondelpark

FIG. 4.9 Vertical visibility analysis combined with 3D landscapes to show the complexity/diversity scenes in the renovation plan of Vondelpark.

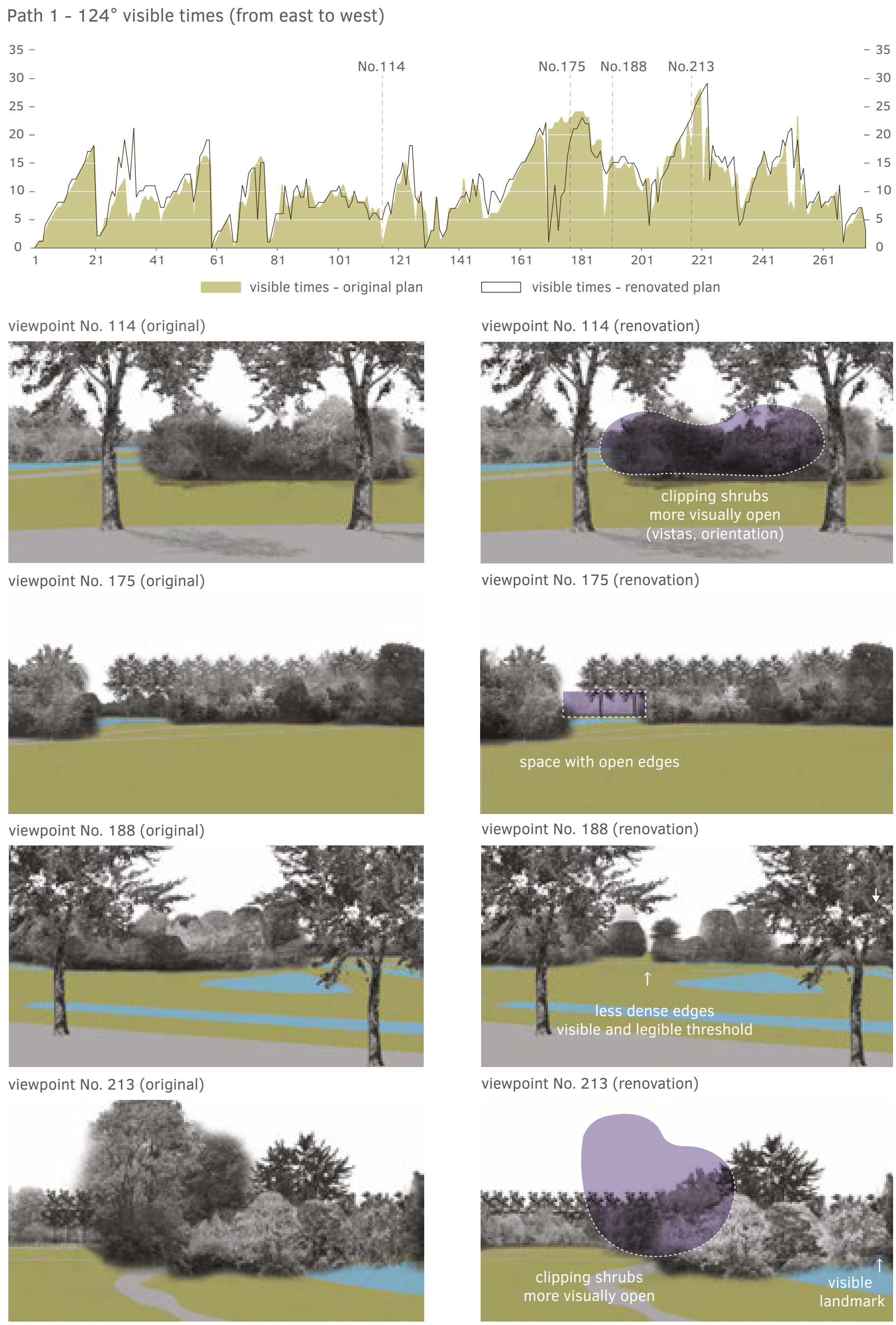


FIG. 4.10 Visibility analysis (line chart) with 3D landscapes showing the sequential experience along the Path 1 in the original plan and renovation plan of Vondelpark.

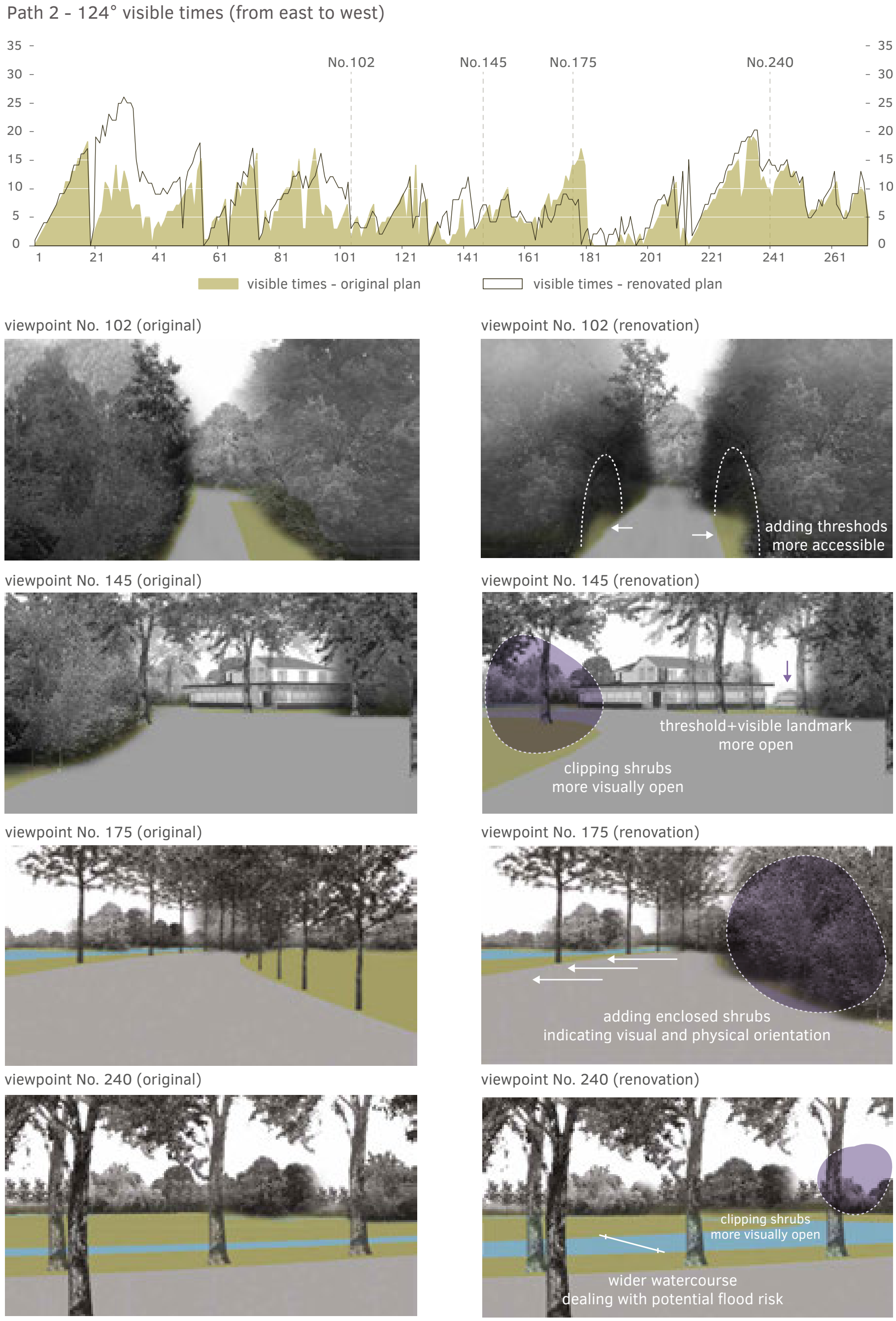


FIG. 4.11 Visibility analysis (line chart) with 3D landscapes showing the sequential experience along the Path 2 in the original plan and renovation plan of Vondelpark.

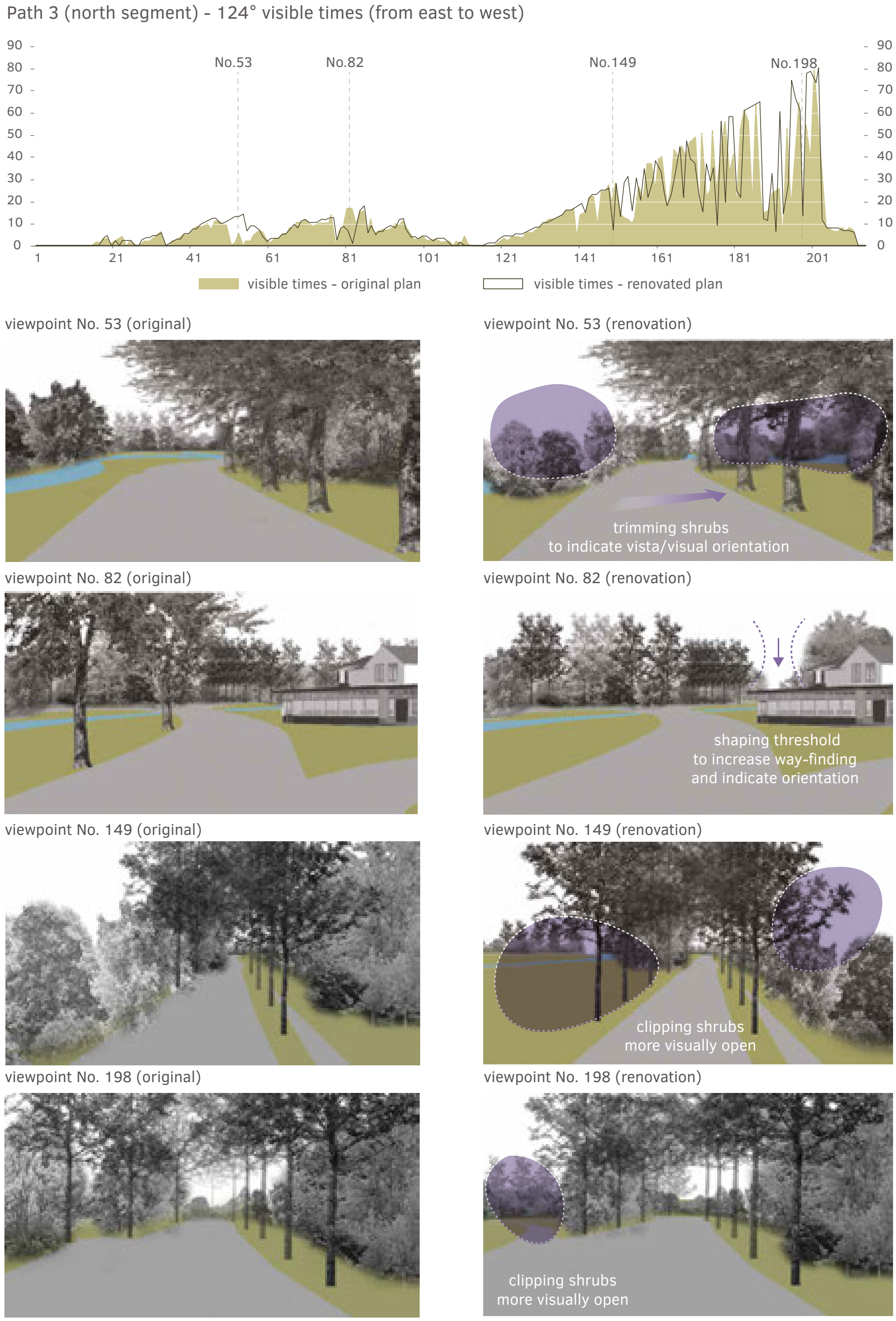


FIG. 4.12 Visibility analysis (line chart) with 3D landscapes showing the sequential experience along the Path 3 in the original plan and renovation plan of Vondelpark.

4.3.3 Hypothetical Design Assignment 2

4.3.3.1 Redesign the Spatial-visual Organisation of Vondelpark

As one of the largest urban open spaces in Amsterdam, the location of Vondelpark plays an important role as the partition between Amsterdam-Zuid and Amsterdam-West neighbourhoods, which, respectively, are the most densely populated and prosperous boroughs in the city. It is also located in proximity to numerous major tourist attractions in Amsterdam, such as the Rijksmuseum, the Van Gogh, and Stedelijk Museum. Thus, there is an enormous pressure on the capacity of the park to contend with the recreational demands of both visitors and locals. Given that Vondelpark is an important urban landscape that must respond to today's contextual requirements, rather than its heritage elements, what spatial-visual organisation could be established and designed here? Responding to the time challenges (Challenge A, B, C, D), some design principles can be devised and adapted into a preliminary design plan with a certain spatial-visual organisation (Figure 4.13 and Figure 4.14).

The plan of a new urban park (at the original site of Vondelpark)

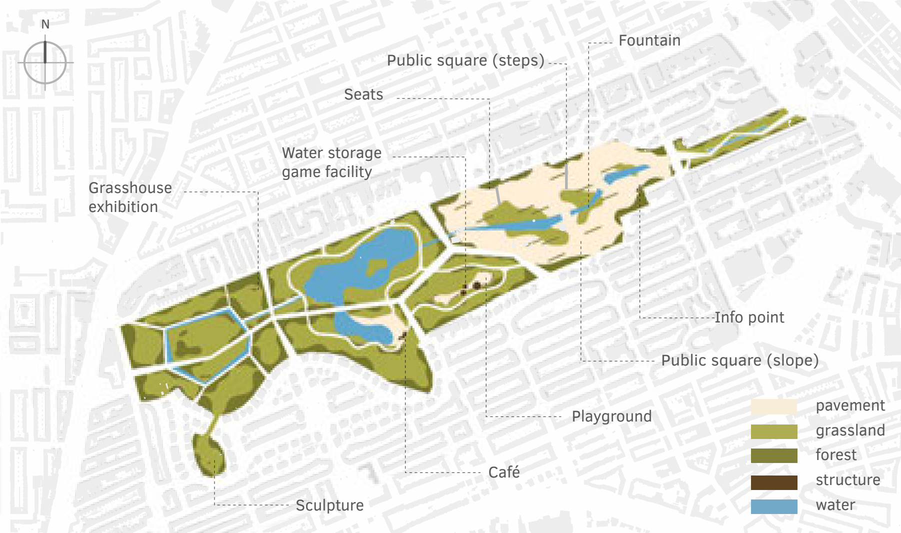
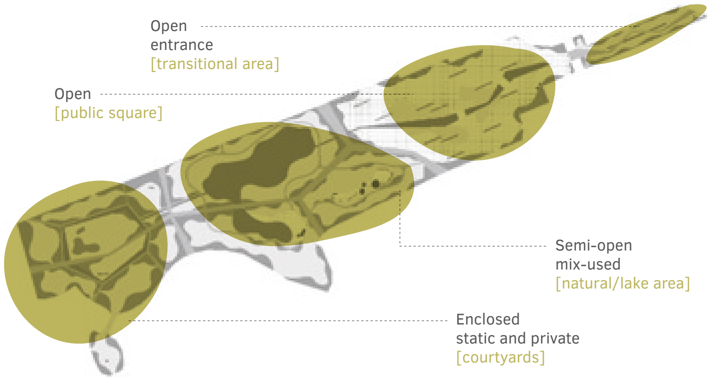


FIG. 4.13 The plan of the redesigned urban park at the original site of Vondelpark.

TOC

Four sections of the redesigned plan



Connections between the park and urban context
(vistas and passable routes)

FIG. 4.14 Schematic diagrams of the redesigned plan of the park (compartment analysis showing four sections and connectivity).

1 To deal with the growing number of visitors and encourage possibilities of activity in the park, four sections of space with different degrees of enclosure are proposed, including *a transitional/entrance area* with linear and open layouts; *a public open square* for potential recreation uses (e.g. gathering, performing, backyard of the adjacent Vondelkerk and the Orgelpark); *a natural/lake area* with semi-open spaces and water features for walking, jogging, dog-walking, café, and playground etc.; *a series of relatively enclosed courtyards* providing a static and private atmosphere. (Challenge D)

2 Open vistas and passable routes are built up to improve the connection between the landscape and surrounding neighbourhoods. (Challenge C)

3 To address the subsidence and maintain the ground water level, landforms and wet forests are designed in the natural segment. (Challenge A)

4 Moreover, permeable paving, bio-swales, and water storage (functioning as recreation facilities in the children's playground) are considered to prevent flood risk caused by heavy rains. (Challenge B)

4.3.3.2 Mapping Spatial-visual Characteristics of the Space

Compartment analysis, grid-cell analysis (Challenge A and B)

To manifest the spatial-visual organisation adapted from a variety of design principles, such as the creation of landforms and wet forests to deal with increasing subsidence, compartment analysis can be easily applied to show the section elevation of the park. As Figure 4.15 demonstrates, landforms are designed throughout segments of the landscape in order to create a resilient surface level. According to the redesigned DEM processed in ArcGIS, the average height of the terrain is -1.50m, which is higher than the current situation (-1.71m). Together with water tolerant species specifically chosen for maintaining the ground water level (e.g. *Quercus nigra, Salix babylonica, Euonymus europaeus*), the subsidence problem would be well managed.

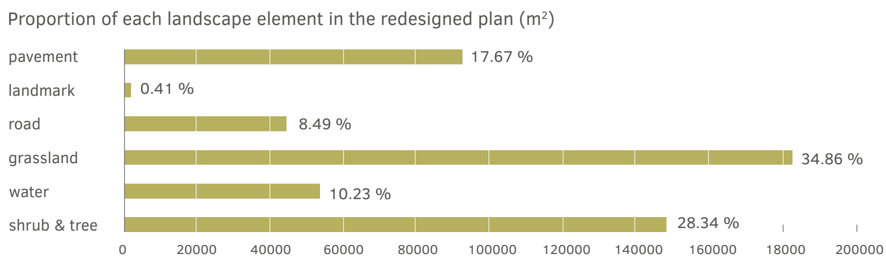


FIG. 4.15 Bar chart showing the proportion of land-use in the redesigned plan of the landscape.

Moreover, in order to slow, collect, infiltrate, and filter storm water caused by heavy rainfalls, landscape features such as permeable pavements, bio-swales, and sinking grasslands are proposed in the redesigned plan of the landscape According to the new spatial composition and configuration, land use with soft materials such as permeable pavement, grassland, water, trees, and shrubs account for 91.1%, which provide a natural and permeable environment to address flood risk (Figure 4.16).

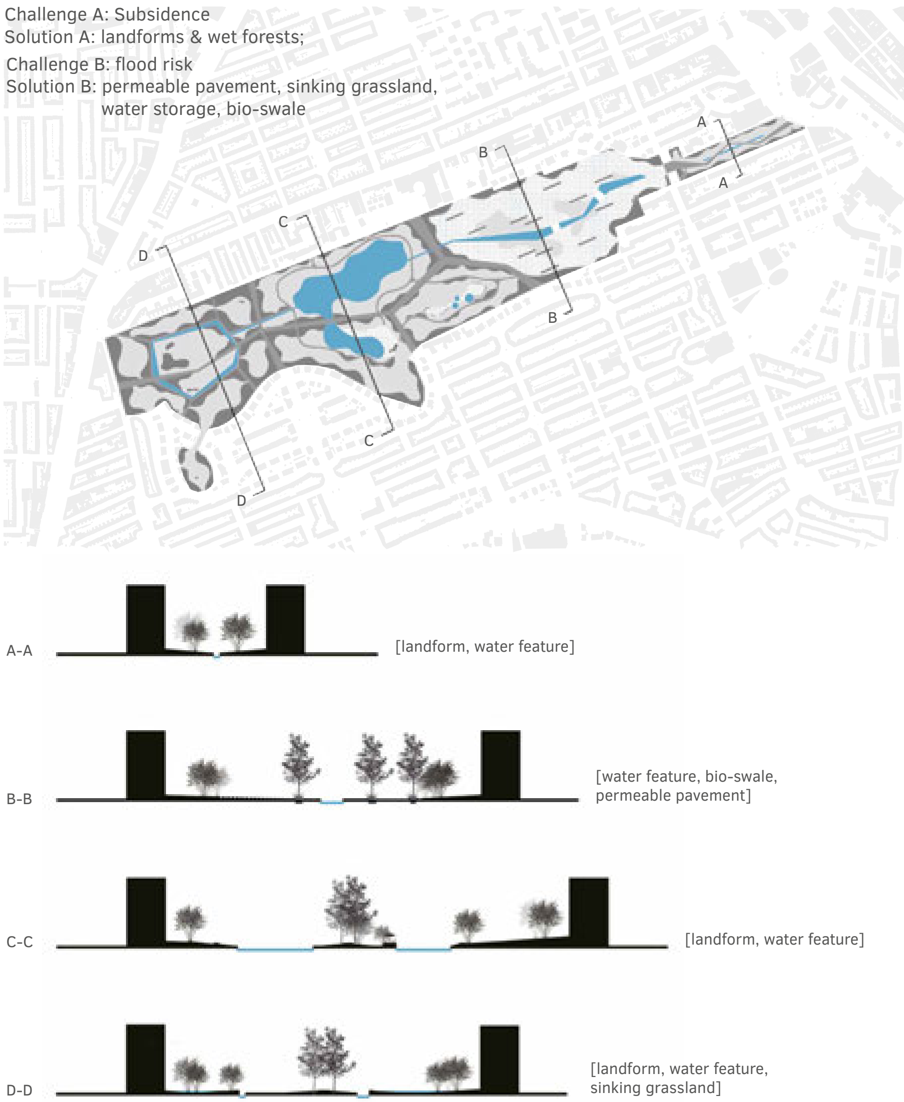
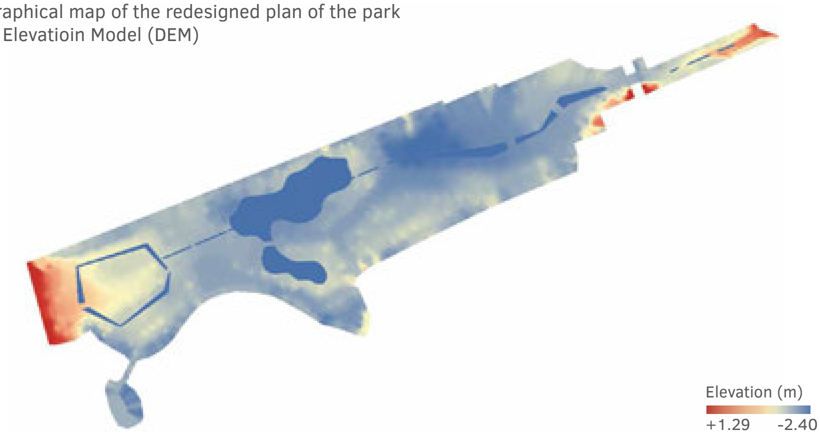


FIG. 4.16 Compartment analysis (cross section elevations) showing the spatial-visual organisation of the redesigned park for challenge A and B.

Flow accumulation using the redesigned elevation map (DEM) as a basis is helpful to calculate the accumulated flow and identify the stream channels during the floods. As figure 4.17 presents, assuming all rain becomes runoff, water will flow to the water features designed in the park or drain the water outside the park. No potential water hazards exist in the redesigned plan.

Typographical map of the redesigned plan of the park
Digital Elevatioin Model (DEM)



Flow accumulation of the redesigned plan of the park
(based on DEM)

FIG. 4.17 Flow accumulation of the redesigned plan of the park (based on the DEM processed through ArcGIS 10.5.1).

Compartment analysis, grid-cell analysis, and landscape metrics (Challenge C)

To estimate the spatial-visual connection between the park and urban context, compartment analysis through the measurement of space syntax indicators (i.e. integration) can quantitatively provide more accurate and verifiable clues. Using an axial map to analyse the redesigned path network in the landscape, the higher integration value indicates better connectivity with the transportation network at an urban scale. Figure 4.18 shows that park entrances around the open public square are mostly well connected with the city, which have good accessibility for people from the adjacent museum square to turn into the park. Other entrances with a high integration value are all connected with the main path of the landscape.

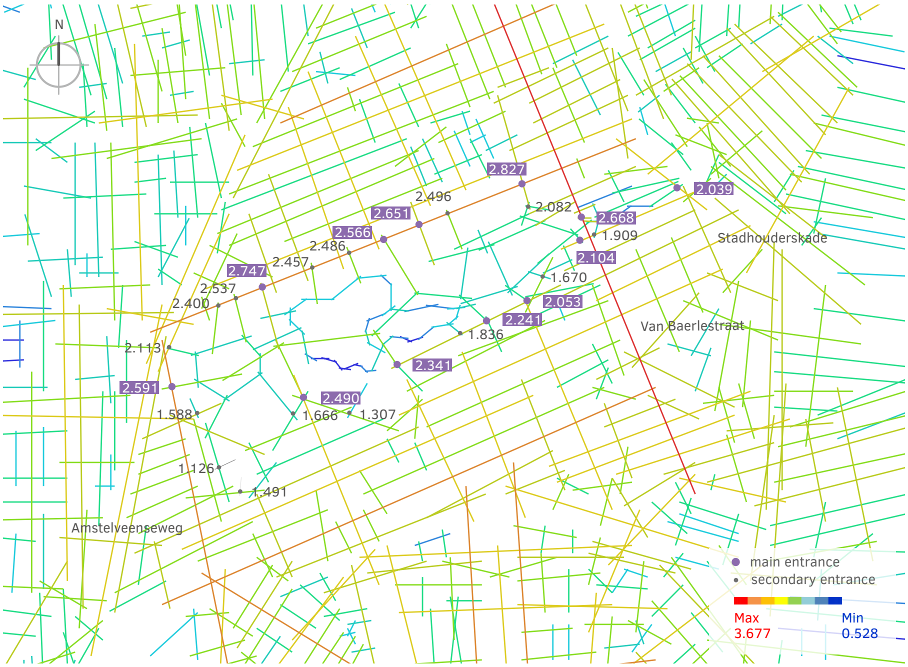


FIG. 4.18 Compartment analysis based on an axial map showing the integration value of each entrance of the park to indicate the connectivity between the park and the urban context.

TOC

An axial map from a local scale can demonstrate the connectivity of the interior path system and validate the potential of accessibility. Red and yellow lines in Figure 4.19 show higher integration values compared with other segments through the path network. Two important thresholds/transitional areas connecting three primary sections of the park show a similar integration index (1.195 and 1.229). It means in a linear landscape, the dominating sections (i.e. open square, natural area, and private courtyards) are well connected by the path network with proper accessibility.

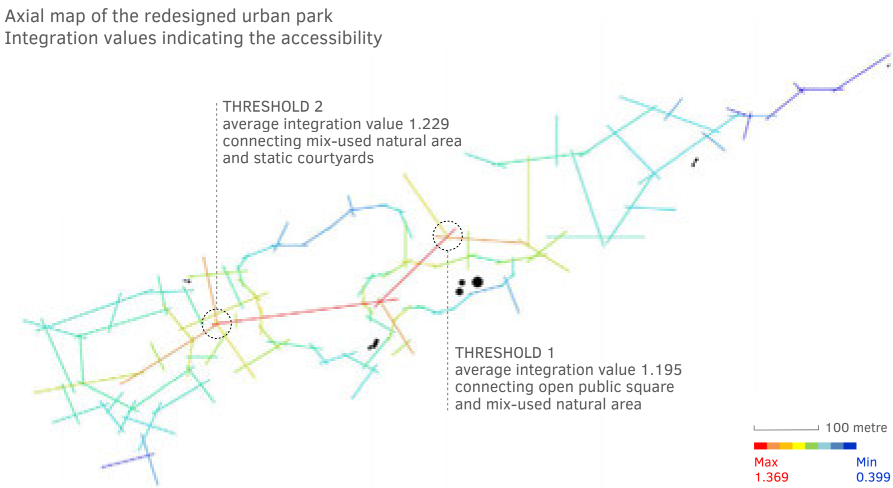


FIG. 4.19 Compartment analysis based on axial map showing the integration value of the path network.

Apart from physical accessibility, visual connection is also crucial and should be considered to shape the overall connectivity in the landscape. Grid-cell analysis via the measurement of point density is applied to identify the sense of enclosure along the path system from an observer's point of view. Figure 4.20 firstly illustrates purple circles as physically open (i.e. free to access spaces around this viewpoint) while the green yellow circle as visually open (i.e. free to look through into spaces around this viewpoint). After merging two maps together, the permeability of the enclosure map indicates main facilities, like the children's playground and café platform, are located at visual and physically open areas, which makes them easy to be recognized and accessed. However, it still points out that some areas lack connection. During further improvement of the design, either visual or physical connections should be considered in order to increase holistic connectivity.

FIG. 4.20 Grid-cell analysis through the use of GIS-based measurements indicating the connectivity (physical and visual connections) in the redesigned plan of the park.

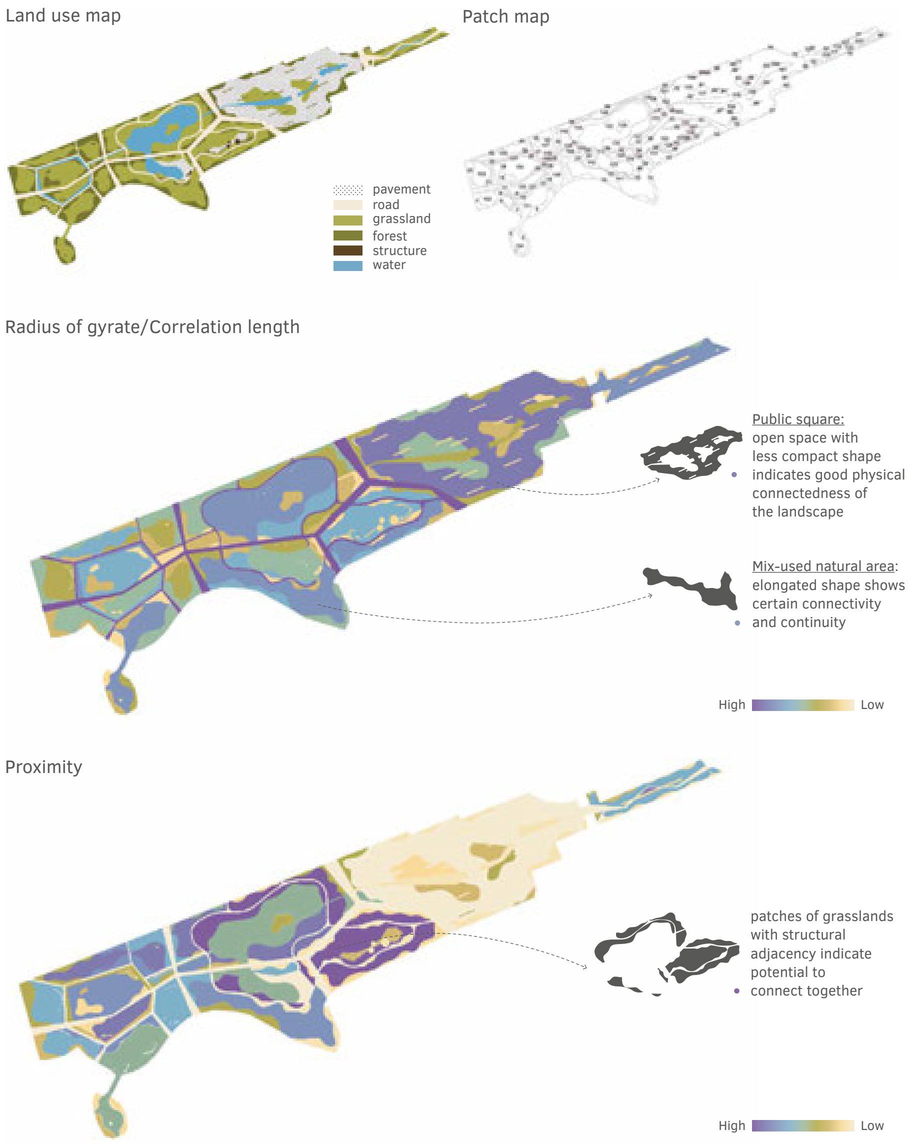


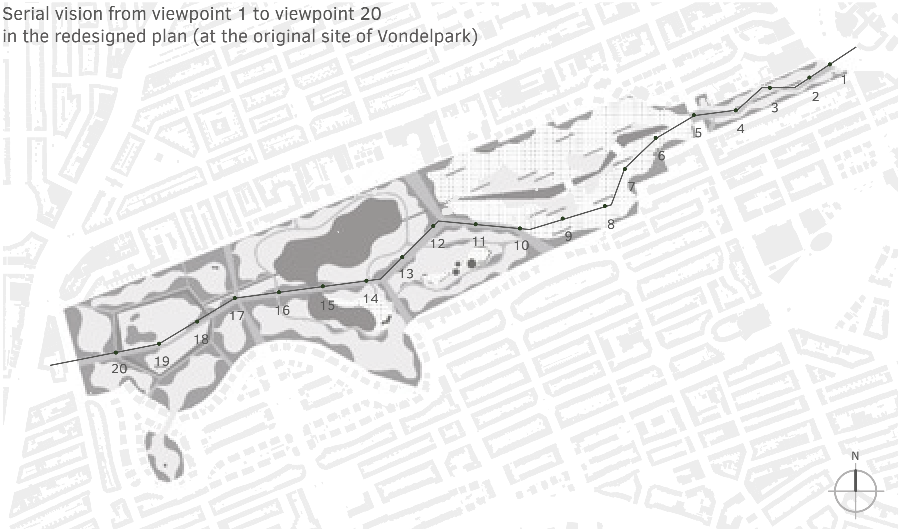
FIG. 4.21 Landscape metrics maps showing the value of two landscape ecological indicators, Radius of gyrate and Proximity, which indicate the spatial connectivity of the redesigned plan.

TOC

Connectivity is also an important spatial indicator for landscape ecology in the urban environment. To characterise this spatial pattern of the redesigned plan, landscape metrics are utilised to evaluate the spatial compositions and configurations based on land-use layout. Figure 4.21 initially maps Radius of gyrate (GYRATE). The form of the open square is elongated and less compact, which indicates good connectivity and integration. Grasslands in the natural/lake sections also shows good elasticity and potential to be extended. By comparison, spaces in the West section of the landscape are more compact and not well-connected, however, they are suitable for private and static activities. The measurement of Proximity (PROX) reveals certain spaces have the potential to be connected in order to shape physical and visual connectivity, especially in the lake and courtyard sections.

Grid-cell analysis, 3D landscapes, visibility analysis (Challenge D)

Open-enclosed variation plays an important role in the construction of the redesigned plan of the park. Different enclosures influence the sequential experiences through the space. To explore this spatial-visual characteristic, grid-cell analysis, and 3D landscapes are applied together to reveal the sequence. A 3D model of the design is built by SketchUp; 20 scenes with 100 meters equidistance are later selected (Figure 4.22). The proportions of different landscape elements are calculated and combined into two groups, which are open elements (sky, ground, grassland, water) and enclosed elements (tree, shrub, structure). The results are generated as a line chart (Figure 4.23) which intuitively expresses the sequential experience based on the sense of openness along the path. Views are relatively enclosed in the transitional section (viewpoint 1 to 5), while scenes of the public square become open (viewpoint 6 to 11). In the natural/lake area (viewpoint 12-18), the overall sequence is more enclosed, while in the courtyards (viewpoint 17 to 20) the open-enclosed variation changes alternatively.



Scenarios from viewpoint 1 to viewpoint 20 (from the horizontal/eye-level perspective)

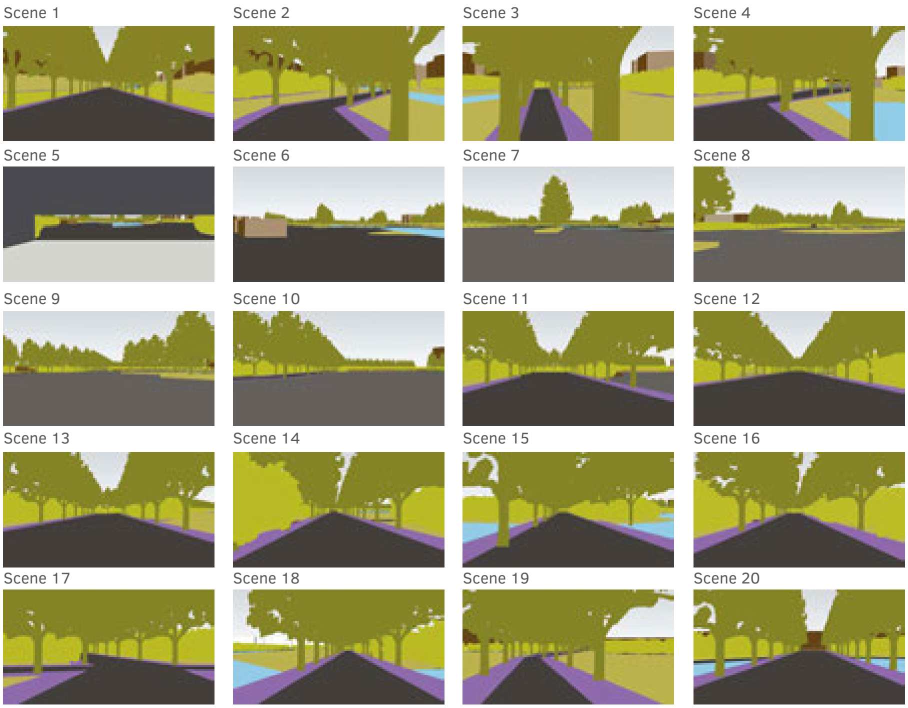


FIG. 4.22 Scenes from the 3D model of the redesigned park plan.

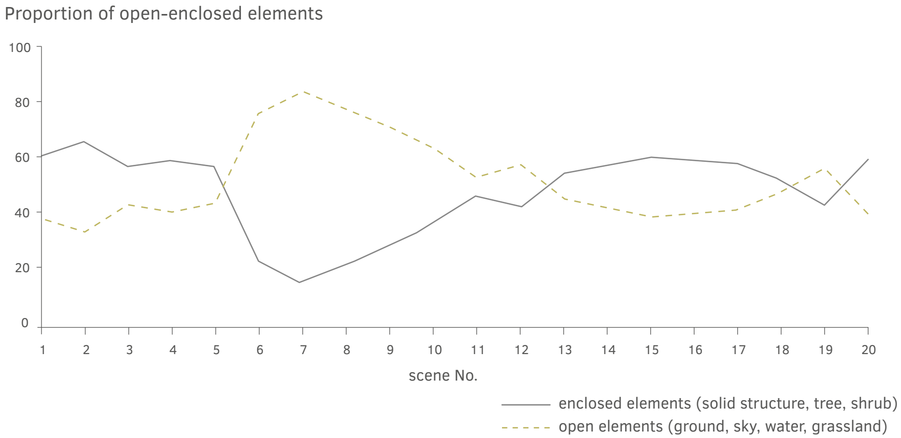
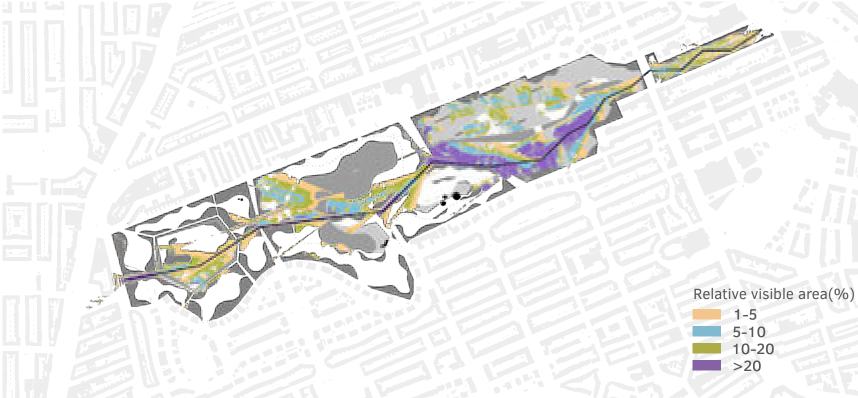


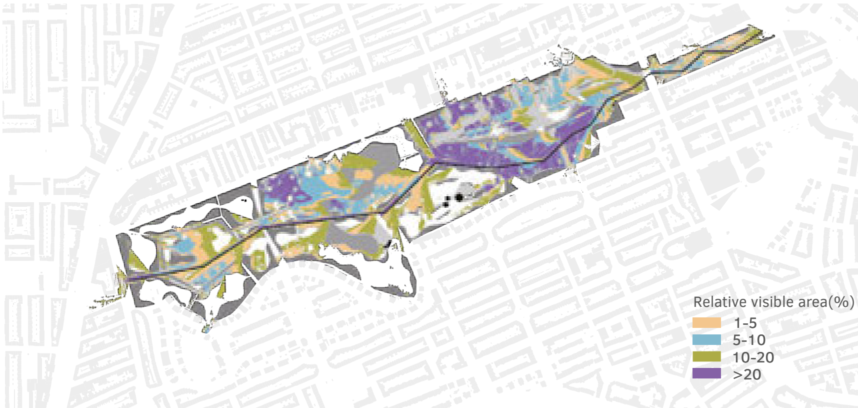
FIG. 4.23 Line chart showing proportions of open and enclosed elements in landscape scenes which indicates the sequential experience along the path

Furthermore, to explore the sequential experience, visibility analysis is also helpful in providing more accurate measurements of visible areas. When people moving forward from Northeast to Southwest along the path, the trends of the spatial-visual sequence are revealed in Figure 4.24. Through the transitional area, the perception of openness changes gradually from semi-open to enclosed, while the sequential experience in the public square varies from open to semi-open. Since walking into the natural/lake area and courtyards, the visual perception of openness changes from open/semi-open to enclosed sharply and repeatedly. Moreover, the viewpoints where the feeling of openness changes can be recognised, such as viewpoint No. 210, 250, 318, and 357.

Path (cross the park) - 60° cycling from SW to NE



Path (cross the park) - 124° walking forward from SW to NE



Path (cross the park) - 360° walking from SW to NE

FIG. 4.24 Visibility analysis showing the sequential experience in the redesigned park.

4.4 Discussion

4.4.1 Spatial-visual Mapping Methods and Tools in Landscape Design

As exemplified by the design process, a combination of different mapping methods is not only used to gain an understanding of the spatial-visual character of Vondelpark, but also to evaluate the consequences of hypothetical design interventions.
The mapping methods facilitated a more comprehensive understanding of the restrictions, problems, and potentials of the site from a spatial-visual point of view and provided clues for design interventions. Compartment analysis, landscape metrics, visibility analysis, grid-cell analysis and 3D landscapes prove to be powerful means in *ex-ante* analysis of the proposed spatial-visual organisation. The methods are complementary and when used in combination with each other, they help to think about and visualise landscape space in qualitative and quantitative ways (Table 4.2)

TABLE 4.2 The role of different mapping methods in the design process.

Mapping methods	Analytical tools	Evaluation tools
Compartment analysis	– Clarifying the relationship between the site and the urban context (axial map); – Predicting moving flow and identifying main entrances (axial map);	– Showing the comparison of before and after plans (hand-drawn or digital illustrated schematic diagrams, cross-sections based on DEM); – Testing the integration/connectivity of the transportation network (axial map);
3D landscapes	– Identifying the spatial-visual characteristics from an observer's point of view (hand-drawn schematic diagrams, serial vision diagrams, photographs, and 3D models);	– Combining with vertical visibility analysis to show landscape scenarios from an eye-level perspective; – Combining with horizontal visibility analysis to identify changes and effects of the new spatial-visual organisation; – Combining with grid-cell analysis to show serial vision and explore the sequential experience;
Grid-cell analysis	– Identifying the serial vision/sequence (SegNet); – Identifying the connectivity/visual and physical permeability (GIS-based point density measurement);	– Comparing and testing whether the redesigned sequence/connectivity meet the requirement;

>>>

TOC

TABLE 4.2 The role of different mapping methods in the design process.

Mapping methods	Analytical tools	Evaluation tools
Landscape metrics	– Exploring the ecological condition and potentiality of the site and its surroundings according to land use map (not shown in the pilot study);	– Evaluating ecological impacts of certain spatial compositions and configurations (Fragstats);
Visibility analysis	– Showing sequential experience (the variation of openness) along movements (GIS based visibility analysis); – Identifying complexity of scenes (foreground, middle ground, and background) (GIS based visibility analysis);	– Showing/comparing sequential experience (the variation of openness) along movements (GIS based visibility analysis); – Evaluating complexity of scenes (foreground, middle ground, and background) (GIS based visibility analysis);
Eye-tracking analysis	– Identifying the dominant elements and visual affordance in the landscape (eye-tracker and analytical software).	– Clarifying whether the visual affordance in the landscape meets the expectation or not (eye-tracker and analytical software).

Though the chapter presented a hypothetical design experiment in a highly simplified form, it illustrates how spatial-visual features can play an essential role in the transformation of an urban park and how mixed mapping methods and tools can facilitate the design process. The application of digital mapping methods and tools were part of the iterative design process, while analysing, designing, evaluating, and refining the design (Figure 4.25). The mapping results become part of the design iterations, in which the designer gains a better understanding of landscape space and makes changes and refinements accordingly.

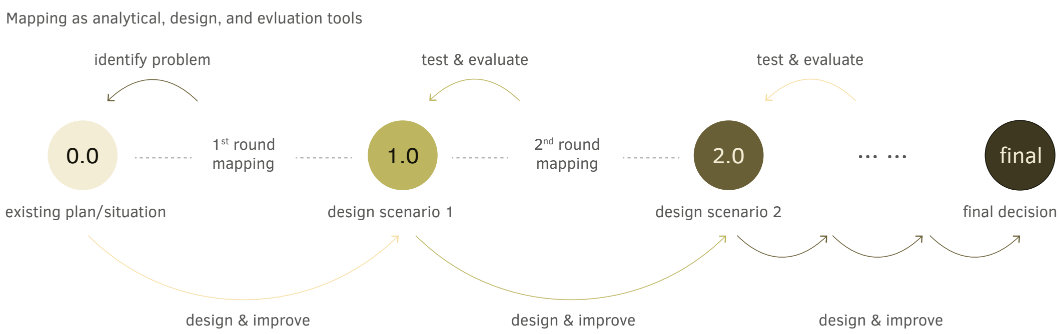


FIG. 4.25 Diagram showing the iterative design process of landscape design and the role of spatial-visual landscape mapping methods and tools

Although the implementation of advanced mapping methods in the design process prove to be useful in analyses and communication about the spatial-visual characteristics of landscape architectonic compositions, functional uses and symbolic meanings and other social, cultural, and ecological aspects should be included. Moreover, some methods have limitations in terms of data properties and processing techniques. For example, raster data, which are used as the basis of visibility analysis in ArcGIS, have major restrictions in modelling forms of vegetation.

4.4.2 Relevance

The above-mentioned methods help designers to think about and visualise landscape space in qualitative, quantitative, and combinatory ways. They show enormous potential for integration and implementation into landscape practice and research by:

1. *Expanding the digital toolbox for landscape practitioners to interpret landscape spaces.* The overview of the mapping toolbox creates opportunities for landscape architects to describe and understand known and unknown aspects of landscape space. Employing digital methods for mapping landscape space provides alternative perspectives and integrates disciplines. It also connects qualitative and quantitative approaches to reveal spatial relationships and the visual organisation of landscape in unprecedented ways.

2. *Introducing advanced analytical mapping methods is indispensable for new generations of landscape architects.* Digital mapping methods advocate a multidisciplinary approach towards landscape design while, extracting, translating, and adapting theories and technologies from the fields of urban morphology, visual landscape study, and landscape ecology, employing them to gain new insights of landscape spaces.

3. *Adapting these data-based mapping methods and tools into practices help to develop research by design and design by research approaches.* On the one hand, the developed mapping methods can be applied in multiple steps in the design process, as analytical, design, and evaluation tools. On the other hand, designs produced in different projects can supplement the body of spatial-visual landscape knowledge.

4.5 Conclusion

This chapter showcases that mapping technology can be practically applied throughout the landscape design process while connecting design concepts about space and the powerful possibilities that the mapping toolbox offers. Through hypothetical design experiments, this chapter implements the spatial-visual mapping toolbox into each stage of the design process as analytical, generative, and evaluative instruments, which allows for a thorough understanding of landscape space. Advanced mapping methods combined with digital technology and measurements can produce new insights for landscape architects to gain a more complete understanding of landscape compositions and their spatial-visual characteristics. It enables more comprehensive ways for interpretation, measurement, and the evaluation of spatial effectiveness compared to traditional methods. This chapter demonstrates that spatial-visual mapping methods and tools in combination with practical ways in the design process can provide broader possibilities to think and communicate about landscape space from a theoretical perspective. It also helps to bridge the gap between technology and landscape design – a gap which has always existed in the field of landscape architecture. These integrated methods for mapping landscape spaces are important for the advancement of landscape research and to extend the toolbox of knowledge-based landscape design.

Vondelpark, Amsterdam (Photo by Mei Liu, 2020)

TOC

TOC


Vondelpark, Amsterdam (Photo by Mei Liu, 2020)

5 Reflections of Mapping Spatial-Visual Characteristics from Landscape Practitioners

Chapter five conducts semi-structured open-ended interviews to investigate how and what means are used by spatial designers to map and describe space in their day-to-day work, and also discuss whether mapping approaches have the potential to be part of the design tools in the landscape design process. Eleven interviewees with a design background from various design practices, multiple levels of government, and academia are selected. The interviews consisted of two parts. First, they explored the way in which designers commonly describe space and the practical applications of mapping methods and tools in their daily design work. The further implementation of this mapping toolbox is discussed and explores the designer's outlook regarding advanced mapping technology, as well as their corresponding values and concerns.

5.1 Introduction

The profession of landscape architecture is a multidisciplinary and integrated approach in which various artistic, technical, scientific intentions, and requirements have to be addressed in terms of visual arts, spatial design, historical geography, descriptive geometry, social aspects, urbanism, biology, ecology, hydrology, soil science, economics, and so on (Almusaed, 2019). To achieve these versatile desires, spatial designers, in their daily practice, generally deal with form and meaning providing physical, functional, and an aesthetically pleasing arrangement of a variety of structural elements (Vroom, 2006). As the vital craftsman's toolbox, different mapping technologies critically play essential roles in shaping complex and intelligent designs and help designers to communicate about landscape spaces more effectively.

The previous chapters show that spatial-visual characteristics are of significance for landscape architects to interpret and talk about space. Despite their importance, rich possibilities of different mapping methods and tools are provided to depict and recognise the spatial-visual organisation of the landscape. Additionally, hypothetical design experiments effectively demonstrate the feasibility of implementing the mapping toolbox into both new and restorative design processes. In everyday design practice, mapping is also widely used in design work, together with multiple considerations through the practical design process, including the achievement of design intention, analytical, generative, and evaluative functions, personal attitude, limitation of knowledge and technology, and future education etc. It is valuable to mutually reinforce the previous research findings and discuss the relevance with practitioners for their involvement in and knowledge of spatial design, in order to gain a better understanding about what methods landscape practitioners use to describe and experience space in their daily work, and how they think about the implementation of advanced mapping methods in the future of landscape practices.

This chapter answers research question 3: How to apply spatial-visual mapping methods throughout the design process in landscape practice? It aims to investigate how and what means are used by spatial designers to map and describe space in their day-to-day work, and also discusses whether mapping approaches have the potential to be part of the design tools in the landscape design process. Referring to descriptive social surveys, semi-structured open-ended interviews are organised to involve an active interpretation of what the respondents are saying about mapping methods and tools they used and expected. Representative examples including the pilot study and potential applications via analyses of the landscape architectonic compositions of Vondelpark, Piazza San Marco, and Stourhead are introduced to show the usability of advanced mapping methods and tools to describe landscape spaces during the interviews. Eleven interviewees with a design background from various design practices, multiple levels of government, and academia are selected. As the results demonstrate, most of the interviewees show increasing interest and a positive attitude about the analytical and validated achievement of the spatial-visual mapping methods and tools. However, they also have serious concerns about the functional use, symbolic meaning, and other social, cultural, and ecological aspects through the design process. Moreover, educational and research institutions have an important part to play in raising awareness, who should take the lead in educating students, inspiring practitioners, building up their knowledge, passing it on, and adding new tools to the traditional craftsman's toolbox.

5.2 Methods

To achieve the objective and supplement the previous research, this chapter conducts a practical investigation about the utility and professional attitudes of current mapping approaches. A semi-structured in-depth interview is designed to collect information and communicate ideas with experts from various positions within the field of landscape architecture about the role of the mapping toolbox related to different discourses across professional boundaries.

5.2.1 Goal of the Interview

Interviews were conducted to explore experts' insights on mapping techniques in day-to-day landscape practices and elaborate how effectively the mapping methods and tools can impact the understanding of space through the design process. To underpin this research, two goals are established to frame the overall interview structure, which are:

Goal 1: This interview is to explore how spatial designers analyse, design, and evaluate landscape space through conventional and advanced mapping techniques, as well as the effectiveness, difficulties, and limitations during the practical implementation.

Goal 2: The interview is intended to discuss the possibilities of applying advanced mapping techniques in future landscape practices.

5.2.2 Identity of the Interviewee

Eleven interviewees are selected on the basis of recommendations and reputation as reflective practitioners from different branches of landscape practices. They are asked to communicate their points of views on the understanding of landscape space, the application of mapping methods and tools in their daily work, and their attitudes of using mapping technology in the profession. Considering that the goal focuses on the interpretation and understanding of spatial-visual characteristics of landscape, people without a design background are excluded. Then, taking the diversity of occupied positions into account, interviewees were confirmed including five from a design practice, two from the government, three from a university, and one from a consultant service (Table 5.1).

TABLE 5.1 Occupation background of the interviewees.

Interviewee	Occupation
Interviewee 1	– Landscape architect from professional office – Professor of Landscape Architecture in TU Delft (former)
Interviewee 2	– Urban designer from professional office – Professor of Urban Design in TU Delft (former)
Interviewee 3	– Urban designer in Knowledge and Quality Assurance in Spatial Planning Department, Municipality of Amsterdam – Teacher of Landscape Architecture in TU Delft (former)
Interviewee 4	– Landscape architect, Spatial quality consultant for the province of Utrecht (former) – Project leader of urban development and cultural history studies in the Planning Bureau (former)
Interviewee 5	– Urban designer from professional office
Interviewee 6	– Regional designer in Province Noord-Holland – Landscape architect from professional office (former)
Interviewee 7	– Landscape architect from professional office
Interviewee 8	– Professor of Geodesign and Landscape Informatics in Weihenstephan-Triesdorf University of Applied Science
Interviewee 9	– Teaching/researching assistant in the chair of Landscape Architect at ETH Zurich and the Future Cities Laboratory in Singapore
Interviewee 10	– Professor of Landscape Architecture in the University of Sheffield
Interviewee 11	– Landscape architect in Shenzhen Urban Planning & Design Institute of Design (China)

5.2.3 Interview Design and Analysis

To articulate professional thoughts and knowledge, the ethnography used to carry out unstructured or semi-structured, open, and in-depth interviews, included an extended conversation between the interviewer and a subject or group of subjects could be conducted to explain and share visions (Deming & Swaffield, 2011). This research has relatively clear topics, thus a semi-structured interview guided by specific themes, with an open-ended format was much more appropriate to gain interpretive results based on experts' everyday working experiences. A few planned questions are prepared following the rhythms of an unfolding interpersonal exchange, which allowed the openness of the conversations to interpretation (Secor, 2010). Moreover, in order to assure significant confidentiality, the interview is undertaken one-on-one.

TABLE 5.2 Interview questions for the interviewees.

Part 1: Practical applications of mapping methods and tools	
Question 1	Looking through your practical work, have you ever used advanced mapping techniques for exploring landscape spaces in any planning and design projects, such as GIS, space syntax, and eye-tracking analysis? If you have no experience using advanced mapping techniques, what kinds of methods and tools you commonly use to understand and communicate space in design practices? Please give some examples.
Question 2	What purposes are they exactly used for in the design process? What is the scale of the project (local scale or regional scale)?
Question 3	In what respect or how did these different mapping techniques affect the design (analytical, design, or evaluation stage)?
Question 4	What are the difficulties and limitations of applying these mapping methods and tools in practices?
Part 2: Design-oriented implementation and discussion	
Question 5	Based on the cases I've just shown, if it is possible to describe spatial-visual landscape as such, do you think these mapping approaches are potential to be part of design tools in the future landscape design process?
Question 6	If yes, what do we need to do in order to implement them into design world? If no, why not?

Each interview starts from an introduction of the research topic, objective, and the purpose of the interview. An individual's profession background is collected in the beginning (e.g. education background, relevant working experiences). To achieve the interview goals, relevant questions were asked to encourage discussions focusing on two main themes (Table 5.2). At first, interviewees were asked questions from Part 1 about the existing applications of mapping landscape space in their daily practices. Specific examples were required to investigate when, and in what cases the mapping methods and tools are used to help the design process. Then, selected pilot studies were shown to the interviewees to elaborate how these advanced mapping methods and measurements work for interpreting the spatial-visual organisation of landscape space. Three cases were included, which are the sequential experience in Piazza San Marco (Venice, Italy) and Vondelpark (Amsterdam, the Netherlands) through an isovist and visibility analysis, respectively. The pictorial views framed in Stourhead (Wiltshire, UK) were examined through a vertical visibility analysis (Figure 5.1). Then, an open discussion was provoked via the questions in Part 2 to explore whether proper mapping methods have the potential to be used in design practices in the future. The detailed questions asked during the interview are shown as follows:

FIG. 5.1 Three selected pilot studies shown to the interviewees to elaborate how advanced mapping methods work for interpreting the landscape architectonic compositions (spatial-visual characteristics) of landscape space.

TOC

All the interviews lasted between one and two hours and were tape-recorded (with permission), which took place between May 2019 to August 2019. Discourse analysis is used fosr analysing the conversation and summarising the conversation, which permeates both through the interviews by asking questions for further clarification and understanding, and during the transcription of the reflection and translation referring to the goals. Instead of searching for the truth, it is often more effective to understand how the conversation unfolded into broader discourses (Secor, 2010). Transcription of the interviews are coded based on condense analysis, by which highlights were extracted through careful replaying and analysis of individual in-depth interviews, in terms of themes and points and presenting them in summary form.

5.3 Findings

5.3.1 Mapping as Representation & Communication Tools

In practice, landscape designers and planners always rely on a variety of performative visualisations to simulate and communicate design and planning ideas. Visual representations tools are mentioned a lot by the interviewees, for example 3D modelling/rendering and photorealistic collage. These mapping methods and tools are widely employed into landscape practices in order to help designers change the ways to read space and understand spatial characters, like topography, the form of volumes, and the compositions of spatial elements etc. Today innovation in mapping approaches is thriving; real-time interactive presentations and virtual reality (VR) environments are tentatively put into action which are helpful to mimic and present the existing or future landscape realities in an immersive way. Moreover, the implementation of data visualisation techniques and the current state-of-the-art functioning of GIS technology shows great potential for illustrating the relationship between spatial information and different types of global data and displays real-time changes as well.

'In the project of Atelier 2050-An energetic Odyssey, a large amount of data is mapped and shown through an animation of 15mins and illustrated via Dreamweaver, which includes maps of depths, maps of shipping routes, maps of designated natural areas, maps of coastal times, maps of migrating birds of the North Sea, maps with oil and gas infrastructure, and the rigs on the north, but also the pipes under the North Sea etc.' (Transcript of the interview with an interviewee, landscape architect)

These evocative and vivid mapping techniques have been mainstreamed in the relevant professional fields, such as landscape architecture, urban design, and urban planning for many years. As representation and communication instruments, they are predominantly used to integrate scientific knowledge, narrate the story, and achieve collaborative planning and design approaches. However, knowing how well these illustration tools can function, people have started to become a bit tired of the over-developed, rendered images. Increasingly, design offices are emphasising the interpretation of spatial organisation by using concise illustrations that are more artistic and more tangible.

Additionally, in order to communicate with experts, major progress in the visual representation of mapping approaches have been used for interactive sharing and participatory collaboration with different stakeholders and the public both in urban/landscape design and planning projects. For instance, 3D landscapes are commonly used to model spatiotemporal climate scenarios in local planning and effectively enable public participation in landscape management. In addition, a virtual reality model applied in the NDSM project (Amsterdam) promotes the communication between the municipality and developers to evaluate and modify the design plan in terms of specific consideration and requirements. Most of these examples are focused on inter-subjective knowledge transfer and achieve effective landscape-human interaction.

'In stakeholder participation or public process, the composition of people and learning preferences are quite diverse, therefore it is best to provide various mapping media and different formats so as to meet different needs. Layman have problem reading maps, thus it is better to have 3D models or landscape visualisation with simplified information and present one after another, while for the experts, maps with high density of information is much more preferred.' (Transcript of the interview with an interviewee, professor of Geo-design and Landscape Informatics)

As shown in this interview, practitioners from the authorities and consultant services know slightly more about the potential of advanced mapping methods like GIS, space syntax, eye-tracking analysis etc., especially younger generations. A small number of projects are referred to in the process of utilising GIS to map topography, landscape habitats, land uses, and user behaviours, in order to look for transformation guidance from a spatial perspective. They mostly link measurement, spatial description, and performance to address planning and policy-oriented landscapes issues related to agricultural, ecological, and urban sustainability. As exemplified, these advanced mapping approaches are generally used in larger scale projects to gather information together, however, they are not interactive enough for layering different information for everybody to collaborate.

In general, these types of applications in mapping methods and tools are mostly focused on representation in the final stage of design and communication in participatory landscape management and planning. They provide useful clues for visualisation and systematic evaluation of spatial-visual landscape characteristics to achieve knowledge acquisition, however, the effectiveness of analysis and design purposes in landscape design is still implicit.

5.3.2 Mapping as a Design Tool

In landscape practice, mapping is a vital process through which information is compiled and formatted into a representative image. It is used by professionals for every sort of subject throughout the empirical process of landscape planning and design projects. Conventional, but classic, mapping methods for operationalising landscape are hand-drawn maps, sketches, schematic diagrams etc. These methods are powerful tools for describing, interpreting, and polishing landscape characteristics in real-time to realise certain design concepts and perceptions (Pinzon Cortes et al., 2009). Many practitioners mentioned that, nowadays, even though advanced mapping techniques are involved in day-to-day work, hand-drawn maps and sketches are still fundamental and are the primary way in which to understand and represent design ideas.

'As designers, the way we depict space is actually quite primitive, automatic, like a child, without much consciousness. Drawing is definitely very helpful. The mechanism of design always starts from some abstraction/intuitive feeling/approximation of the space and changes all the time. Thus, through the design, you make the line while you evaluate and elaborate the line as well. The mapping technique is not just the mean for representation, but an instrument to develop your thinking and the whole process of invention within the design process itself.' (Transcript of the interview with an interviewee, urban designer)

TOC

These instantaneous drawings can effectively describe visible objects but also evoke the intangible experience of space. The idea of using hand-drawings to convey a thought is due to the iterative and dynamic process of design thinking. Preliminary sketches provide a sense of immediacy and are extensively used to seek solutions and adapt spatial strategies which might not be instantly apparent. Relying on professional knowledge and experience, designers tend to use selective elements to express the core of the design idea without unnecessary details. The combination of multi-dimensional mapping approaches, such as bird's eye view plans, schematic diagrams, sections, and section-elevations, as well as perspective views, are helpful for spatial designers to gain a comprehensive understanding of the space. Thus, compared with the time-consuming digital mapping methods which requires building models or preparing data, most of the experts are still supporters of traditional hand-drawn mapping approaches which are more easily used to achieve design results.

Nevertheless, there are still some practitioners who are eager to apply and explore advanced mapping methods to interpret spatial landscape characteristics and effects in order to understand site conditions and guide design decisions. For example, an initial measurement through preliminary viewshed analysis was brought into the study about how high-rise building adjacent to the Green Heart of the Randstad in Zuid Holland (the Netherlands) would influence people's perception of openness. Moreover, GIS-based visibility analysis is mentioned throughout the interview, which helps to identify proper vista points, providing better visual interfaces during the design and planning of a rural forestry park in China. Besides, GIS-based measurements are also partly applied in city scale urban design and planning projects mainly on the analysis of geomorphology, site suitability, flood risk etc. These mapping outcomes effectively provide more precise and scientific three-dimensional clues for landscape architects/planners to understand spatial attributes and guide the generative process of design.

Traditional mappings, especially done by hand, are still the most common means to represent design thinking because of their fluidity and flexibility to test and represent interventions during the design process. Few advanced mapping methods, used as analytical instruments, are implemented for designers to gain new insights about site conditions and provide valuable clues to guide the further design. To sum up, it is worthwhile to merge data and design thinking in order to fulfil the narrative of landscape space inter-subjectively and from a design perspective.

5.3.3 Data, Information, Knowledge, Design

The essence of landscape architecture is about gaining knowledge from various types of data and information; then interpreting and converting them into design interventions. Referring to the data, information, knowledge, and wisdom (DIKW) pyramid, 'information is defined in terms of data; knowledge in terms of information; wisdom in terms of knowledge' (Adler, 1986; Rowley, 2006). Landscape designers normally do not directly use raw data, but generated data, such as soil, topographic, and green and blue infrastructure maps etc. Designers often manipulate data/information with contextual consideration, value, and meanings, and derive more knowledge and insights from it. Based on practical experience, these internalised forms of knowledge can be transformed into design principles for problem solving and guiding the actions of design (Nijhuis, 2015) (Figure 5.2).

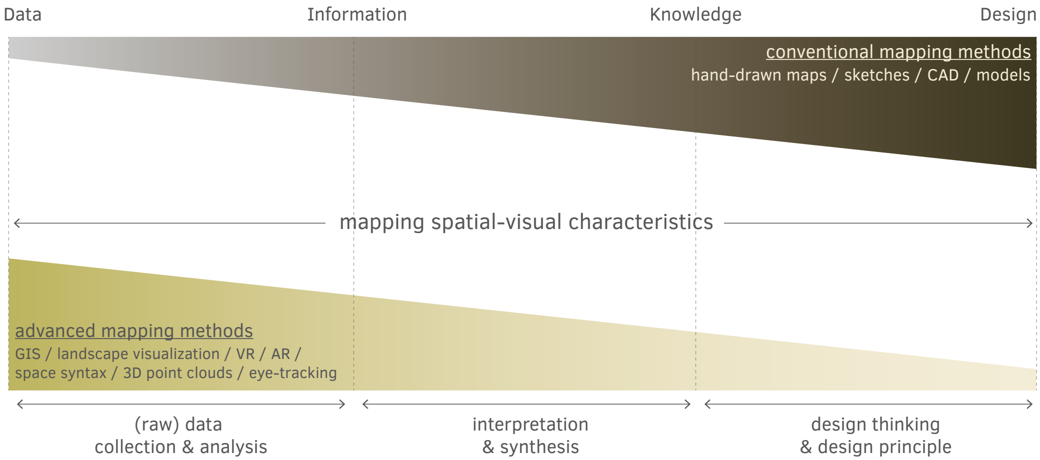


FIG. 5.2 Positions of the conventional and advanced mapping methods based on the Data, Information, Knowledge, and Wisdom (DIKW) pyramid in landscape mapping context.

Mapping approaches that are analytical, generative, and evaluative are substantially employed in each of the above stages. They play an essential role in the processing and organising of data, in terms of initial analysis and model construction; exploring and simulating landscape architectonic compositions and evaluating and refining design proposals. From the interviews with experts, conventional mapping methods (e.g. hand-drawn sketches and preliminary models) commonly used to deliberate design ideas are not good at dealing with data but rely on the designers' personal involvement. They can help ideate design thinking into intervention decisions in a straightforward manner. Advanced mapping methods, such as GIS, space syntax, and landscape metrics etc., can process data and provide more precise and objective information about landscape, however, they are not always efficient enough to conduct design plans. Under these circumstances, most of the mapping methods and tools on the market either focus on data processing or design thinking.

‘There is this separation between the world of the data and the world of concern. The French philosopher Bruno Latour said: we have to come from a matter of fact to a matter of concern. And that is also a barrier in a way, because the designers are inclined to be at the side of the matter of concern. And on the other side is the world which is fascinating the big data and data mining.’ (Transcript of the interview with an interviewee, landscape architect)

In this research, mapping spatial-visual characteristics, through mapping techniques advanced by the mapping toolbox (both qualitatively and quantitatively) becomes a notable way to build a bridge between data processing and design intervention. Some representative examples were displayed to all the interviewees, for example using isovist analysis to understand how a spatial sequence is constructed when moving through the landscape; by means of GIS-based visibility analysis, how the classic and diverse pictorial views are formed in the landscape. In accordance with the interviewees’ responses, almost everybody showed an active interest and positive attitude towards the capacity of these mapping methods. In addition, they emphasised the importance of spatial-visual characteristics and the adaption of mapping methods from different disciplines might be the future development of landscape architecture.

5.3.4 Raising Awareness of Spatial-Visual Characteristics

Through a dialogue with interviewees, most of them showed strong concerns about the appreciation of spatial-visual characteristics and mention the importance of raising awareness of spatial properties in the development of each project. In many circumstances, landscape practitioners must deal with problems from multiple subjects at the same time, which can be overwhelmed by data from all disciplines, such as demography, energy, climate change, policy, and ecology etc. This imposes that their visions mostly focus on the programme, fashion, trends, or pattern making, rather than taking a matter of rational spatial properties into consideration. Spontaneously, several experts state that looking back to the success of nineteenth-century monumental parks (in the style of English gardens and landscapes), there is much to learn. Their spatial-visual organisation, which are not only for aesthetics, also trigger certain functions and provide flexibility.

Designers use design vocabulary to articulate spatial-visual properties of space and indicate the corresponding perceptions, such as infinity, intimacy, sequence, route, dominant access, mystery, imagination, recall memory, 'what's behind the corner', variation, water connecting with water (connection/continuity), axis, pictorial view, panorama etc. There is no identical and stable interpretation of each design term due to the multitude of personal views. Nevertheless, supported by accumulating design principles and generic knowledge from the past, most of the design terms are represented by particular spatial compositions.

'People has common sense during the understanding of space unconsciously. Because they are looking to 'the same/objective' objects, the same spaces, and the same measurements. Designers have to develop their own preferences with empathy for understanding what they know from the observers and help them to see by making an interpretation of what are the most important elements in the drawing.' (Transcript of the interview with an interviewee, urban designer)

Mapping is the most pervasive method to help raise the awareness of spatial-visual phenomenon and implies a conscious perception of spaces during the design process. Despite the fact that they are often based on subjective understandings and personal descriptions, conventional hand-drawing is still the most useful mapping method in design. However, because of the increasing complexity of projects, some progressive practitioners have begun to harness the rich database and explore the mapping toolbox to reveal fundamental aspects of spatial-visual organisation, but also complement design principles to provide more visions for the future of design practice.

Overall, the application of using different mapping methods and tools to examine and understand landscape through brief examples has positively increased the interviewees awareness of spatial-visual characteristics in landscape practices. It also facilitates profound consideration for the demands of precise mapping techniques to earn more thorough comprehension of spatial information. Despite the availability, there are also major concerns about the limitations and deviations of advanced mapping methods and measurements, which result in prejudice and a refusal to implement them into daily practices.

5.3.5 Denials of Advanced/Quantitative Mapping Methods

This research, in fact, does not develop any mapping methods and tools from scratch, but adapts existing potential mapping techniques to describe and interpret spatial-visual landscape characteristics from a design perspective. Then a remarkable question comes out which is, why were these potential mapping approaches not implemented realistically into daily practice in the past especially since they help to gain a more rational, precise, and verifiable knowledge base.

Time and cost consuming: Based on personal experiences and viewpoints, the interviewees set out several reasons of the hysteretic nature of advanced mapping methods (digital and quantitative) in the daily work of landscape architecture. First, landscape design is a subject that incorporates systematic understanding, logical thinking, and strategic design, in order to achieve reasonable design solutions to solve problems, however, the creative process of design always starts from abstraction, intuitive feelings, and approximations. To capture these fleeting design inspirations, designers rely on mapping, especially hand-drawn maps and sketches, which are more 'fluid' and able to express their ideas in a quickest way. Most of the practitioners (from government or design offices) see mapping technology with measurements as extra input, which does not radically change their working methods. Compared with these effective mapping methods, which can easily show spatial problem at the same time through hand drawings, advanced mapping approaches are useful for studying the spatial-visual characteristics of the space more precisely, but are hardly used to produce a design from the concept. Besides, in the pre-processing stage, it is rather time-consuming to build models and prepare data.

Nowadays, most design firms and institutions have a standardised workflow and scheduling approach for each project, with the aim of increasing efficiency and the guarantee of performative quality. Even though advanced mapping procedures can provide comprehensive ex-ante site analyses for knowledge acquisition and an assessment of design interventions, concerning time limitations, cost of software, availability, and quality of data, they are not distinctly highlighted but considered as 'sufficient but unnecessary tools' in the day-to-day practice of landscape architecture. Optimised design methods, relying heavily on computer models and digital visualisations, are common and improving in the field of architecture. However, landscape and urban design is embedded within a more complex environmental and social context, meaning that the effectiveness and financial gain of using advanced analysis tools are less direct. Both designers and customers do not see the results over a short period of time.

TOC

Data does not lie, nor does it tell the whole truth. With multidisciplinary and integrated approaches, landscape design deals with forms and meanings, providing a physical, functional, and aesthetically attractive arrangement of a variety of structural elements (Vroom, 2006). Most of the current advanced mapping methods (e.g. GIS, space syntax, landscape metrics) only focus on one aspect of the landscape or its specific characteristics, which may ignore other perspectives. While the mapping toolbox discussed in this thesis makes an effort to interpret the inner-relationship between the spatial-visual experience and landscape architectonic compositions, it is still difficult to thoroughly describe spatial qualities, such as colour, smell, light etc. Furthermore, landscape designers are often in a position that requires them to be pragmatic. They first need to deal with a series of urgent contextual problems such as pollution, flood risk, and transportation issues, rather than starting from the organisation of landscape compositions. Each medium, in and of itself, has restrictions, thus it is essential to combine different mapping methods in order to form the whole story and provide integral knowledge to inform design decisions.

Abundant data, technique barrier, and commutation disorders: Interviewees from the municipality and the province point out the fact that the government has a large number of valuable open data sources from different departments, including social, economic, ecological, geographic, energy, health, GPS, climate sensors, the physical environment, and the transportation etc. Some of the data is spatially accurate and geo-located with attributes that have the potential to help identify, understand, and analyse spatial problems or to evaluate the effectiveness of proposed design plans in order to strengthen design thinking. Only detailed GIS-based 3D models have been prepared and implemented in order to provide more precise and accurate spatial evidence for some projects. Meanwhile, most of the technology has been originally developed for other analytical or evaluative functions in the field of geography, hydrology, or landscape ecology, instead of design. When multidisciplinary teams are collaborating, technical barriers and communication issues (because of a lack of common languages) are common. Mapping methods with data and digital technology are then hardly used to transform landscape solutions.

The interviews generated an in-depth discussion about the reasons why practitioners do not formally apply advanced mapping methods and measurements into their daily design work. Both objective limitations (time and cost, the restriction of data and software) and subjective explanations (lack of knowledge to edit and analysis data) are summarised and deliberated. To deal with these concerns, recommendations to guide future development and implementation are needed.

5.3.6 Recommendations for Practical Implementation and Future Outlook

Mapping methods and tools have progressively merged with the development of big data and technology, which provide realistic visualisations of landscape scenarios, accurate simulations of spatial patterns, precise analysis of landscape characteristics, and rational assessments of design proposals. More and more, progressive landscape designers and researchers are involved in the discussion and experimentation of how landscape architecture should further implement digital, advanced, quantitative, and inter-subjective mapping techniques (e.g. GIS, landscape metrics, Virtual Reality, Augmented Reality, drone, 3D lancer, and algorithm landscapes) to help understand real world dynamics and act on design decisions.

After introducing the strengths and weakness of advanced mapping approaches with examples, a set of challenges for landscape professionals are posed based on the positive feedback of the interviewees. This includes the necessity to understand new technologies and gain new skills, how to combine mapping methods and tools, and knowing when, how, and in what cases to integrate advanced mapping toolboxes into landscape design and planning.

Applying design thinking to the manipulation of data. New techniques are not just a means for representation and communication, but also have the potential to develop design thinking and the whole process of invention within the design procedure itself. Spatial designers should apply design thinking appropriately into the manipulation of data in order to be more targeted and to reveal the essence of spatial-visual organisation, while providing additional information to possibly change the quality of design. Following the framework of this research, extending design vocabulary, and exploring the corresponding landscape architectonic compositions would be a good approach to enrich principles and guidelines for everyday design practices.

When, which, what, and how. To promote implementation and increase the usage of advanced mapping toolboxes, it is crucial to integrate them into the whole design process and clarify which method is appropriate to employ at what design stage. Also, landscape designers should be familiar with the capacity and dimension of each mapping method and tool, identifying which instrument is best by taking different aspects into consideration (e.g. scales and particular issues). Conventional and advanced mapping techniques should be employed together in order to address different requirements during the entire design process. Furthermore, as is already known, landscape design is often pragmatic and multidisciplinary, so the combination of different mapping methods and tools can work together to describe the landscape more comprehensively.

The importance of education. As gathered from the interviews, younger generations of designers have already started working with different types of data in order to address landscape space from a wider perspective. The government is also eager to use digital technology in order to fill the gap between the outside world and themselves. In order to raise awareness of the strength of advanced mapping approaches, educational and research institutions have an important part to play. They must take the lead in educating students and inspiring practitioners, building their knowledge, passing it on, and adding new tools to the traditional craftsman's toolbox. This approach aims to stimulate the development of a digital culture in landscape architecture while exploiting advanced mapping methods and tools for their powerful integrative, analytical, and graphic capacities.

The development of real-time mapping techniques. To forecast the future development and implementation of advanced mapping methods, almost all the interviewees mentioned the expectation of real-time presentation and analysis. Prophase analysis, design invention, evaluation, and assessment could be contained simultaneously, which could address the concern of time-consuming data analysis and the complexity of working with various types of data/resources. For example, the Augmented Reality Sandbox, invented by the University of California-Davis, combines 3D landscapes, which is a an exhibit combining a sandbox with GIS analysis as an interactive topographic map showing the dynamic spatial changes and effects through design. Also, ETH Zurich has been processed the implementation of 3D point cloud in landscape design and planning projects, but also at the master's level education track. Compared with GIS, point cloud data accumulated via a laser scanner can offer more precise simulations of reality. This can help people understand how the landscape is structured and animates the landscape through consecutive sections, to present direction, water flows, textures, and spatial information like dikes, drainage channels etc. In the landscape course at ETH Zurich and the National University of Singapore, 3D point cloud data is used by students to model the existing terrain, vegetation, and structures and to visualise future design interventions. It is also used to calculate more technical aspects such as the amount of soil that must be moved, wind simulations, and local flood risk. In addition, point cloud can create a kinematic replication through a performative dataset. Based on educational feedback (and despite initial difficulties to manipulate and work with the data), students were excited to use point cloud to conduct their analyses in a way that other models are not able to.

‘Landscape design is definitely not comparable to architecture design. It includes much more elements/pre-existing elements on the site. The design intervention will probably modify eighty to ninety percent of what is on the site, and the rest remains existing. I think 3D point cloud will help designers to work more with the existing elements in the landscape, taking choices of want to integrate or what to remove from a design. As a designer, I need a tool that helps me to address the existing as much as possible when I am working with the future interventions.’ (Transcript of the interview with an interviewee, teaching/research assistant on the topic of 3D Point clouds in the field of landscape architecture)

In order to ensure that landscape architects remain at the forefront of spatial design, it is crucial to continually explore knowledge-based landscape principles, make use of new technologies, as well as implement them at different design stages. Furthermore, educational and research institutions play an essential role to build knowledge, develop new mapping methods, and lead young generations and practitioners to achieve a better understanding of landscape.

5.4 Conclusion

In this chapter, empirical perspectives on how to use spatial-visual mapping methods and tools in landscape practices are provided through expert interviews. This underpins valuable information and knowledge from every part of the design industry, from describing landscape spaces in daily work, the practical use of different mapping methods and tools, dialectical opinions of digital techniques during their application, to recommendations of how to effectively implement technology into the design process.

The interviews point out that most of the digital mapping techniques (e.g. CAD, 3D landscape modelling, illustrated visualisations) widely used in current landscape/urban design practices are used as representation tools, in order to show landscape scenarios in a more realistic and performative way and also support designers to communicate with stakeholders and the public. Mapping methods containing quantitative measurements and spatial-visual analyses, which broaden the perception of landscape spaces, are still not fully applied and are often ignored in practice. However, almost all the interviewees showed interest in the integration and implementation of spatial-visual mapping methods in the future development of landscape architecture. Merging traditional and advanced mapping methods to describe landscape space advocates for a multidisciplinary approach towards landscape design while extracting, translating, and adapting theories and technologies, employing them to gain new visions of landscape spaces.

Through the interviews, recurring concerns about combining data and design thinking are discussed in-depth. Considering the limited capacities of technology, it is important to clarify the strengths and limitations of each mapping method and tool. Further investigation is needed to explore how to combine advanced and conventional processes and elucidate the compatibility of the mapping toolbox in a standard design situation. In addition, the interviews indicate that introducing advanced mapping methods with further analyses and measurements into landscape education is indispensable for training new generations of landscape architects. With the development of this integrated mapping toolbox, designers can engage in issues of landscape development, transformation, and preservation while providing realistic and instrumental clues for interventions in urban landscapes.

Vondelpark, Amsterdam (Photo by Mei Liu, 2020)

TOC

TOC

Vondelpark, Amsterdam (Photo by Mei Liu, 2020)

TOC

6 Synthesis and Outlook

Chapter six provides a discussion, conclusion, and recommendations drawn from this research. In order to answer the main research question, each of the sub-research questions are answered accordingly. Following this, reflections from theoretical and methodological perspectives are included. This comprises the limits to the theoretical basis of the research, methodological and data limitations, and technical restrictions. To deal with these challenges, recommendations for further research are discussed for the future of landscape practice and research.

6.1 Introduction

This research focuses on developing and implementing multidisciplinary mapping approaches to help describe the spatial-visual manifestation of landscape spaces. It includes the relationship between space-determining elements and their visual organisation from both a qualitative and quantitative perspective. The basic premise is that the form and functioning of three-dimensional landscape space creates a certain spatial dynamic and determines the relation between design and perception. The research provides insights for the measurement, interpretation, understanding, and communication of landscape spaces from a design perspective. This is achieved by identifying the spatial-visual properties of landscape design vocabulary, exploiting mapping methods and tools and their powerful capacity for integration, exploring the potential of mapping techniques in the design process, while investigating professional attitudes of implementing a mapping toolbox into daily practice.

The research starts from a comprehensive overview of design vocabulary which describes the construction and articulation of landscape spaces. Four dominant spatial-visual design terms are identified – sequence, orientation, complexity, and continuity – and are summarised, resulting in landscape architectonic compositions based on established landscape design syntax. In order to understand and communicate about these spatial-visual properties, mapping methods are of fundamental importance. They help designers study the framing of a view or urban panorama, the construction of a spatial sequence along a route, or the construction of a pictorial landscape composition. Adapted from previous visual landscape research, there are six principal mapping methods for exploring the spatial-visual characteristics of landscape, from both qualitative-quantitative perspectives and horizontal-vertical dimensions, which are compartment analysis, 3D landscapes, grid-cell analysis, visibility analysis, landscape metrics, and eye-tracking analysis. Vondelpark serves as a pilot study to demonstrate the application of these mapping approaches when analysing the spatial-visual organisation of the landscape. It complements and reveals new insights to understand landscape spaces in an inter-subjective way. To facilitate this, hypothetical design experiments are conducted to explore the role of the spatial-visual mapping toolbox in the design process. It provides a systematic framework of implementing mapping methods and tools, which are an essential means for thinking and communicating about the spatial-visual characteristics of the landscape during different design procedures. To strengthen the research, interviews with designers were carried out to reflect on techniques for mapping spatial-visual characteristics in the daily practice of landscape architecture in order to substantiate their ideals for the future of landscape design.

This chapter provides a discussion, conclusion, and recommendations drawn from this research. In order to answer the main research question, each of the sub-research questions will be discussed and answered accordingly. Following this, reflections from theoretical and methodological perspectives are included. This comprises the limits to the theoretical basis of the research, methodological and data limitations, and technical restrictions. To deal with these challenges, recommendations for further research will be discussed for the future of landscape practice and research.

6.2 Answers to Research Questions

6.2.1 Sub-question 1 (Chapter 2): Design Vocabulary

What are relevant spatial-visual landscape characteristics for landscape design?

A landscape architect's level of understanding on spatial-visual landscape properties are related to the vocabulary the landscape architect knows. As the breakthrough point and theoretical base, this research first sets up an extensive literature review in order to summarise the way in which designers commonly describe space in multidisciplinary fields, such as landscape architecture, urban design, architecture, visual landscape research, environmental psychological research, urban morphology, landscape ecology etc. These words make people aware of a certain spatial-visual phenomenon and implies a conscious observation and identification in terms of landscape architectonic compositions.

In this research, spatial-visual design vocabulary establishes the spatial organisation and visual experience composed by the content of landscape (i.e. vegetation, water, landform, structure) and form that, spatial elements are assembled (i.e. space and mass, edge, path, threshold, foci). Four dominant categories are identified, describing landscape architecture and related spatial disciplines, which are sequence, orientation, complexity, and continuity. To characterise these compositional properties, certain terms are indicated and a landscape design syntax is concluded. This represents the hierarchical structure (vocabulary, perspective, element, characteristics) of developing abstract spatial-visual concepts to detailed landscape characteristics. Overall, the exploration of the visual manifestation of landscape spaces (how space is organised) determines what ordering principles play an important role for understanding landscape spaces from a design perspective. Together with relevant mapping approaches, landscape architectonic compositions are depicted from both qualitative and quantitative dimensions.

The presented systematic framework shows the potential for recognising inter-relationships between sensory experiences of space and spatial landscape constructions. Considering landscape architecture as a complex process, experts from related disciplines (e.g. landscape ecology, urban morphology, hydrology, historical geography) use the same or different vocabulary to present spatial notions as well. As such, a framework is valuable for landscape architects to make distinct knowledge acquisition and promote better communication through design language and their visual interpretation instruments, but also from different disciplines through the design process.

6.2.2 Sub-question 2 (Chapter 3): Mapping Spatial-Visual Characteristics

What are potential mapping methods and tools to analyse and visualise spatial-visual landscape characteristics?

Landscape architects are often eager to develop and employ manual and digital media that can support thinking and communicating about spatial-visual properties of landscape architectonic compositions. Visual landscape research investigates the relationship among landscape architecture concepts, landscape perception approaches, and representation techniques. It can be divided into two main discourses: expert approaches and public preference approaches (Sevenant, 2010). Research on visual landscape mapping can be categorised into horizontal-vertical perspectives and qualitative-quantitative approaches. The horizontal perspective explores the landscape from an observer's point of view and addresses spatial-visual characteristics from an eye-level perspective. The vertical perspective considers the landscape from 'above' and analyses spatial patterns and relationships from a map view. Qualitative approaches are understood as the empirical interpretation of observation, while quantitative approaches gather numerical information or translate knowledge into numbers to describe and analyse certain phenomena more objectively. Though these discourses and perspectives are not mutually exclusive, this chapter mainly focusses on expert approaches, the mode in which landscape architects usually operate, to visual landscape research inter-subjectively.

TOC

Six types of spatial-visual mapping methods, including compartment analysis, 3D landscapes, grid-cell analysis, visibility analysis, landscape metrics, and eye-tracking analysis, are introduced to map four crucial spatial-visual design vocabulary (sequence, orientation, complexity, and continuity). Using Vondelpark as a pilot study, the mapping approaches demonstrate a great potential in the interpretation of spatial compositions and the visual organisation of landscape spaces substantially. These mapping methods and tools explore spatial-visual landscape properties based on various data types, mapping dimensions, and disciplines. They provide a fresh perspective and additional knowledge for landscape designers to understand the spatial-visual aspects related to landscape design. Thus, to gain a more comprehensive understanding of landscape space, it is better that they are used together instead of separately.

The overview of the mapping toolbox creates opportunities for landscape architects to describe and understand known and unknown aspects of landscape space. It shows enormous potential for the development of a digital culture in landscape architecture while exploiting advanced mapping methods and tools in their powerful integrative, analytical, and graphic capacities. Moreover, the application of mapping spatial-visual landscape also advocates for a multidisciplinary approach towards landscape design while, extracting, translating, and adapting theories and technologies from the fields of urban morphology, visual landscape study, and landscape ecology etc., in order to gain new insights of landscape spaces.

6.2.3 Sub-question 3 (Chapter 4 & 5): Application of Mapping Spatial-Visual Characteristics in Landscape Practice and Research

How to apply spatial-visual mapping methods in the landscape design process?

Hypothetical design assignments (research through design) are conducted on the site of Vondelpark to generate a normative investigation of implementing different mapping methods and tools for analysing and/or evaluating spatial-visual landscape aspects in an iterative design process. The methods are complementary, and in combination with an iterative design procedure; they help theorise and visualise landscape space in qualitative and quantitative ways, while providing verifiable and reliable clues for designers to make refinements accordingly.

Considering the site of this landscape suffers from problems related to climate change and the popularity of the park, four main spatial challenges are defined, which are: A) ever-increasing subsidence of the ground surface by drainage; B) increasing flood risk from heavy rainstorms; C) lack of visual connectivity with the surrounding neighbourhoods; and D) overcrowding and cycling. To show the capacity of the mapping toolbox, two hypothetical design experiments with different intentions are set up, including 1) the modification of Vondelpark, preserved as a cultural heritage site, but with minor improvements of the current spatial-visual organisation addressing the challenges stated above; 2) the design of a new urban park at the original site of Vondelpark to meet today's contextual requirements. All relevant geo-data and topographic datasets of the park are available as a basis for the construction of the Digital Landscape Model (DLM) (and its hypothetical changes) that serves as a basis for the computational analysis.

As the findings reveal, mapping throughout the design flow encourages sufficient consideration of spatial-visual context and consequences of design interventions. In a renovation design project, the mapping toolbox plays an important role in providing more precise and objective clues of understanding the original purpose of the design in order to maintain its historical value, while in a new design project, it is useful to recognise the site situation and the context. Through the mapping analyses, it is likely that the designer will identify specific spatial-visual problems that will guide the following design interventions. In addition, mapping the spatial-visual effects of before and after plans is helpful for landscape architects to evaluate the effectiveness of the design strategies and review whether the earlier requirements are achieved or not.

The research of implementing mapping methods and tools in the design process is important for landscape architects to understand, design, and communicate about landscape space. It opens a way for visual landscape characterisation supporting multidisciplinary approaches for landscape design. With the development of this toolbox, designers can engage in issues of landscape development, transformation and preservation, while providing realistic and instrumental clues for interventions in urban landscapes.

How to apply spatial-visual mapping methods in the landscape practices?

As exemplified by the previous research, spatial-visual mapping methods and tools have proven to be a powerful means in ex-ante and the post-analysis of landscape spaces during design. The interviews with eleven experts from various design practices, multiple levels of government, and academia are carried out, in order to investigate how and what means are used by spatial designers to map and describe landscape spaces in their day-to-day work, and also to discuss whether the mapping approaches have the potential to be part of a set of design tools in the landscape design process.

To conclude, mapping approaches, such as 3D modelling, rendering, and photo-realistic illustrations, are widely used to simulate design and planning ideas for visualisation and communication purposes in design. In recent years, real-time interactive presentations and virtual reality environments are also employed to represent landscape spaces, especially in assessment and participation processes. As a design tool, conventional mapping methods like hand-drawings are still the main way for describing, interpreting, operationalising, and polishing design concepts into landscape architectonic compositions at any moment. Reflecting on the interviews, advanced mapping methods and tools with quantitative analysis (e.g. GIS, space syntax, landscape metrics) are hardly applied in daily landscape design because of technical barriers and communication issues (lack of common languages).

After being introduced to the potential of spatial-visual mapping methods and tools via previous research, most of the interviewees showed increasing interest and positive attitudes about the importance of spatial-visual landscape characteristics, but also the analytical and validated achievement of the potential methods and tools. In order to implement mapping approaches in the further development of landscape architecture, educational and research institutions have an important part to play in raising awareness, and should take the lead in educating students, inspiring practitioners, building knowledge, passing it on, and adding new tools to the traditional craftsman's toolbox.

6.2.4 Conclusion of the Findings

To achieve the main research objective, this thesis provides a systematic framework to identify spatial-visual landscape characteristics and implement mapping methods and tools to describe landscape spaces inter-subjectively and from a design perspective. A mixed method approach is used in which, first, a comprehensive literature review is undertaken to understand the nature of design vocabulary for landscape architectonic compositions. The sequence tends to be done in adapting and applying different mapping methods and tools to depict spatial-visual characteristics through a pilot study in both qualitative and quantitative ways. Hypothetical design assignments are conducted to show the potential to implement a mapping toolbox in an iterative design process. Then, in-depth interviews with experts are organised to talk about the existing situation of using mapping approaches in the design world and the future development of this research in practice and theory. The conclusions are as follows:

1. Based on the analysis of the vocabulary used in the extensive body of literature available in landscape architecture and related disciplines, four dominant categories in describing spatial-visual organisations are identified: sequence, orientation, complexity, and continuity.
2. The landscape design syntax developed in this research helps understand and describe the spatial-visual manifestation of landscape spaces based on a scientific framework through four levels, which are design vocabulary, perspective, element, and characteristic.
3. According to visual landscape research, there are six predominant mapping methods which can be summarised and are available and efficient for interpreting and understanding spatial-visual landscape characteristics from a designer's point of view, including compartment analysis, 3D landscapes, grid-cell analysis, landscape metrics, visibility analysis, and eye-tracking analysis.
4. Horizontal, three-dimensional mapping methods (i.e. 3D landscapes, visibility analysis, and eye-tracking analysis) provide complementary interpretations on visual properties to vertically two-dimensional methods (i.e. compartment analysis and landscape metrics) which mainly concentrate on spatial attributes.
5. Mapping methods based on measurements (i.e. grid-cell analysis, visibility analysis, landscape metrics, and eye-tracking analysis) offer more precise spatial-visual clues of landscape compositions than qualitative conventional mapping methods (i.e. hand-drawn compartment analysis and 3D landscape visualisations).
6. Considering that each mapping method has its own merits, it is crucial to combine horizontal-vertical dimensions, subjective-objective (inter-subjective) perspectives, qualitative-quantitative methods, to gain a comprehensive understanding of landscape pictorials and dynamics.

7 The implementation of mapping approaches during the design process (hypothetical design experiments) not only demonstrates considerable potential to gain an understanding of the spatial-visual character of the landscape for ex-ante analysis, but also evaluates and compares the consequences of design interventions in the post-analysis stage.

8 Mapping techniques play an important role in the iterative design process, while analysing, designing, evaluating, and refining the design, and the mapping results become part of the design iterations, in which the designer gains a better understanding of landscape space and makes changes and refinements accordingly.

9 In current landscape practices, mapping methods, such as 3D landscapes and GIS, are widely used by landscape architects as visualisation tools in the communication and participation stages, while traditional, but classic, hand-drawings are still the predominant way to communicate design concepts for landscape architectonic compositions in the design phase.

10 Digital mapping techniques with quantitative analysis is still lacking in design practices. A few possible reasons are related to time and cost factors and the technical barriers of the preparation of data and building models. This approach also only focuses on the spatial-visual aspects of landscape spaces but leaves out other aspects such as social and cultural values.

11 The achievement of applying mapping methods and tools to describe landscape spaces in this research helps the experts (interviewees) raise awareness of spatial-visual characteristics. In addition, they showed great interest in the mapping toolbox in order to gain more rational, precise, verifiable knowledge from inter-subjective perspectives.

12 Educational and research institutions have an important part to play in leading the education of students and inspiring practitioners, building up their knowledge and passing it on, and adding new tools to the traditional craftsman's toolbox.

6.3 Limitations

6.3.1 Theoretical Limitations

Landscape architecture is both a practical and research-based discipline, incorporating integrated approaches that mainly deal with form and meaning. It not only contains physical arrangements, but also values from various disciplines. The basis of this thesis is on mapping architectonic compositions of landscape space from a spatial-visual perspective. Mapping methods and tools are established to address spatial compositions and visual organisations, which is further indicated by the selected design vocabulary. Thus, mapping approaches displayed in this research cannot fully represent the intact quality of landscape space. Although the implementation of mapping methods in the design process proved to be useful in analyses and communication about the spatial-visual characteristics of landscape space, functional uses, symbolic meanings, social, cultural, and ecological aspects must also be included. The systematic framework developed in Chapter 2 shows the potential for extending design principles through the exploration of the inter-relationship between additional design vocabulary (e.g. design notions related to landscape preference, interactive emotions, symbolic connotations, environmental psychology, and ecological sustainability), and corresponding landscape compositions and configurations. On these bases, the vocabulary cloud for spatial-visual characteristics could be extended. Moreover, the established network analysis only shows a networked structure of the spatial-visual design vocabulary without attaching weights to clarify specific “compose and be composed” relations. The consequence of network analysis and dominant design vocabulary might be alternated, however, these will not influence the mapping methods and tools. In addition to describing and comprehending landscape from a positivistic perspective, there is potential to explore and demonstrate the relationship between humans and nature by taking a phenomenological mapping approach as well. Considering landscape design as a multidisciplinary process, in the future, a framework as such is valuable for landscape architects to make distinct knowledge acquisition and promote improved communication across different disciplines throughout the design process.

6.3.2 Practical Limitations

This research has merged design thinking into data-generated mapping methods and attempts to explore integrated possibilities for describing landscape spaces inter-subjectively. The mapping results show great potential for enhancing the advancement of landscape architecture and extends the toolbox of knowledge-based landscape design, however, they do not replace traditional means such as hand-drawn sketches and models. These conventional mapping methods are more effective for designers to achieve dynamic design intentions and an instantaneous realisation of design concepts, which are still the operative way to express creativity during the design process.

The mapping methods introduced in this research are more like complementary tools for landscape architects to communicate design intentions and validate the interventions. They are powerful for providing rational and validated clues to analyse and evaluate landscape characteristics in the ex-ante and post-analysis stage of design procedures. Nevertheless, most of the advanced mapping approaches adapted from other disciplines require designers to have specific knowledge as a basis to interpret the results. Also, considering data availability, access to the platform and software, budget limitations of a project, time and cost of data preparation, and analysis, landscape architects are often restricted and unable to address complicated measurements and perform critical evaluations. To solve this problem, educational and research institutions have an important role to play, they should take the lead in knowledge acquisition and the development of a digital culture in landscape architecture.

6.3.3 Technical Limitations

The mapping methods used in this dissertation also have limitations in terms of data acquisition, processing time, and technical skills. Most of the results are dependent on the quality of the data and existing calculation formulas. For instance, even though the Digital Terrain Model used in the pilot study of Vondelpark is a very precise raster dataset and includes all topographic elements (e.g. landform, build structures, vegetation etc.), it has major restrictions in visibility analysis from an eye-level, especially because it is hard to distinguish if vegetation canopies block sightlines or not. In that respect, using 3D point cloud technology provides promising clues to achieve more accurate results. However, 3D point cloud data processing and analysis requires high levels of processing capacity, which is not always possible in practical terms. The grid-cell analysis produced via SegNet platform also shows an inexact identification of spatial components from photographs, which causes certain deviations for further analysis. Eye-tracking analysis depends also on the size of the sample (in this case only fifteen respondents) which is statistically not significant. A larger sample size will not only increase the accuracy of the findings, but it will also have an effect on practical and organisational aspects, like how many eye-tracking devices one needs, and the processing of huge amounts of data. The next step would also be to include the dynamic aspects of spatial-visual perception using videos instead of static photographs. Further research is needed to identify and address practical hurdles of the implementation of advanced mapping methods and tools in design.

6.4 Recommendations

6.4.1 Recommendations for Landscape Practices

This research reveals a new way for landscape architects to understand landscape spaces by providing potential mapping methods and tools to describe and communicate about the spatial-visual quality of the landscape, from both a qualitative and quantitative perspective. As a powerful means for design thinking and representation, exploiting mapping approaches for their analysis, interpretation, and evaluative abilities shows how these can be implemented into landscape practices. Throughout the research, three main aspects could be further developed in the future of landscape architecture practice processes: 1) enhancing an awareness of landscape architectonic compositions; 2) encouraging the usage of data and digital technology in a real design project; 3) educating landscape architects with advanced mapping methods and tools.

As is already known, landscape design is about the construction and articulation of landscape architectonic compositions which results in physical, functional, and aesthetic effects. Because of every individual's subjective agenda, each designer cannot have a consistent interpretation of landscape spaces. However, no matter the intention, spatial-visual properties should be a substantial basis for understanding and reaching a certain landscape quality. Instead of only focusing on pragmatic problems, raising the awareness of spatial-visual characteristics could be helpful for designers to more deeply understand the site and context and provide sustainable and flexible ways to design the space and guarantee certain design outcomes.

With the development of open data all over the world, governments have rich and valuable datasets for various aspects, such as demographics, economics, ecology, geography, energy, health, GPS, climate sensors, the physical environment, transportation etc. Some of the data carries accurate spatial and geo-located information and attributes which has the potential to help identify, understand, and analyse spatial problems or evaluate the effectiveness of a proposed design plan to strengthen design thinking. It is essential to encourage landscape designers and planners to make full use of these datasets and apply advanced mapping technologies in their day-day work, connecting design decisions with more comprehensive information from other disciplines, in order to work with the increasing complexity of current practical projects.

Education of mapping toolboxes is indispensable for new generations of landscape architects in order to learn about an inclusive way of understanding landscape spaces, but also in its capacity to analyse, evaluate, and guide design at work. Teaching inter-subjective mapping methods helps landscape researchers and landscape architects develop research by design and design by research skills. The implementation of this mapping toolbox could provide precise and unbiased guidance for designers in the design process, while designs produced in different projects can supplement to the body of design principles.

6.4.2 Recommendations for Future Research

This research provides a comprehensive overview of using mapping methods and tools to describe spatial-visual aspects of landscape spaces from a design perspective, which can be seen as the first step in the development of a digital cultural in the design process. Following current stages of achievement, there are three main directions which have the potential to evolve: 1) extending the knowledge of additional design vocabulary; 2) combining expert mapping approaches with public perception research, 3) developing a more precise and complete mapping toolbox.

Firstly, the systematic framework developed to characterise spatial-visual properties shows great potential to explore the inter-relationship between design language and corresponding landscape compositions and configurations. Considering that landscape design as a multidisciplinary process, a possible framework should be further investigated in order to extend design principles by linking landscape architectonic compositions and vocabulary from other disciplines, such as social economics, interactive emotions, symbolic connotations, environmental psychology, and ecological sustainability. Under these circumstances, landscape architects can make distinct knowledge acquisition from relevant research fields and promote better communication with different stakeholders in the future. Meanwhile, based on the established network analysis, the relationship between each design vocabulary could be weighted in order to clarify the specific “compose and be composed” relations, which might directly influence the ultimate dominant design vocabulary.

Secondly, visual landscape research integrates landscape architecture concepts, landscape perception approaches, and mapping methods and techniques. This dissertation focuses on the rational results of mapping landscape spaces, especially of spatial-visual aspects, but lacks a subjective assessment of users’ perception of landscapes. Based on the analysis and evaluation of landscape spaces performed by experts and trained observers, in public perception approaches, psychophysical, psychological, social, and phenomenological effects of the spatial-visual organisation could be added as a new direction in the future development of this research in order to test and evaluate visual properties and experience of the landscape.

To forecast the future of mapping landscape spaces, abundant mapping techniques adapted from related disciplines should be explored sequentially as an important means for designers to inter-subjectively understand landscape spaces. Most of the mapping methods shown in this research have limitations in terms of data precision and technique. Nowadays, instead of a Digital Terrain Model, where it is difficult to distinguish realistic vegetation shapes, using 3D point cloud data could provide a solution for designers to achieve a more accurate simulation of landscape spaces (visibility analysis). Moreover, mapping technology with real-time presentation and analysis following design interventions could be another direction for landscape architects to avoid time-consuming data analysis and gain immediate feedback based on the refinement of design plans (eye-tracking analysis, landscape metrics). Last but not the least, nowadays, to manage the enormous urban or landscape datasets (i.e. satellite imagery, environmental sensors, social data from the internet), deep learning or machine learning based on cybernetic techniques are being applied to perform evaluation, design, construction, and post-occupancy tasks of landscape spaces (Tebyanian, 2020). The on-going exploration and application of deep/machine learning can effectively help classify and calculate landscape features (grid-cell analysis), understand inner-relationships between spatial patterns and performances (landscape metrics), or simulate landscape transformations etc.

6.5 Conclusion

The aim of this research is to provide a framework for describing, understanding, and communicating about landscape spatial-visual characteristics in landscape design. This begins with a discussion of spatial-visual design vocabulary, an exploration of mapping methods and tools, their implementation into the iterated design process, and an investigation of the reflections of mapping spatial-visual characteristics from landscape practitioners. Firstly, this research explores the nature of design vocabulary and the way of characterising landscape architectonic compositions. Then, mapping methods and tools are summarised and applied in order to interpret the spatial-visual characteristics of landscape spaces. Further, the research shows the feasibility of implementing potential mapping toolbox into an iterative design process in order to provide more precise and objective clues as references for design decisions. Finally, expert interviews are conducted to understand the attitudes of practitioners in using advanced mapping techniques, and recommendations of employing more mapping methods with a quantitative analysis of the future of landscape practices.

The results show that mapping spatial-visual landscape characteristics have great potential for landscape architects to discuss landscape spaces from an inter-subjective perspective. The overview and analysis of design vocabulary is a useful step in establishing an improved knowledge base and form of communication for spatial designers through landscape architectonic compositions. The mapping applications introduce new ways to visualise and comprehend landscape spaces from both qualitative and quantitative perspectives, which are able to make design proposals more comparable and increase inter-subjectivity and transparency in design competitions. As exemplified by the hypothetical design assignments, the applied mapping toolbox also demonstrates powerful analytical, evaluation, and graphic possibilities and effectively connects with design concepts and multidisciplinary disciplines throughout the design process. Each method has its own strengths and weaknesses. Employing them consecutively enables designers explore different aspects of landscape space in complementary ways. As the results reveal, the exploration of mapping technology for describing landscape spaces are crucial for enhancing the awareness of spatial-visual characteristics of landscape architecture and extending knowledge-based landscape design. With a greater understanding of design vocabulary and the development of corresponding mapping methods in the future, landscape architects can engage in issues of landscape development, transformation, and preservation while providing realistic and instrumental clues for interventions in landscape design processes.

Vondelpark, Amsterdam (Photo by Mei Liu, 2020)

TOC

APPENDIX A

Detailed Literature Review about Design Vocabulary

1 Relevant Literature about SEQUENCE

SEQUENCE (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Sequence	Lynch, 1960	Urban design	Landmarks, joints, space changes, dynamic sensations along the movements.	Hand-drawing maps
Sequence	Simonds, 1961	Landscape	Fluid design of modulations of objects, spaces, and views.	Hand-drawing diagrams
Sequence	Thiel, 1961	Architecture/ urban design	Relationship between surfaces, screens, and objects in over, side, and under positions.	Hand-drawing graphic notations
Sequence	Cullen, 1961	Urban design	Serial vision: a series sudden contrasts and visual impact to reveal the mystery during the movement.	Perspective sketches
Sequence	Appleyard, Lynch, & Meyer, 1964	Landscape (highway)	Topography (road elevation, boundary of water system) landmarks, pavements, and human senses.	Hand-drawing maps, oblique and ground photos, perspective sketches, movies, preliminary viewshed analysis
Sequence	Litton, 1968	Landscape	Recording contrasts/changes in landscape attributes with the principles in purpose, form, space, and scale.	Perspective sketches, hand-drawing maps

>>>

TOC

SEQUENCE (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Sequence	Jakle, 1987	Landscape	Combination of prospect and refuge. The search for the recognition of vistas, enclosure, enclave, point of pause, speed of the movement.	Photos
Sequence	Colville National Forest, 1989	Landscape	The series of viewed or potentially viewed spaces and features as an observer might experience them from a road, trail, waterway, or other travel routes.	/
Sequence	Sutton, 1992	Landscape	Sequence is the linear order and direction of the rhythmic movement.	/
Sequence	Crandell, 1993	Landscape	Visual organisation composed by a series of 'pictorialisation' (stage settings) and its sequence.	Photos
Sequence	Ohno & Kondo, 1994	Landscape	Visual sequential-experience relates to ambient visual information perceived from surrounding scenes and also focal visual information taken when focusing on symbolic objects. Using indicators to measurement the visual information.	Measurements
Sequence	Loidl & Bernard, 2003	Landscape	Spatial sequences are connected, independent spatial situations that refer to each other through their access links (from closed to open spaces);	Graphic notations
Sequence/ Order	Dee, 2004	Landscape	Sequential experience refers to the characteristics of edge, spaces, paths, and thresholds.	Sketches
Sequence	Robinson, 2004	Landscape	The appearance of a planting composition changes or unfolds before the observer.	Hand-drawing graphic notations
Sequence	Ronnen, Demera, Kawasaki, & Higuchi, 2005	Landscape	Refers to the total experience of the observer and participants in the landscape.	Measurement, photos, maps, graphic notations
Sequence	Jackson, 2008	Landscape	Sequence is a natural way of directing the vision to a desired point of focus. It is a result of gradual variations in colour, texture, size and shape.	/
Sequence	Booth, 2011	Landscape	Moving experience refers to the degree of enclosure, descriptive qualities, path travelled, connections and thresholds, and views for each space in association to adjacent spaces.	Hand-drawing graphic notations
Sequence	Nijhuis, 2011 Nijhuis, 2014	Landscape	Stacking of individual isovists and shows the gradual change of visible space by moving forward; The sequence of the views in relation to distance, time, and height of the path.	Isovist, GISc-based measurement, 3D models, statistics

>>>

TOC

SEQUENCE (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Sequence	Queensland Government, 2013	Landscape	A successful landscape sequence will contain the following: breaks in vegetation; alternation of closed forest themed landscapes with open forest themed landscapes, at appropriate locations; consistent treatments along the road cross section; for example, batter and embankment slopes, street furniture and so on; and use of appropriate visual cues to establish location along a journey.	Graphic notations
Sequence	Blumentrath & Tveit, 2014	Landscape	The creation of sequence is part of visual design of road landscape, and also enhancing orientation, range from facilitating views from the road (e.g. transparent noise screens), the use of road art, to the illumination of landmarks (e.g. bridges, churches).	/
Sequence	Fathi & Masnavi, 2014	Landscape	vegetation as a key element in scenic beauty should be distributed in a way that create successive sequences of landscapes with enough variety to be more attractive and less complex at the same time.	Photos
Sequence	Qin, Gao, & Shen, 2016	Landscape	Road landscape environment space forms can be assorted into three forms in terms of the distribution characteristics of natural road landscape elements: flat form, wave form, and climax form, with some changes of form, colour, and texture.	Measurements, photos
Sequence	Apostol, Palmer, Pasqualetti, Smardon, & Sullivan, 2016	Landscape	Sequence includes varying views, vistas, and features. It creates an interplay between built and natural appearing elements that highlights visual variety and can create a sense of intrigue and relief.	/
Rhythm	Appleyard, Lynch, & Meyer, 1964	Landscape	Particular visual rhythms set by various kinds of channels – freeways, collectors, local streets etc.	Sketches
Rhythm	Jakle, 1987	Urban design	The sequence of repetition: height/depth, constriction/openness, or darkness/light.	Photos
Rhythm	Sutton, 1992	Landscape	Rhythm is driven by the searching of human vision.	/
Rhythm	Bell, 1996	Landscape	Similar elements repeated at related regular or similar intervals create rhythms, especially when there is also a strong sense of direction involved.	Photos, graphic notations
Rhythm/ Ordering	Motloch, 2000	Landscape	The rhythm unifies a composition through the reoccurrence of similar items which can be created through line, form, colour, value, or texture. The diurnal rhythm changes scale, character, and mood from day to night.	Hand-drawing graphic notations

>>>

TOC

SEQUENCE (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Rhythm	Loidl & Bernard, 2003	Landscape	Non-directional sequence with a characteristic combination repeat again and again.	Graphic notations
Rhythm	Robinson, 2004	Landscape	Rhythm of the space can be regular and simple, or more complex and varied	Hand-drawing graphic notations
Rhythm	Jackson, 2008	Landscape	Rhythm is a result of repetition. Three objects are needed for a rhythm to be noticeable. When rhythms are established, the observer has a better connection to the land.	/
Rhythm	Booth, 2011	Landscape	Rhythm of a line is locating regularly spaced variations directly on the line or its edge.	Hand-drawing graphic notations
Rhythm	Marciniak, 2011	Landscape	Rhythm sets up those patterns, leading the eye to the next point, and the next, and the next. There are five flavours of rhythm: Repetition and alternation; Progression or gradation; Transition; Opposition or contrast; Radiation	Photos
Rhythm	Ching, 2014	Architecture	Movement characterised by a patterned repetition or alternation of formal elements or motifs in the same or a modified form.	Hand-drawing sketches
Rhythm	Kiss, 2017	Landscape	Rhythm is created by directing the eye across the scene in a progressive pattern.	/

2 Relevant Literature about ORIENTATION

ORIENTATION (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Orientation	Appleyard, Lynch, & Meyer, 1964	Landscape	The most powerful experiences occur when space, motion, orientation, and meaning reinforce each other-when a landmark that is rooted.	Hand drawing maps
Orientation	Newton, 1971	Landscape	Path patterns and shape of the pool influence the orientation of urban blocks. (La Couronne case study)	Hand-drawing maps, photos
Orientation	Appleton, 1975	Landscape	Both the prospect-refuge theory and the information processing theory suggest that half-open landscapes would get the highest ratings, and the least open landscapes, which offer less prospect or ability for orientation.	Questionnaires, statistics
Orientation	Lynch, 1981	Urban design	The need for spatial orientation is to know where, or how far, you are. The formal structure of the landscape and the presence of local and distant landmarks are important factors in this respect.	/
Orientation	Sanoff, 1991	Visual research	Modifications in the physical characteristics of our surroundings can strongly affect our sense of orientation: demolition of buildings, or changes in the system of paths, can sometimes deprive us of important reference points. Visual access, or the ability to differentiate environmental features, is a factor that influences people's spatial orientation (Garling, Book, & Lindberg, 1986).	Cognitive/ behaviour maps, sketches, photos
Orientation	Baker, 1992	Landscape ecology	Each Disturbance Patch: Orientation - compass direction of central axis of a patch. (spatial elasticity)	Graphic notions, Measurement
Orientation	Chalmers, 1993	Landscape	Landmarks visible from most of the region allow for orientation.	Preliminary GIS maps
Orientation	Yahner, Korostoff, Johnson, & Battaglia, 1995	Landscape	Creating landmarks like signage can provide orientation. Also open views can give a sense of orientation.	Maps
Orientation	Dramstad, Olson, & Forman, 1996	Landscape ecology	A patch oriented with its long axis parallel to the route of dispersing individuals will have a lower probability of being (re-)colonized, than a patch perpendicular to the route of dispersers.	Hand-drawing graphic notations
Orientation	Fu & Rich, 1999	Landscape	Surface orientation as an import variable affects the spatial patterning of natural processes and human endeavour.	Solar analysis by GIS
Orientation	Lyle, 1999	Landscape	Shaping openness or slopes to indicate the orientation. (the high meadow case study)	Hand-drawing sketches, maps

>>>

TOC

ORIENTATION (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Orientation	Carr, 1999	Landscape	Path and vista of the mall provide the orientation.	Hand drawings
Orientation	Bell, 1999	Landscape	Orientation is a combination of position and direction. The position of an element in relation to a particular compass direction, the observer or some other factor, e.g. wind or sun direction.	Hand-drawing graphic notions, photos
Orientation	Thwaites, 2001	Landscape	The presence of strong visual devices, such as landmark features, vistas and views, is important because they help emphasize a sense of direction as well as providing orientation aids.	/
Orientation	Doner, Lertzman, & Fall, 2002	Landscape	To capture directionality of patches and patch edges, we compute edge orientation, expressed as the angle between direction of patch edge and slope direction. Thus, we compute patch orientation, defined for each patch, as the ratio of (length of) patch edge following the slope direction (angle with slope < 30 degrees) to length of patch edge across slope (angle with slope > 60 degrees).	GISc
Orientation	Loidl & Bernard, 2003	Landscape	Changing the surface, the width of the path, or marking a change of significance like a junction may mean a change of orientation. Focal points are essential for creating orientation.	Graphic notations
Orientation	Ronnen, Demura, Kawasaki, & Higuchi, 2005	Landscape	The direction and orientation of the streets and pathways relates to the directionality of its surrounding mountains.	Maps, graphic notations
Orientation	Attia, 2006	Landscape	This pattern provides the physical continuity of the axes in the form of the unbroken channels. In addition, the inward orientation towards the centre is apparent, and is furthermore emphasized by the direction of the centripetal water flow.	Maps, photos
Orientation	Wissen, Schroth, Lange, & Schmid, 2008	Landscape	For a better orientation, viewpoints were chosen that are easily recognisable due to landmarks.	3D virtual visualisation based on GIS
Orientation	Booth, 2011	Landscape	Path axis can shape the orientation. Changing eye direction can transform the orientation. Shape of the spaces also influence the orientation.	Graphic notations
Orientation	Nijhuis, 2011	Landscape	Visible openings and foci provide orientation.	3d models, isovist analysis
Orientation	Yahia & Johansson, 2014	Urban design	Seasonal thermal aspects influence the design of landscape elements resulting in the orientation.	Solar analysis via ENVI-met.

>>>

ORIENTATION (Spatial-visual organisation / design vocabulary)				
Synonym	**References**	**Research field**	**Description of the composing spatial-visual characteristics**	**Method of representation**
Orientation	U.S. Department of Transportation, 2015	Landscape	The community's cultural landmarks particularly provide orientation.	/
Direction	Lynch, 1960	Urban design	Paths constitute the line of motion, which should have clarity of direction. Objects along the path can help to sharpen the effect of that motion. Events along the path, such as landmarks which are in contrast with its context, also facilitate clarity of image. Edges provide the opportunity to differentiate and evoke the sensations of being inside or outside. Nodes are the anchor points in cities; this type of element implies a distinct place, one that is defined with clear boundaries and an intensity of use (also guide visual directions).	Maps
Direction	Cullen, 1961	Urban design	Looking from Hawksmoor's great forum into another place whose individuality, direction and character is unequivocally stated by the two monuments (edge mountain).	Sketches, photos
Direction	Newton, 1971	Landscape	When one looks in a fixed direction, the line along which he looks is called a sightline, a series of spaces depends in large part upon discernment of the relationships between or among the sightlines.	Photos
Direction	Clouston, 1977	Landscape	Medium to large shrubs are used largely to give direction, provide enclosure and privacy and to obstruct or frame a view. Edge height also causes direction. Where a change of direction is desired, groundcovers as well as trees and accent shrubs can be used to create pivot points at which one is physically and visually forced to change direction.	Hand drawing graphic notations
Direction	Booth, 1989	Landscape	Threshold, open space, edge, visual, foci	Hand-drawing graphic notations
Direction	Sanoff, 1991	Urban design	Perception of motion and space includes self-motion, such as speed and direction, and the motion of the visual field: passing alongside, overhead, or underneath. Spatial characteristics include the position of enclosing surfaces, proportions of space enclosed, quality of light, and the views which direct the eye to different aspects of the enclosed space.	Hand drawing maps, graphic notations

>>>

TOC

ORIENTATION (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Direction	Bell, 1996	Landscape	A description of the position or location of elements which lead the eye from one part of a composition to another. The shape of an element may imply direction. In the landscape, lines such as paths or roads often produce a sense of direction and lead the viewer towards them. The position of clumps of trees may be precisely designed to direct the eye towards a particular feature, perhaps a point element designed as an 'eye- catcher'.	Photos
Direction	McClelland, 1998	Landscape	Path and path edge can influence the change of direction. Open views also indicate shift orientation.	Photos
Direction(ality)	Baskent, 1999	Landscape ecology	For both the edge progressive and nuclei progressive strategies, the spatial direction of harvest progression is guided, at each iteration, by forecast volume loss of stands geographically suitable (adjacent) for harvesting in the period.	Statistics
Direction	Motloch, 2000	Landscape	Threshold, foci, edge	Graphic notations
Direction(ality)	Ronnen, Demura, Kawasaki, & Higuchi, 2005	Urban design	The direction and orientation of the streets and pathways relates to the directionality of its surrounding mountains. The second element, directionality, refers to the directionality of path, and the directionality of the mountain's natural feature.	Graphic notation, maps
Direction	Beck, 2012	Landscape	Edges indicate landscape direction from the ecological perspective.	/
Direction	Queensland government, 2013	Landscape	Wayfinding in the road landscape provides direction.	Photos
Direction	Fathi & Masnavi, 2014	Landscape	This spatial organisation can be accentuated through going uphill or downhill and having turns on the road and the conformity of changes in the landscape with these variations in the direction of sight.	/
Direction	U.S. Department of Transportation, 2015	Landscape	Viewsheds are directional to a traveller on a highway. The viewshed for a traveller moving in one direction can be quite different from that of a traveller moving in the opposite direction, even at the same point along a highway.	Hand-drawing viewshed maps, aerial photos
Legibility	Smardon, Palmer, & Felleman, 1986	Landscape	The correlation of legibility with landscape pattern indices in the foreground and mid-ground also suggests that legibility is arrived at via the observer's interpretation of his/her immediate surroundings.	/

>>>

TOC

ORIENTATION (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Legibility	Kaplan, Kaplan, & Ryan, 1998	Landscape	To increase legibility, a scene has to have some memorable components that help with orientation. In a legible place, one can imagine finding one's way, not only to a destination but back again as well. An opening can increase legibility by serving as a landmark.	Maps, photos, hand-drawing sketches
Legibility	Franco, Franco, Mannino, & Zanetto, 2003	Landscape	Perceptive legibility: the open spaces and enclosure configuration allow the identification possible paths	Maps, photos, statistics
Legibility	Herzog & Leverich, 2003	Landscape	Legibility refers to features of the larger environment that foster understanding by aiding wayfinding and the building of a useful cognitive map. Visual access, openness, and landmark can be major components of legibility in a forest setting.	Photos, statistics
Legibility	Stamps, 2004	Landscape	How easy would it be to find your way around the environment depicted to figure out where you are at any given moment or to find your way back to any given point in the environment.	/
Legibility	Talen, 2006	Urban design	Edges are supposed to bound and give shape and identity (or legibility), but ideally, they are supposed to function like seams and lines of connection rather than barriers.	Maps, photos
Legibility	Fuente de Val, Atauri, & de Lucio, 2006	Landscape	Legibility: permeability of the scene, accessibility, and ease of orientation. Legibility correlated with several spatial pattern indices (number of patches, diversity, and evenness). The more legible landscapes were those found to be less heterogeneous, suggesting that a smaller number of patches may create a greater sensation of landscape legibility.	Maps, photos, statistics
Legibility	Kaymaz, 2012	Landscape	Legibility: The concept of legibility is about orientation. Landmarks or focal points may increase the legibility of a setting. Spaciousness also supports legibility by increasing the individual's range of vision.	/

>>>

TOC

ORIENTATION (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Legibility	Queensland government, 2013	Landscape	Legible areas are those where users can identify where they are and how to get to their destination. Legible layouts with an obvious arrangement of spaces and distinct visual patterns ensure that users can read the landscape. Clear and recognisable symbols assist in providing identifiable and memorable points of reference. There are also other aspects, or visual cues that contribute to the creation of legible spaces which includes paths, edges, precincts, nodes, and landmarks.	Photos
Legibility	Rega, 2014	Landscape	The scenic assessment supported this landscape project by mapping the rural areas which play a role in maintaining the legibility of historic and symbolic landmarks, and the openness towards important landscape frames in the background, such as the Alps.	Maps, photos

3 Relevant Literature about CONTINUITY

CONTINUITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Continuity/ Continuance	Lynch, 1960	Urban design	Continuity: continuance of edge or surface; nearness of parts; repetition of rhythmic interval; similarity, analogy, or harmony of surface, form, or use. A landmark feature may be so alien to the character of a district as to dissolve the regional continuity, or it may, on the other hand, stand in just the contrast that intensifies that continuity. Edges as well as paths call for a certain continuity of form throughout their length.	Graphic notations, photos,
Continuity	Newton, 1971	Landscape	Curve shape of riverside has a controlled sweep and continuity effect.	Photos
Continuity	Trancik, 1986	Urban design	Lack of continuity at intersections could be overcome by regular lines of tree to the benefit of both the grid and the diagonal.	Maps
Continuity	Sanoff, 1991	Visual design	An orientation sequence diagram would describe the continuity of the path, the elements associated with the path, and the location of decision points.	Graphic notations
Continuity	Lefebvre, 1991	Urban design	Visible boundaries, such as walls or enclosures in general, give rise for their part to an appearance of separation between spaces where in fact what exists is an ambiguous continuity. The street's continuity, meanwhile, is founded upon the alignment of juxtaposed facades.	/
Continuity	Yahner, Korostoff, Johnson, and Battaglia, 1995	Landscape ecology	Another important ecological objective aimed at countering the deleterious impacts of habitat fragmentation was to establish habitat linkages and connectivity between significant existing wildlife habitat areas (Harris, 1984). Wherever possible, a continuous forested strip with a minimum width of 100 m (330 ft) would be established within the trail corridor to connect both existing and reforested patches of valley forest (Ranney et al., 1981).	Graphic notations

>>>

TOC

CONTINUITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Continuity	Bell, 1996	Landscape	Continuity: The sense of a pattern or landscape extending as a similar character over space or time; the use of repeated elements or characteristics in a design or their occurrence in nature. The edges of planes laid end to end can create a continuous line as the eye runs along the contiguous edge. Continuity will be strong, giving a visual result which is harmonious, balanced and in scale with the landscape. These lines represent continuity of movement and time—cyclical or linear but varied in frequency and intensity. Interconnections between patterns at different scales also contribute to continuity. In many natural patterns the repetition of a particular shape at a range of sizes and scales, according to fractal geometry, represents an aspect of continuity which can be seen from a range of observer positions.	Photos, graphic notations
Continuity	Herrington & Studtmann, 1998	Landscape	The serpentine path modified the children's spatial experience and understanding of the yard because it offered a continuous line of movement that was distinct in character.	Photos
Continuity	Homma, Morozumi, & Iki, 1998	Urban design	Continuity: Continuity of the skyline and colours of the site with the facility.	Maps, 3d models, photos, measurement
Continuity	Thwaites, 2001	Landscape	A sequence of long and short views terminating in landmarks, along which are variations in shape and size of space, heightens awareness of a setting by emphasizing a series of revelations, strengthening the experience of progression and continuity (Cullen, 1971; Kaplan et al., 1998; Rudlin & Falk, 1999).	/
Continuity	Jim & Chen, 2003	Landscape	At the city scale, three major greenways, including city-wall circular greenway, Inner-Qinhuai River greenway, and canopy-road greenway, are designed as a permeating framework to guide new greenspace location, configuration and continuity, and to link existing parks. Tree-lined streets can be enlisted as green corridors to provide continuity to the greenway network where the drainage system cannot reach.	Maps, graphic notations

>>>

TOC

CONTINUITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Continuity	Thwaites, Helleur, & Simkins, 2005	Landscape	Continuity represents spatial sensations that make us aware of what is beyond the immediate location. Continuity echoes the linear attributes of corridor. Continuity characterised by an unfolding sequence of existing and emerging views. Engender sensations of continuity, a sense of there-ness and future possibility through, for example: deflective facades, facade continuity, rhythm of boundary treatment, linearity of floorscape. Continuity should contain along their length a range of transitional and locational spaces.	Photos
Continuity	Ronnen, Demura, Kawasaki, & Higuchi, 2005	Landscape	Path direction, slope elevation and the angle of elevation are moderate, offer continuity of space, view and motion.	Graphic notations, photos, maps
Continuity	Carmona et al., 2010	Urban design	Meiss (1990) uses the notion of radiance to describe the spatial impact of facades. He suggests that while the built fabric gives and image of continuity of expansiveness stretching to infinity.	/
Continuity	Weitkamp, 2010	Landscape	The creation of subspaces simplifies the complex structure of the continuous space of landscapes.	Maps, bar chart
Continuity	Stoecklein, 2011	Landscape	Groundcovers can be used as the addition of continuity to the landscape by tying together and unifying the various beds and borders and the plants with them. The hierarchy of plant groups that will go into the site, your structural placement and continuity of plants will always fall into place much more readily.	/
Continuity	Nijhuis, 2011	Landscape	The hallmark of continuous space is that spatial elements do not confine the space. Any landscape elements present exist as separate elements in a continuous space. The new arrangement of the landscape means that the characteristic continuous space is transformed into a number of fully confined spaces.	Viewshed analysis by GIS
Continuity	Beirão, 2012	Urban design	One of the main axes in each area connects with another main axis in another area creating some urban continuity in spite of the significant barriers that both the railway and the main road create.	Maps
Continuity	Kandjee, 2013	Landscape	For instance, in the Barcelona garden the path-system allows a continuous movement across separate and disused open areas, expanding the domestic domain of the site.	/

>>>

TOC

CONTINUITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Continuity	U.S Department of Transportation, 2015	Landscape	As the driver rides up and over hills and into the next valley, the landscape is being presented as a continuously unfolding series of viewsheds.	Descriptive viewshed maps
Continuity	Kirkwood, 2016	Landscape	The concept is to maintain visual east-west access across the site to provide.	/
Continuity/ Continuation	Kaymaz, 2012	Landscape	Continuation: Graham (2008) explains continuation as 'continuation occurs when the eye follows along a line, curve, or a sequence of shapes, even when it crosses over negative and positive shapes'.	Graphic notations
Connectivity	Klarqvist, 1993	Urban design/ Morphology	Connectivity measures the number of immediate neighbours that are directly connected to a space. This is a static local measure.	Space syntax measurement
Connectivity	Baschak & Brown, 1995	Urban design	Within an urban landscape matrix 'edge effect' has a significant impact on the quality of corridors and patches, and the importance of spatial configuration and connectivity has been well documented (Ahern, 1991). 'Connectivity criteria: I, Size and shape; II, connections to species-rich areas; III, degree of edge; IV, habitat structure.'	Photos, statistics
Connectivity	McGarigal & Marks, 1995	Landscape ecology	Connectivity: Degree to which a landscape facilitates or impedes flow; How connected is a particular type/class?	Fragstats measurement
Connectivity	Urban & Keitt, 2001	Landscape ecology	Clearly the result of adding or removing edges in a graph is to affect its overall connectivity.	Measurement
Connectivity/ Connecedness	Wiens, 2002	Landscape ecology	Connectivity (or connectedness) is an aggregate property of the structural configuration of elements in a landscape mosaic, their relative viscosities to movements, and the relative permeability of their boundaries (Taylor et al. 1993; Wiens 1995; Tischendorf and Fahrig 2000). Aquatic ecologists have traditionally viewed streams as a mosaic of riffles, pools, and stream segments with high physical connectivity (e.g., Poff & Ward 1990; Robson & Chester 1999).	/
Connectivity	Blaschke, 2006	Landscape ecology	Interspersion/Juxtaposition Index, Contagion Index or Cohesion Index and other indices compare adjacency frequencies between classes and describe connectivity (Schumaker, 1996; Wu et al., 1997; Gustafson, 1998).	Fragstats measurement
Connectivity	Alcamo, Kok, Busch, & Priess, 2008	Landscape	Planning of 'nature corridors' for increasing the connectivity of protected areas.	/

>>>

TOC

CONTINUITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Connectivity	Nassauer & Opdam, 2008	Landscape ecology	The design of the corridor map was a strong instrument for communicating the need to improve the connectivity.	/
Connectivity	Pont & Haupt, 2010	Urban design/ Morphology	Both island size and the numbers of crossings are related to network density. The connectivity ratio, or the amount of crossings per hectare, increases proportionally to the square of the network density.	Measurement
Connectivity	Gaucherel, Boudon, Houet, Castets, & Godin, 2012	Landscape ecology	Connectivity indicates heterogeneity contagion.	Measurement
Connectivity/ Permeability	Queensland government, 2013	Landscape	Connectivity provides permeability through spaces via clear routes critical for channelling movement, providing linkages and promoting interconnectivity. Connectivity is the direct linkage created between places, areas destinations. Connections can be either or both visual and physical. Connectivity is also linked to the concept of permeability, which relates to the ease with which one can move through a space and get to other locations. The sequencing of spaces as well as clear circulation routes (both within a space and outside of) improves connectivity. Greenways can be applied to achieve regional open space networks and connectivity.	Hand-drawing maps, photos,
Connectivity	Ahern, 2013	Urban landscape	Connectivity in urban ecosystems is often achieved through multifunctional networks known as greenways, ecological networks, blue-green networks, riverways, and parkways, among others.	Photos
Connectivity	Liu, Siu, Gong, & Lu, 2016	Landscape/ Landscape ecology	Link-node ratio of greenway network. This variable is an index of greenway network connectivity, which equals the number of links divided by the number of nodes in the 500-m-buffer zone along each greenway segment, where links were greenway segments and nodes were greenway intersections and cul-de-sacs. A high ratio value indicates better connectivity.	GISc, measurement
Connection	Lynch, 1960	Urban design	Edge is provided with many visual and circulation connections to the rest of the city structure. The Square gains some connection with the exterior, other than. by slopes or paths, by means of outward views.	Maps, graphic notations
Connection	Trancik, 1986	Urban design	The principle of enclosure that gives open space its definition and connection, creating workable links between spaces.	Photos

>>>

TOC

CONTINUITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Connection	Sanoff, 1991	Landscape	The locations of open space use were photographically observed to assess their connections to pedestrian flow patterns and their actual use (Grey, Winkel, Bonsteel, & Parker, 1970).	Photos
Connection	Gustafson, 1998	Landscape	Some explicitly consider physical connections (for example, corridors or hedgerows) and are supported by network theory (Lowe & Moryadas 1975; Lefkovitch & Fahrig 1985).	Measurement
Connection	Mosler, 2006	Landscape	The valuing the group of monuments and heritage sites and their inter-visibility enable connection between artefacts and sites to set and compare.	Photos
Connection	Talen, 2006	Urban design	Edges are supposed to bound and give shape and identity (or legibility), but ideally, they are supposed to function like seams and lines of connection rather than barriers. Connection is not just about streets. It also applies to the linkages between different types of spaces.	Hand drawing graphic notations
Connection	Weitkamp, Bregt, Lammeren, & van den Berg, 2007	Urban design/ Morphology	Space syntax research first split urban space into subspaces, and then analyse the connections between the spaces by using the graph theory notation to describe the subspaces and their connections (Hillier, 1996; Hillier & Hanson, 1984).	Space syntax
Connection	Queensland government, 2013	Landscape	Edges provide a linear connection or an interlocking area between defined spaces, uniting the separate spaces together. A junction is a more complex node bringing together various uses and connections.	Hand drawing graphic notation, photos
Connection	Fathi & Masnavi, 2014	Urban design	Furthermore, in peri-urban areas management of highway landscapes would also reinforce the connection with nature and cohesion in the Tehran city suburban landscape.	/
Connection	U.S. Department of Transportation, 2015	Landscape	The transport link (or connection) has individual characteristics which include length, number of lanes, direction, capacity, and free flow speed.	/
Connection	Liu, Siu, Gong, & Lu, 2016	Landscape	a greenway network (GN) that links different greenways to provide a green matrix for better connections between cities and nature and a counterbalance to the built environment (Kullmann, 2013).	Maps, GIS, measurement

>>>

CONTINUITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Permeability	Klarqvist, 1993	Urban design/ Morphology	Graph: is a figure representing the relationships of permeability between all the convex spaces or axial spaces of a layout. The spaces are represented by circles or dots (called nodes) and the links with lines. It is possible to also use links in order to represent relationships of visibility between spaces.	Space syntax
Permeability/ Linkage	Punter & Carmona, 1996	Urban design/ Landscape	Permeability: access, linkages, spaces	/
Permeability	Dee, 2004	Landscape	Built structures such as open fences, railing or trellis forms are appropriate where visual permeability between one space and another is required without physical access.	Hand drawing graphic notations
Permeability	Robinson, 2004	Landscape	Permeability of enclosure: visual and physical enclosure and openness.	Hand drawing graphic notations
Permeability	Stamps, 2005	Landscape	Because degree of movement through something is permeability, we suggest it might be useful to think of enclosure in terms of permeability. Previous work indicated that permeability, measured as the percentage of a region that completely blocked either sensory or locomotive access, had a strong influence on judgments of enclosure. In this experiment, visual permeability was represented by two factors: boundary height (eye-level) and boundary porosity. Impression of enclosure was indeed related to visual permeability.	3D visualisation, statistics
Permeability	van Bilsen, 2008	Urban design	Visual permeability, locomotive (physical) permeability and enclosure of a pedestrian's environment are amongst others found to correlate with judgements on safety.	Measurement
Permeability	Stamps, 2008	Landscape	The amount of refuge was represented as visual permeability or the amount of the region through which one can see.	Landscape visualisation, statistics

>>>

TOC

CONTINUITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Permeability	Carmona et al., 2010	Urban design/ Morphology	As visual permeability refers to the ability to see the routes through an environment, while physical permeability refers to the ability to move through an environment, there may be visual ability but not physical permeability. Smaller blocks also increase permeability, thereby improving people's awareness of the choice available. While the curves contain views and add visual interest to newly developing neighbourhoods and suburbs, they also reduced visual permeability, discouraging non-residents from entering. A degree of enclosure is required to achieve permeability. A measure of the visual permeability of the space which in space syntax theory is the sum of the integration values of all the lines passing through the body of space.	Maps, graphic notations, photos, space syntax
Permeability	Shach-Pinsly, Fisher-Gewirtzman, & Burt, 2011	Urban design	Spatial Openness Index, which can also be described as a 'three-dimensional' isovist, can explore the three-dimensional visibility and permeability of spatial configurations and enable the ranking of alternative configurations by measuring the volume of the open space. It was the first real attempt to simulate human three-dimensional visual perception (FisherGewirtzman & Wagner, 2003, 2006; Fisher-Gewirtzman et al., 2003).	Measurement
Permeability	Torreggiani, Ludwiczak, Dall'Ara, Benni, Maino, & Tassinari, 2014	Landscape	The visual permeability of the farmyard depends on the shape, height, transparency, continuity, and arrangement of vertical elements.	Graphic notations, measurement
Permeability	Pancholi, Yigitcanlar, & Guaralda, 2015	Urban design	Permeable urban form: Physical and visual connectivity is promoted throughout the KIS by the interconnections between public spaces and opening up of internal vistas. The spatial permeability at the broader level seems to be lacking at the level of connections with the city because of the less permeable outer layer.	Maps, photos
Permeability	Exner & Pressel, 2017	Spatial design	Perforations in the form of openings, and the degree of their light permeability can reveal what a space's border surfaces are actually meant to conceal.	/
Proximity	Lynch, 1960	Urban design	Proximity to special features of the city could also endow a path with increased importance.	Graphic notations, maps, photos

>>>

TOC

CONTINUITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Proximity	Gustafson & Parker, 1992	Landscape ecology	A proximity index (PX) was developed which distinguishes isolated patches from those which are part of a complex of patches.	Measurement
Proximity	McGarigal & Marks, 1995	Landscape ecology	Isolation/Proximity : Spatial context of patches	Fragstats measurement
Proximity/ Nearness	Bell, 1996	Landscape	Nearness: The proximity of elements in space such that they appear to be part of a group in a composition.	/
Proximity	Galle & Modderman, 1997	Urban design	In the heavily urbanized areas of the Randstad and Brabant, proximity appears to have been replaced by accessibility as a structural factor.	/
Proximity	van Der Valk, 2002	Urban design	With respect to transportation, proximity is preferred to accessibility.	/
Proximity	Cheng & Masser, 2003	Urban design	The proximity variables measure the direct access to city centres/sub-centres, industrial centres, major roads, minor roads, rail lines, rivers, constructed bridges.	Measurement
Proximity	Brabyn, 2009	Landscape	Grano (1997) divides the perceived environment into 'the proximity, which we perceive with all our senses, and farther away the landscape, which extends to the horizon and which we perceive by sight alone'.	/
Proximity	Carmona et al., 2010	Urban design	Proximity: enables elements that are spatially closer together to be read as a group and to be distinguished from those that are further apart.	/
Proximity	Simova & Gdulova, 2012	Landscape ecology	Isolation/proximity metrics: MNN: Mean Euclidean nearest neighbour index PROX_MN: Mean proximity index	Fragstats measurment
Proximity	U.S. Department of Transportation, 2015	Landscape	Proximity of the viewer to an object is defined using three distinct distance zones: foreground, middle ground, or background. Understanding and analysing distance zones is essential for determining the effect proximity has on viewer sensitivity. Viewer exposure is a measure of proximity (the distance between viewer and the visual resource being viewed), extent (the number of viewers viewing), and duration (how long of a time visual resources are viewed).	Measurement
Integration	Klarqvist, 1993	Urban design/ Morphology	Integration is a static global measure. It describes the average depth of a space to all other spaces in the system. The spaces of a system can be ranked from the most integrated to the most segregated.	Space syntax

>>>

TOC

CONTINUITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Integration	Thwaites, Helleur, & Simkins, 2005	Urban design	To achieve urban integration means thinking of urban open space not as an isolated unit—be it a street, park or a square—but as a vital part of the urban landscape with its own specific set of functions (Urban Task Force, 1999).	/
Integration	Kofi, 2010	Urban design/ Morphology	Integration – is the degree of integration of a line with other lines. Integration of a line is by definition expressed by a value that indicates the degree to which a line is integrated or segregated from the whole network (global integration) or from few steps away (local integration). Integration will be applied to analyse accessibility and connectivity	Space syntax
Integration	van Nes, 2011	Urban design/ Morphology	Global integration analysis delineating how spatial integrated each street axis is in terms of the total number of direction.	Space syntax s

4 Relevant Literature about COMPLEXITY

COMPLEXITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Complexity/ Diversity/ Richness	Kaplan, 1988	Landscape	Complexity is the 'involvement' component at this surface level of analysis. Perhaps more appropriately referred to as 'diversity' or 'richness'. Loosely speaking it reflects how much is 'going on' in a particular scene, how much there is to look at. Complexity is represented through visual array.	/
Complexity/ Diversity	Bell, 1996	Landscape	COMPLEXITY: Another of the cognitive variables defined by the Kaplans, meaning richness in the structure and variety of a scene. It can be equated with the design principle of diversity.	/
Complexity/ Diversity	Fry & Sarlöv-Herlin, 1997	Landscape ecology	Edges may also vary along their length, both in the complexity of the shape of the edge and in the variety of edge types along a given length (Forman, 1995). Structural complexity will result in different textures, which can be used for designing visual effects. Complexity can be added by introducing a diversity of shrubs of varying height and spread or through systematic cutting regimes (Fuller & Warren, 1991).	Hand-drawing graphic notations, photos
Complexity	Batistella, Robeson, & Moran, 2003	Landscape ecology	The area weighted mean shape index (AWMSI) quantifies the amount of edge present in a class relative to what would be present in a class of the same size but with a circular shape. In other terms, AWMSI provides a relative measurement of shape complexity.	Measurement
Complexity	Dunnett & Hitchmough, 2004	Landscape	This may partly be a result of a rich assemblage of textures, forms and colours, or that in more diverse mixtures there is a greater chance at any one time of components of the vegetation being at the height of their visual display. A large enough size also makes it possible to increase the complexity even more by including glades and denser thickets.	Photos
Complexity	Palmer, 2004	Landscape ecology	Both edge density and landscape shape index provide an indication of visible landscape complexity, which is thought to contribute to scenic value (Kaplan and Kaplan, 1989).	Measurement
Complexity/ Mystery	Galindo & Hidalgo, 2005	Landscape	'Mystery' and 'complexity' are both related to visual diversity.	/

>>>

TOC

COMPLEXITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Complexity	Ronnen, Demura, Kawasaki, & Higuchi, 2005	Landscape	A stroll along the various streets and pathways of Kyoto exhibits the complexity of its landscape. At every glance, from every spot, the appearance of the surrounding mountains is varied, affording numerous views and spaces.	Hand-drawing graphic notations, Photos
Complexity	Blaschke, 2006	Landscape ecology	Complexity of shape: How complex or irregular is the form of the patches? (MFRACT)	Measurement
Complexity/ Diversity/ Richness/ Evenness	Tveit, Ode, & Fry, 2006	Landscape ecology	We define complexity as the diversity and richness of landscape elements and features, their interspersion as well as the grain size of the landscape. Complexity has been identified as a key concept of visual quality (see, for example, Kaplan & Kaplan, 1989; Litton, 1972). In a study by Germino et al. (2001), complexity is divided up into two properties (or dimensions): diversity and edge. Diversity refers to the abundance and evenness of land-cover classes in the view, and edge refers to the amount of edge dividing up land-cover types.	Photos, measurement
Complexity	Mok, Landphair, & Naderi, 2006	Landscape	Berlyne (1971) suggested that attention was aroused as visual stimulus increases up to a level of complexity, at which point if visual stimulus continues to become more complex, subjects will become confused and lose interest.	Photos, measurement
Complexity	Falk & Balling, 2010	Landscape	Earlier studies of visual preference focused on complexity as the significant mediator of visual preference (Day, 1967; Wohlwill, 1968). Results showed that visual preference was an inverted U-shaped function of increasing complexity.	/
Complexity	Persson, Olsson, Rundlo, & Smith, 2010	Landscape ecology	Complexity can be well represented by land use diversity and amount of field borders, and small semi-natural habitats. To describe complexity, we have used detailed information (at the level of that available from aerial photographs) but more easily available data, e.g. the length of field borders, is also valuable.	Photos, measurement
Complexity	Ode, Hagerhall, & Sang, 2010	Landscape ecology	Other measurements of shape complexity include the number of edges present in the landscape, either as a total edge length (Dramstad et al., 2001) or as edge density (ED) (Baessler & Klotz, 2006).	Graphic notations, measurement
Complexity	Weitkamp, 2010	Landscape	The length of this route is an indication of the landscape complexity.	Isovists

>>>

TOC

COMPLEXITY (Spatial-visual organisation / design vocabulary)				
Synonym	**References**	**Research field**	**Description of the composing spatial-visual characteristics**	**Method of representation**
Complexity	Nijhuis, 2011	Landscape	The grid-cell approach samples the landscape by a tessellation of (mostly square) grid-cells, for which one or more variables are measured and used to classify the cell density and complexity or to assign a type to it (De Veer and Burrough, 1978; Palmer and Lankhorst, 1998).	Grid-cell analysis, 3D GIS
Complexity/ Variation	Sang & Tveit, 2013	Landscape ecology	The shape of the edges of the open patches has also decreased in their complexity with less variation between them.	Measurement
Complexity/ Evenness	Surová, Pinto-Correia, & Marušák, 2014	Landscape ecology	In the work of De la Fuente de Valetal. (2004), the most appreciated landscapes were those with perceived complexity measured by SHDI and with uniform distribution of land uses expressed through the Shannon evenness index.	Measurement
Complexity	Sang, Hägerhäll, & Ode, 2015	Landscape	Sang (2011) proposes a metric of visual complexity that is invariant to local changes of viewpoint, being based on the topology (Kinsey, 1991) of the graph of the horizons in a view. The concomitant of this is that within these areas one aspect of perceived complexity (the number of depths of view and horizon edges for the brain to assimilate) is also invariant.	Photos, measurement
Diversity	Turner, O' Neill, Gardner, & Milne, 1989	Landscape ecology	Diversity: (formula) where Pk is the proportion of the landscape in cover type k, and m is the number of land cover types observed. The larger the value of H, the more diverse the landscape.	Measurement
Diversity	McGarigal & Marks, 1995	Landscape ecology	Diversity metrics: (PRD) Patch richness density (number/100 ha) (patch type/total area)	Fragstats measurement
Diversity	Geoghegan, Wainger, & Bockstael, 1997	Landscape ecology	Patch size is thought to be positively correlated to species and/or habitat diversity (Burgess & Sharpe, 1981).	Measurement
Diversity	Palmer & Lankhorst, 1998	Landscape	The primary concern for landscape spaciousness is decreasing diversity.	Photos, statistics
Diversity	Weinstoerffer & Girardin, 2000	Landscape/ landscape ecology	The demand of diversity corresponds to a diversity of views which appeals above all to the ‘hedonistic’ aspect of landscape (Sautter, 1991). For the ‘landscape diversity’ criterion, which only takes into account the nature and relative size of the fields within the farm.	Measurement

>>>

TOC

COMPLEXITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Diversity/ Richness/ Evenness	Palmer, 2000	Landscape ecology	Landscape diversity is generally considered to have two components, richness, and evenness. Patch richness density: Number of different land-uses per 100 ha. Shannon's evenness index: Equals 1 if the distribution of area among all land uses is equal, approaches 0 as one land use becomes dominant, and is 0 if there is only 1 land use. It is based on Shannon's diversity index	Photos, measurement
Diversity	Gulinck, de Lucio, & Atauri, 2001	Landscape ecology	Diversity: Shannon diversity index; Number of cover types; Shape diversity; Sequence of land cover	Measurement
Diversity	Loidl & Bernard, 2003	Landscape	Closeness, landform	Graphic notations
Diversity	Dee, 2004	Landscape	Diversity in landscapes can be achieved through varying size or shape of spaces. As design material, plants provide opportunities for a great deal of diversity in enclosure permeability and form. Monotony can be avoided by creating a diversity of path relationships to the water's edge and incident along the path. The diversity of sensory experiences afforded through abstract elements (colour, texture, pattern) and topography, vegetation, structures, and water.	Hand-drawing graphic notations
Diversity	Dramstad, Tveit, Fjellstad, & Fry, 2006	Landscape ecology	There is a significant correlation between openness (visual preference) and land type diversity. Shannon's diversity index is based on the relative areas of different land types.	Measurement, maps
Diversity	Office of the Architect, University of Virginia, 2011	Landscape	Vegetated Walls: Whether screening undesired views or adding texture and interest to a wall, climbing vines provide dynamic visual appeal and contribute to diversity.	Photos
Diversity	Plexida, Sfougaris, Ispikoudis, & Papanastasis, 2014	Landscape ecology	Diversity (diversity metrics): PRD, SHDI, SIDI, MSIDI, SHEI, SIEI, MSIEI	Measurement
Diversity	Nijhuis, 2015	Landscape	Research into the degree of openness shows that the diversity in size is decreasing.	GISc-based viewshed analysis
Diversity	Olwig, 2016	Landscape	What enclosure generally did (and still does) was to produce a significant reduction in environmental diversity through spatial consolidation and spatial enclosure.	Photos

>>>

TOC

COMPLEXITY (Spatial-visual organisation / design vocabulary)				
Synonym	References	Research field	Description of the composing spatial-visual characteristics	Method of representation
Mystery	de la Fuente de Val, Atauri, & de Lucio, 2006	Landscape ecology	Mystery was related to landcover heterogeneity (number of patches). The results show that landscapes valued as mysterious are those with high topographic variability and a large number of irregular-shaped different patches producing a sense great spatial heterogeneity.	Photos, questionnaires, statistics
Mystery	de la Fuente de Val & Mühlhauser, 2014	Landscape	A landscape with a high percentage of vegetation cover gives forth to the greatest influence on perception of complexity and mystery, which is possibly a result of vegetation heterogeneity. In this case, a higher-vegetation density is required for structurally more complex scenes, and increases expectations of mystery.	Photos, statistics, questionnaires
Mystery	Lau, Gou, & Liu, 2014	Landscape	To attract users' visit and stay, plants design of an open space shall be 'mystery' encouraging people to discover an environment and 'complexity' providing diverse and rich elements.	Photos

APPENDIX B

Identity of Interviewees

- **Frits Palmboom:** Urban designer (Palmbout Urban Landscapes), Professor in TU Delft (Netherlands)
- **Eric van der Kooij:** Head of Knowledge and Quality Assurance in Spatial Planning Department, Municipality of Amsterdam; Urban designer; Former teacher in TU Delft (landscape architecture) (Netherlands)
- **Han Lörzing:** Landscape architect; Former spatial quality consultant for the province of Utrecht; Former project leader of urban development and cultural history studies in the Planning Bureau (PBL) (Netherlands)
- **Bas Horsting:** Urban designer; Architect; SWECO (Netherlands)
- **Mark Eker:** Regional designer in Province Noord-Holland; Landscape architect (Netherlands)
- **Jaap van der Salm:** Landscape architect in H+N+S (Netherlands)
- **Olaf Schroth:** Professor of Geodesign and Landscape Informatics in Weihenstephan-Triesdorf University of Applied Science (Germany)
- **Philipp Urech:** Teaching/researching assistant at the chair of landscape architect at ETH Zurich; PhD research at the Future Cities Laboratory in Singapore (Switzerland)
- **Eckart Lange:** Professor of landscape architecture in the University of Sheffield (England)
- **Cui Honglei:** Landscape architect in Shenzhen Urban Planning & Design Institute of Design (China)

References

Abrams, J., & Hall, P. (2006). *Else/where mapping new cartographies of networks and territories.* Minneapolis, Minnesota: University of Minnesota.

Adler, M. J. (1986). *A guidebook to learning. For a lifelong pursuit of wisdom.* New York, MA: Macmillan.

Afrooz, A., Ballal, H., & Pettit, C. (2018). Implementing augmented reality sandbox in geodesign: A future for geodesign. *ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences, 4(4).*

Ahern, J. (2013). Urban landscape sustainability and resilience: the promise and challenges of integrating ecology with urban planning and design. *Landscape Ecology, 28(6),* 1203-1212.

Alcamo, J., Kok, K., Busch, G., & Priess, J. (2008). Chapter four searching for the future of land: scenarios from the local to global scale. *Developments in Integrated Environmental Assessment, 2,* 67-103.

Alexander, C. (1977). *A pattern language: towns, buildings, construction.* Oxford: Oxford university press.

Almusaed, A. (2019). Introductory chapter: A general reading process on landscape architecture. In A. Almusaed (Ed.), *Landscape Architecture-The Sense of Places, Models and Applications.* London: IntechOpen.

Alphen, B. J. van, Dijkstra, H., & Lankhorst, J. R. K. (1994). *De ontwikkeling van een methode voor monitoring van de 'Maat van de Ruimte'* (Report 334). Wageningen: DLO-Staring Centrum.

Amoroso, N. (2015). *Representing landscapes: digital.* London and New York: Routledge Taylor & Francis.

Antrop, M. (2007). *Perspectieven op het landschap: achtergronden om landschappen te lezen en te begrijpen.* Gent: Academia Press.

Antrop, M. (2007). Reflecting upon 25 years of landscape ecology. *Landscape Ecology, 22(10),* 1441-1443.

Antrop, M., & Van Eetvelde, V. (2000). Holistic aspects of suburban landscapes: visual image interpretation and landscape metrics. *Landscape and urban planning, 50(1-3),* 43-58.

Apostol, D., Palmer, J., Pasqualetti, M., Smardon, R., & Sullivan, R. (2016). *The renewable energy landscape: Preserving scenic values in our sustainable future.* London: Routledge.

Appleton, J. (1975). *The Experience of Landscape.* London: Wiley.

Appleyard, D., Lynch, K., & Myer, J. R. (1964). *The View from the Road.* Cambridge, Massachusetts: The MIT Press.

Aspinall, R. J., & Hill, M. J. (2007). *Land use change: science, policy and management.* Boca Raton, Florida: CRC Press.

Attia, S. (2006). The role of landscape design in improving the microclimate in traditional courtyard buildings in hot arid climates. *Proceedings of 23rd International Conference on Passive and Low Energy Architecture-PLEA 2006* (pp. 22-24). PLEA-Université de Genève-groupe énergie.

Badrinarayanan, V., Kendall, A., & Cipolla, R., (2017). Segnet: A deep convolutional encoder-decoder architecture for image segmentation. *IEEE transactions on pattern analysis and machine intelligence, 39(12),* 2481-2495.

Baker, W. L. (1992). The landscape ecology of large disturbances in the design and management of nature reserves. *Landscape Ecology, 7(3),* 181-194.

Baschak, L. A., & Brown, R. D. (1995). An ecological framework for the planning, design and management of urban river greenways. *Landscape and urban planning, 33(1-3),* 211-225.

Baskent, E. Z. (1999). Controlling spatial structure of forested landscapes: a case study towards landscape management. *Landscape Ecology, 14(1),* 83-97.

Batistella, M., Robeson, S., & Moran, E. F. (2003). Settlement design, forest fragmentation, and landscape change in Rondônia, Amazônia. *Photogrammetric Engineering & Remote Sensing, 69(7),* 805-812.

Beck, T. (2012). *Principles of ecological landscape design.* Washington, DC: Island Press.

Beirão, J. N. (2012). *CityMaker: Designing Grammars for Urban Design* (Doctoral thesis). Delft University of Technology, Delft, the Netherlands.

Bell, S. (1996). *Elements of Visual Design in the Landscape.* London: E. & F. N. Spon.

TOC

Bell, S. (1999). *Landscape: Pattern, Perception and Processes.* London: Taylor & Francis.

Berendsen, H. J. A. (2000). *Landschappelijk Nederland. Vol. IV, Fysische geografie van Nederland.* Assen: Van Gorcum.

Bianchetti, R. A. (2017). Raisz's Physiographic Method of Landform Mapping. *Progress in Physical Geography, 41(6),* 850-857.

Bishop, I. D., & Lange, E. (2005). Communication, perception and visualisation. *In Visualisation in landscape and environmental planning*. London: Taylor & Francis.

Bishop, I., & Lange, E. (2005). *Visualisation in landscape and environmental planning. Technology and applications.* New York, NY: Taylor & Francis.

Bishop, I., Wherrett, J. R., & Miller, D. R. (2000). Using image depth variables as predictors of visual quality. *Environment and Planning B: Planning and Design, 27(6),* 865–875.

Blaschke, T. (2006). The role of the spatial dimension within the framework of sustainable landscapes and natural capital. *Landscape and urban planning, 75(3-4),* 198-226.

Blumentrath, C., & Tveit, M. S. (2014). Visual characteristics of roads: A literature review of people's perception and Norwegian design practice. *Transportation research part A: policy and practice, 59,* 58-71.

Boeing, G. (2018). Measuring the complexity of urban form and design. *Urban Design International, 23(4),* 281-292.

Booth, N. (2011). *Foundations of landscape architecture: integrating form and space using the language of site design*. Hoboken, New Jersey: John Wiley & Sons.

Booth, N. K. (1989). *Basic Elements of Landscape Architectural Design.* Long Grove, Illinois: Waveland Press.

Brabyn, L. (2009). Classifying landscape character. *Landscape research, 34(3),* 299-321.

Brabyn, L., & Mark, D. M. (2011). Using viewsheds, GIS, and a landscape classification to tag landscape photographs. *Applied Geography*, *31(3),* 1115–1122.

Bruns, C. R., & Chamberlain, B. C. (2019). The Influence of Landmarks and Urban Form on Cognitive Maps Using Virtual Reality. *Landscape and Urban Planning, 189,* 296-306.

Burrough, P. A., Buitenhuis, A., & De Veer, A. A. (1982). *Het Informatiesysteem Landschapsbeeld, Reeks Landschapsstudies.* Wageningen, Pudoc.

Cantrell, B., & Mekies, A. (Eds.). (2018). *Codify: Parametric and computational design in landscape architecture*. London and New York: Routledge.

Cantrell, B., & Michaels, W. (2010). *Digital Drawing for Landscape Architecture: Contemporary Techniques and Tools for Digital Representation in Site Design.* Hoboken, New Jersey: John Wiley & Sons.

Carmona, M., Heath, T., Tiesdell, S., & Oc, T. (2010). *Public places, urban spaces: the dimensions of urban design.* London: Routledge.

Carr, D. (1999). Guidelines for designing information visualisation applications. *Proceedings of the 1999 Ericsson Conference on Usability Engineering.* Retrieved from www.staff.science.uu.nl/~telea001/uploads/VACourse/Carr99.pdf.

Carvalho Filho, L., De Sá, W. F., Puttini, C., & Monteiro, C. (2015). The Capibaribe Park: Restructuring the urban fabric of the city of Recife by articulating public spaces. *In Proceedings of the 10th International Space Syntax Symposium* (pp. 1-17). London.

Chalmers, M. (1993). Using a landscape metaphor to represent a corpus of documents. *European Conference on Spatial Information Theory.* Berlin, Heidelberg: Springer.

Chatwin, B. (2016). *The songlines*. New Yokr: Open Road Media.

Cheng, J., & Masser, I. (2003). Urban growth pattern modelling: a case study of Wuhan city, PR China. *Landscape and urban planning, 62(4)*, 199-217.

Ching, F. D. (2014). *Architecture: Form, space, and order*. Hoboken, New Jersey: John Wiley & Sons.

Clouston, B. (1977). *Landscape design with plants.* Oxford: Newnes.

Coeterier, J. F. (1994). Cues for the perception of the size of space in landscape. *Journal of Environmental Management, 42,* 333-347.

Coeterier, J. F. (1996). Dominant attributes in the perception and evaluation of the Dutch landscape. *Landscape and urban planning, 34,* 27-44.

Colville National Forest (1989). *Draft environmental impact statement: proposed land and resource management plan.* U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Council of Europe. (2000). European Landscape Convention. *European Treaty Series, 176 (10).*

Crandell, G. (1993). *Nature Pictorialized: 'The View' in landscape history.* Baltimore: The Johns Hopkins University Press.

Crawford, T. W., Bin, O., Kruse, J. B., & Landry, C. E. (2014). On the importance of time for GIS view measures and their use in hedonic property models: does being temporally explicit matter? *Transactions in GIS, 18(2),* 234-252.

Cuckovic, Z. (2016). Advanced viewshed analysis: a Quantum GIS plug-in for the analysis of visual landscapes. *Open Source Software, 1(4),* 32.

Cullen, G. (1961). *The Concise Townscape*. London: Van Nostrand Reinhold Company.

Curdes, G. (1993). *Stadtstruktur und Stadtgestaltung.* Stuttgart: W. Kohlhammer.

Cureton, P. (2016). *Strategies for Landscape Representation: Digital and Analogue Techniques.* London and New York: Routledge Taylor & Francis.

Daniel, T. C., & Boster, R. S. (1976). *Measuring landscape esthetics: the scenic beauty estimation method* (Res. Pap. RM-RP-167). U.S. Department of Agriculture, Forest Service, Rocky Mountain Range and Experiment Station.

De Boer, H. (1979). *Landschapswaardering : rapport ten behoeve van het landschapsbeeldkarteringsonderzoek van het Rijksinstituut voor onderzoek in de bos- en landschapsbouw 'De Dorschkamp' te Wageningen* (Report 209). Wageningen: De Dorschkamp.

De la Fuente de Val, G., & Mühlhauser, H. (2014). Visual quality: An examination of a South American Mediterranean landscape, Andean foothills east of Santiago (Chile). *Urban forestry & urban greening, 13(2),* 261-271.

De la Fuente de Val, G., Atauri, J. A., & de Lucio, J. V. (2006). Relationship between landscape visual attributes and spatial pattern indices: a test study in Mediterranean-climate landscapes, *Landscape and Urban Planning, 77,* 393 – 407.

De Lucio, J. V., Mohamadian, M., Ruiz, J. P., Banayas, J., & Bernaldez, F. G. (1996). Visual landscape exploration as revealed by eye movement tracking. *Landscape and Urban Planning*, *34(2)*, 135–142.

De Veer, A. A. (1977). De ruimtelijke classificatie van het Nederlandse landschap. *KNAG Geografisch Tijdschrift (XI) 2*, 98-109.

De Veer, A. A., & Burrough, P. A. (1978). Physiognomic landscape mapping in The Netherlands. *Landscape Planning*, *5(1),* 45–62.

Dee, C. (2004). *Form and Fabric in Landscape Architecture: A visual introduction.* London and New York: SPON Press.

Deming, M. E., & Swaffield, S. (2011). *Landscape Architectural Research: Inquiry, Strategy, Design.* Hoboken, New Jersey: John Wiley & Sons.

Dijkstra, H., & van Lith-Kranendonk, J. (2000). *Schaalkenmerken van het landschap in Nederland; monitoring kwaliteit groene ruimte (MKGR)* (No. 40). Alterra.

Dijkstra, H., van den Berg, A., & Farjon, J. M. J. (1985). *Visuele en ecologische effecten van nieuwbouw in Burgers Dierenpark.* Wageningen, De Dorschkamp.

Dinkov, D., & Vatseva, R. (2016). 3D modelling and visualisation for landscape simulation. *6th International Conference on Cartography and GIS* (p. 320). Albena, Bulgaria.

Doherty, G., & Waldheim, C. (2016). *Is Landscape …?* London and New York: Routledge Taylor & Francis.

Dong, R., Zhang, Y., & Zhao, J. (2018). How green are the streets within the sixth ring road of Beijing? An analysis based on tencent street view pictures and the green view index. *International journal of environmental research and public health, 15(7),* 1367.

Dorner, B., Lertzman, K., & Fall, J. (2002). Landscape pattern in topographically complex landscapes: issues and techniques for analysis. *Landscape Ecology, 17(8),* 729-743.

Dramstad, W. E., Fry, G., Fjellstad, W. J., Skar, B., Helliksen, W., Sollund, M. L., ... & Framstad, E. (2001). Integrating landscape-based values - Norwegian monitoring of agricultural landscapes. *Landscape and Urban planning, 57(3-4),* 257-268.

Dramstad, W. E., Tveit, M. S., Fjellstad, W. J., & Fry, G. L. (2006). Relationships between visual landscape preferences and map-based indicators of landscape structure. *Landscape and urban planning, 78(4),* 465-474.

Dramstad, W., Olson, J. D., & Forman, R. T. (1996). *Landscape ecology principles in landscape architecture and land-use planning.* Washington, DC: Island Press.

Drummond, W. J., & French, S. P. (2008). The future of GIS in planning: Converging technologies and diverging interests. *Journal of the American Planning Association*, *74(2),* 161-174.

Dunnett, N., & Hitchmough, J. (2004). *The dynamic landscape: design, ecology and management of naturalistic urban planting.* London: Taylor & Francis.
Dupont, L., Antrop, M. & van Eetvelde, V. (2014). Eye-tracking Analysis in Landscape Perception Research: Influence of Photograph Properties and Landscape Characteristics. *Landscape Research, 39(4),* 417–432.
Dupont, L., Ooms, K., Duchowski, A. T., Antrop, M., & van Eetvelde, V. (2017). Investigating the visual exploration of the rural-urban gradient using eye-tracking. *Spatial Cognition & Computation, 17(1-2),* 65-88.
Entwistle, T., & Knighton, E. (2013). *Visual Communication for Landscape Architecture.* London: A & C Black.
Ervin, S. M. (2001). Digital landscape modelling and visualisation: a research agenda. *Landscape and urban planning, 54(1),* 49-62.
Esri. (2016). Viewshed. Retrieved from https://pro.arcgis.com/en/pro-app/tool-reference/3d-analyst/viewshed.htm.
Evert, K. J., Ballard, E. B., Oquinena, I., Schmerber, J. M., & Stipe, R. E. (2010). *Encyclopedic Dictionary of Landscape and Urban Planning.* Berlin, Heidelberg: Springer.
Exner, U., & Pressel, D. (2017). *Basics Spatial Design.* Basel: Birkhäuser.
Fairclough, G., Herlin, I. S., & Swanwick, C. (Eds.). (2018). *Routledge handbook of landscape character assessment: current approaches to characterisation and assessment.* London, New York: Routledge.
Falk, J. H., & Balling, J. D. (2010). Evolutionary influence on human landscape preference. *Environment and Behavior, 42(4),* 479-493.
Fathi, M., & Masnavi, M. R. (2014). Assessing environmental aesthetics of roadside vegetation and scenic beauty of highway landscape: preferences and perception of motorists. *International Journal of Environmental Research, 8(4),* 941-952.
Federal Highway Administration. (1988). *Visual Impact Assessment for Highway Projects* (Publication No. FHWA-HI-88-054). USDOT (US Department of Transportation).
Felleman, J. P. (1979). *Landscape Visibility Mapping: Theory and Practice.* School of Landscape Architecture. State University of New York, College of Environmental Forestry, Syracuse, NY.
Fisher, P. (1996). Extending the applicability of viewsheds in landscape planning. *Photogrammetric Engineering and Remote Sensing*, *62*, 1297–1302.
Franco, D., Franco, D., Mannino, I., & Zanetto, G. (2003). The impact of agroforestry networks on scenic beauty estimation: The role of a landscape ecological network on a socio-cultural process. *Landscape and urban planning, 62(3),* 119-138.
Freundschuh, S. M., & Egenhofer, M. J. (1997). Human conceptions of spaces: implications for GIS. *Transactions in GIS, 2(4),* 361-375.
Fry, G., & Sarlöv-Herlin, I. (1997). The ecological and amenity functions of woodland edges in the agricultural landscape; a basis for design and management. *Landscape and urban planning, 37(1-2),* 45-55.
Fu, P., & Rich, P. M. (1999). Design and implementation of the Solar Analyst: an ArcView extension for modelling solar radiation at landscape scales. *Proceedings of the Nineteenth Annual ESRI User Conference.* San Diego.
Galindo, M. P., & Hidalgo, M. C. (2005). Aesthetic preferences and the attribution of meaning: Environmental categorization processes in the evaluation of urban scenes. *International Journal of Psychology, 40(1),* 19-26.
Galle, M., & Modderman, E. (1997). VINEX: National spatial planning policy in the Netherlands during the nineties. *Netherlands journal of housing and the built environment, 12(1),* 9-35.
Gaucherel, C., Boudon, F., Houet, T., Castets, M., & Godin, C. (2012). Understanding patchy landscape dynamics: towards a landscape language. *PLoS One, 7(9),* e46064.
Geoghegan, J., Wainger, L. A., & Bockstael, N. E. (1997). Spatial landscape indices in a hedonic framework: an ecological economics analysis using GIS. *Ecological economics, 23(3),* 251-264.
Girot, C., & Truniger, F. (2012). *Landscape Vision Motion.* Berlin: Jovis.
Girot, C., Freytag, A., Kirchengast, A., & Richter, D. (2013). *Topology: Topical thoughts on the contemporary landscape (Vol. 3).* Berlin: Jovis.
Göçmen, Z. A., & Ventura, S. J. (2010). Barriers to GIS use in planning. *Journal of the American Planning Association*, *76*(2), 172-183.
Griffon, S., Nespoulous, A., Cheylan, J. P., Marty, P., & Auclair, D. (2011). Virtual reality for cultural landscape visualisation. *Virtual Reality, 15(4),* 279-294.

Gulinck, H., Múgica, M., de Lucio, J. V., & Atauri, J. A. (2001). A framework for comparative landscape analysis and evaluation based on land cover data, with an application in the Madrid region (Spain). *Landscape and urban planning, 55(4),* 257-270.
Gustafson, E. J. (1998). Quantifying landscape spatial pattern: what is the state of the art? *Ecosystems, 1(2),* 143-156.
Gustafson, E. J., & Parker, G. R. (1992). Relationships between land cover proportion and indices of landscape spatial pattern. *Landscape ecology, 7(2),* 101-110.
Halprin, L. (1970). *The RSVP cycles: Creative processes in the human environment.* New York: George Braziller.
Hansen, G. (2009). Landscape Design: Ten Important Things to Consider. *EDIS, 2009(2).* Retrieved from https://journals.flvc.org/edis/article/view/117697.
Hansen, G. (2010). *Basic principles of landscape design. Research report CIR536*. Retrieved from Environmental Horticulture Department, UF/IFAS Extension, https://edis.ifas.ufl.edu/pdffiles/MG/MG08600.pdf.
Hassan, R., Hansen, T. B., & Nordh, H. (2014). Visualisations in the Planning Process. Rethinking Comprehensive Design: Speculative Counterculture. *Proceedings of the 19th International Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA 2014).* Kyoto.
Herrington, S., & Studtmann, K. (1998). Landscape interventions: new directions for the design of children's outdoor play environments. *Landscape and urban planning, 42(2-4),* 191-205.
Herzog, T. R. (1992). A cognitive analysis of preference for urban spaces. *Journal of environmental psychology, 12(3),* 237-248.
Herzog, T. R., & Leverich, O. L. (2003). Searching for legibility. *Environment and Behavior, 35(4),* 459-477.
Higuchi, T. (1988). *The Visual and Spatial Structure of Landscapes.* Cambridge: MIT Press.
Hillier, B. (1997). *Space is the machine: a configurational theory of architecture.* London: Press Syndicate of the University of Cambridge.
Hirsch, A. B. (2008). *Lawrence Halprin: Choreographing Urban Experience.* Philadelphia: University of Pennsylvania Press.
Hirschfeld, C. C. L. (2001). *Theory of garden art.* Philadelphia, PA: University of Pennsylvania Press.
Homma, R., Morozumi, M., & Iki, K. (1998). Network-based dynamic evaluation process for urban landscapes. *Proceedings of The Third Conference on Computer Aided Architectural Design Research in Asia.* Osaka, Japan.
Ikemi, M. (2005). The effects of mystery on preference for residential facades. *Journal of environmental psychology, 25(2),* 167-173.
Jackson, L. L. (2008). Who 'designs' the agricultural landscape? *Landscape journal, 27(1),* 23-40.
Jakle, J. A. (1987). *The visual elements of landscape.* Cambridge, MA: The MIT Press.
Jim, C. Y., & Chen, S. S. (2003). Comprehensive greenspace planning based on landscape ecology principles in compact Nanjing city, China. *Landscape and urban planning, 65(3),* 95-116.
Junker, D., & Nollen, C. (2018). Mobile Eye Tracking in Landscape Architecture: Discovering a New Application for Research on Site. In Almusaed, A. (Eds.), *Landscape Architecture: The Sense of Places, Models and Applications (45-66).* London: IntechOpen.
Kamalipour, H., & Dovey, K. (2019). Mapping the visibility of informal settlements. *Habitat International, 85,* 63-75.
Kanagy, C. L., & Kraybill, D. B. (1999). *The riddles of human society*. California: Sage Publishing.
Kandjee, T. (2013). *Designing the skeleton of/for robust landscapes* (Doctoral dissertation). School of Architecture and Design, RMIT University, Australia.
Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective.* Cambridge: Cambridge University Press.
Kaplan, R., Kaplan, S., & Ryan, R. L. (1998). *With People in Mind: Design and Management of Everyday Nature.* Washington, DC: Island Press.
Kaplan, S. (1988). Perception and landscape: Conceptions and misconceptions. In J. Nasar (Ed.), *Environmental Aesthetics: Theory, Research, and Application* (pp. 45-55). Cambridge: Cambridge University Press.
Kaymaz, I. C. (2012). Landscape perception. In M. Ozyavuz (Ed.), *Landscape planning* (pp. 251-276). London: IntechOpen.

Kirkwood, N. (2016). Is landscape technology? In C. Waldheim & G. Doherty (Eds.), *Is landscape…?* (pp.304-327). Abingdon: Routledge.
Kiss, D. (2017). *Designing Outside the Box: landscape seeing by doing.* Morrisville, North Carolina: Lulu.com.
Klarqvist, B. (1993). A space syntax glossary. *Nordisk Arkitekturforskning, 6(2).*
Kofi, G. E. (2010). *Network Based Indicators for Prioritizing the Location of a New Urban Transport Connection: Case Study Istanbul, Turkey* (Unpublished thesis). International Institute for Geo-Information Science and Earth Observation Enschede, the Netherlands.
Koh, I. (2019). Discrete Sampling: There is No Object or Field… Just Statistical Digital Patterns. *Architectural Design*, *89(2),* 102-109.
Krøgli, S. O., Dramstad, W. E., & Skar, B. (2015). World heritage and landscape change–heritage buildings and their changed visibility in the coastal landscape of Vega, Norway. *Norsk Geografisk Tidsskrift-Norwegian Journal of Geography, 69(3),* 121-134.
LAF. (2019). *Virtual Reality in Landscape Architecture.* Retrieved from https://www.lafoundation.org/resources/2019/04/vr-in-land-arch.
Landscape Institute, & Institute of Environmental Management and Assessment. (2013). *Guidelines for landscape and visual impact assessment.* London, New York: Routledge Taylor & Francis.
Lange, E. (2001). The limits of realism: perceptions of virtual landscapes. *Landscape and urban planning, 54(1),* 163-182.
Lau, S. S. Y., Gou, Z., & Liu, Y. (2014). Healthy campus by open space design: Approaches and guidelines. *Frontiers of Architectural Research, 3(4),* 452-467.
Lausch, A., Blaschke, T., Haase, D., Herzog, F., Syrbe, R. U., Tischendorf, L., & Walz, U. (2015). Understanding and quantifying landscape structure–A review on relevant process characteristics, data models and landscape metrics. *Ecological Modelling, 295,* 31-41.
Lefebvre, H. (1991). *The production of space.* Blackwell: Oxford.
Lin, L., Homma, R., & Iki, K. (2018), Preferences for a Lake Landscape: Effects of Building Height and lake width. *Environmental Impact Assessment Review, 70,* 22-33.
Lindquist, M., Lange, E., & Kang, J. (2016). From 3D landscape visualisation to environmental simulation: The contribution of sound to the perception of virtual environments. *Landscape and Urban Planning*, *148*, 216-231.
Lindsey, G., Wilson, J., Anne Yang, J., & Alexa, C. (2008). Urban greenways, trail characteristics and trail use: implications for design. *Journal of Urban Design, 13(1),* 53-79.
Litton, R. B. (1968). *Forest landscape description and inventories: a basis for land planning and design* (U. S. D. A. Forest Service Research Paper PSW-49). Pacific Southwest Forest and Range Experiment Station Forest Service, U. S. Department of Agriculture, Berkeley, California
Liu, K., Siu, K. W. M., Gong, X. Y., Gao, Y., & Lu, D. (2016). Where do networks really work? The effects of the Shenzhen greenway network on supporting physical activities. *Landscape and Urban Planning, 152,* 49-58.
Liu, M., & Schroth, O. (2019). Assessment of Aesthetic Preferences in Relation to Vegetation-Created Enclosure in Chinese Urban Parks: A Case Study of Shenzhen Litchi Park. *Sustainability, 11(6),* 1809.
Llobera, M. (2003). Extending GIS-based visual analysis: The concept of visualscapes. *International Journal of Geographical Information Science*, *17(1),* 25–48.
Loidl, H., & Bernard, S. (2003). *Open(ing) Spaces: Design as Landscape Architecture.* Berlin: Walter de Gruyter.
Lyle, J. T. (1999). *Design for Human Ecosystems.* Washington, DC: Island Press.
Lynch, J. A., & Gimblett, R. H. (1992). Perceptual values in the cultural landscape: A computer model for assessing and mapping perceived mystery in rural environments. *Computers, environment and urban systems, 16(5),* 453-471.
Lynch, K. (1960). *The image of the city.* Cambridge, MA: MIT Press.
Lynch, K. (1981). *A theory of good urban form.* Cambridge, MA: MIT Press.
Ma, Y., Wright, J., Gopal, S., & Phillips, N. (2020). Seeing the invisible: From imagined to virtual urban landscapes. *Cities, 98,* 102559.
Macdonald, A. (2012). *Windfarm Visualisation: Perspective Or Perception?* United Kingdom: Whittles.
Maertens, H. (1877). *Der Optische-Maassstab. Oder die Theorie und Praxis des ästhetischen Sehens in den bildenden Künsten. Auf Grund der Lehre der physiologischen Optik. Für Architekten, Maler, Bildhauer, Musterzeichner.* Bonn: Cohen & Sohn.

Marciniak, D. (2011). *Principles of Design: Rhythm in the Landscape.* Retrieved from https://www.revolutionarygardens.com/principles-of-design-rhythm-in-the-landscape/

Massaro, D., Savazzi, F., Di Dio, C., Freedberg, D., Gallese, V., Gilli, G., & Marchetti, A. (2012). When art moves the eyes: A behavioral and eye-tracking study. *PLoS ONE*, *7(5).*

McClelland, L. F. (1998). *Building the National Parks: Historic Landscape Design and Construction.* Baltimore: JHU Press.

McEwan, C. (2018). The Analogical Surface: City, Drawing, Form and Thought. *Drawing On, (2),* 18-31.

McGarigal, K. (2001). *Landscape metrics for categorical map patterns* (Research report). Retrieved from http://www.umass.edu/landeco/teaching/landscape_ecology/schedule/chapter9_metrics.pdf.

McGarigal, K. (2002). *Landscape pattern metrics. Encyclopedia of Environmetrics.* Hoboken, New Jersey: John Wiley & Sons, Ltd.

McGarigal, K., & Marks, B. J. (1995). *FRAGSTATS: Spatial Pattern Analysis Program for Quantifying Landscape Structure* (Gen. Tech. Rep. PNW-351). USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Melsom, J., Girot, C., & Hurkxkens, I. (2015). Directed deposition: exploring the roles of simulation and design in erosion and landslide processes. *Proceedings of the 35th Annual Conference of the Association for Computer Aided Design in Architecture* (pp. 211-221). Cincinnati.

Meyer, E. K. (2016). *Lawrence Haplrin biography.* The Landscape Architecture of Lawrence Halprin (The Cultural Landscape Foundation). Retrieved from tclf.org/sites/default/files/microsites/halprinlegacy/lawrence-halprin.html

Mok, J. H., Landphair, H. C., & Naderi, J. R. (2006). Landscape improvement impacts on roadside safety in Texas. *Landscape and Urban Planning, 78(3),* 263-274.

Möller, B. (2006). Changing wind-power landscapes: Regional assessment of visual impact on land use and population in Northern Jutland, Denmark. *Applied Energy, 83(5),* 477–494.

Montello, D. R. (2007). The contribution of space syntax to a comprehensive theory of environmental psychology. *Proceedings of the 6th International Space Syntax Symposium.* Istanbul.

Mosler, A. S. (2006). *Landscape architecture on archaeological sites: establishing landscape design principles for archaeological sites by means of examples from West Anatolia, Turkey* (Doctoral dissertation). Technischen Universität München, München.

Motloch, J. L. (2000). *Introduction to landscape design.* Hoboken, New Jersey: John Wiley & Sons.

Mouflis, G. D., Gitas, I. Z., Iliadou, S., & Mitri, G. H. (2008). Assessment of the visual impact of marble quarry expansion (1984–2000) on the landscape of Thasos island, NE Greece. *Landscape and urban planning, 86(1),* 92-102.

Nasar, J. (1994). Exteriors Urban Design Aesthetics. The Evaluative Qualities of Building Exteriors. *Environment and Behaviour, 26(3),* 377-401.

Nassauer, J. I., & Opdam, P. (2008). Design in science: extending the landscape ecology paradigm. *Landscape ecology, 23(6),* 633-644.

Nelson, G. (1977). *How to see: Visual adventures in a world God never made.* Boston: Little, Brown and Company.

Newton, N. T. (1971). *Design on the land: the development of landscape architecture.* San Juan, Puerto Rico: La Editorial UPR.

Nijhuis, S. & De Vries, J. (2020). Research through Design in Landscape Architecture. *Landscape Journal, 38 (1).*

Nijhuis, S. (2011). Visual research in landscape architecture. *Research in urbanism Series, 2,* 103-145.

Nijhuis, S. (2013a). Principles of landscape architecture. In E. Farina, & S. Nijhuis (Eds.), Flowscapes: *Exploring landscape infrastructures.* Madrid: Mairea Libros Publishers.

Nijhuis, S. (2013b). *Mapping landscape architectonic compositions with GIS: Stourhead as a case-study.* Presented at Geodesign Summit Europe, Herwijnen, Geofort

Nijhuis, S. (2014). GIS-based landscape design research: Exploring aspects of visibility in landscape architectonic compositions. In *Geodesign by Integrating Design and Geospatial Sciences* (pp. 193-217). New York, NY: Springer.

Nijhuis, S. (2015). *GIS-based landscape design research: Stourhead landscape garden as a case study* (Doctoral thesis). Delft University of Technology, Delft, the Netherlands.

Nijhuis, S. (2016). Applications of GIS in landscape design research. *Research in urbanism series, 4(1),* 43-56.

Nijhuis, S., & Reitsma, M. (2011). Landscape policy and visual landscape assessment. The Province of Noord-Holland as a case study. *Research In Urbanism Series, 2(1),* 229-259.
Nijhuis, S., van Lammeren, R., & Antrop, M. (2011). Exploring visual landscapes. An introduction. *Research in urbanism series, 2,* 15-39.
O' Malley, T., Kryder-Reid, E., & Helmreich, A. (2010). *Keywords in American landscape design.* London: Yale University Press.
Ode, Å., Fry, G., Tveit, M. S., Messager, P., & Miller, D. (2009). Indicators of perceived naturalness as drivers of landscape preference. *Journal of environmental management, 90(1),* 375-383.
Ode, Å., Hagerhall, C. M., & Sang, N. (2010). Analysing visual landscape complexity: theory and application. *Landscape Research*, *35(1),* 111-131.
Ode, Å., Tveit, M. S., & Fry, G. (2008). Capturing landscape visual character using indicators: touching base with landscape aesthetic theory. *Landscape research, 33(1),* 89-117.
Office of the Architect, University of Virginia. (2011). *Landscape Typologies + Standards.* Retrieved from http://www.officearchitect.virginia.edu/pdfs/typologies.pdf.
Ohno, R., & Kondo, M. (1994). Measurement of the multi-sensory information for describing sequential experience in the environment: an application to the Japanese circuit-style garden. In S. J. Neary, M. S. Synes, & F. E. Brown (Eds.), *The Urban Experience: A People-Environment Perspective* (pp. 425-438). London: Taylor & Francis.
Olmedo, É., & Christmann, M. (2018). Perform the Map: Using Map-Score Experiences to Write and Reenact Places. *Cartographic Perspectives, (91),* 63-80.
Olwig, K. R. (2016). Virtual enclosure, ecosystem services, landscape's character and the 'rewilding' of the commons: the 'Lake District' case. *Landscape Research, 41(2),* 253-264.
Palmboom, F. (2018). *Ijsselmeer A Spatial Perspective.* Nijmegen: Vantilt.
Palmer, J. F. (1996). *Modelling spaciousness in the Dutch Landscape* (Report 119). Wageningen: DLO-Staring Centrum.
Palmer, J. F. (2000). Reliability of rating visible landscape qualities. *Landscape Journal, 19,* 166-178.
Palmer, J. F. (2004). Using spatial metrics to predict scenic perception in a changing landscape: Dennis, Massachusetts. *Landscape and Urban Planning, 69,* 201-218.
Palmer, J. F., & Lankhorst, J. R. K. (1998). Evaluating visible spatial diversity in the landscape. *Landscape and Urban Planning, 43(1-3),* 65-78.
Pancholi, S., Yigitcanlar, T., & Guaralda, M. (2015). Public space design of knowledge and innovation spaces: learnings from Kelvin Grove Urban Village, Brisbane. *Journal of Open Innovation: Technology, Market, and Complexity, 1(1),* 13.
Panero, J., & Zelnik, M. (1979). *Human dimension & interior space: a source book of design reference standards.* New York: Watson-Guptill.
Persson, A. S., Olsson, O., Rundlöf, M., & Smith, H. G. (2010). Land use intensity and landscape complexity—Analysis of landscape characteristics in an agricultural region in Southern Sweden. *Agriculture, ecosystems & environment, 136(1-2),* 169-176.
Pevsner, N. (1956). *The Englishness of English art.* New York: Frederick A. Praeger.
Pinzon Cortes, C. E., Bekkering, H. C., & Meyer, V. J. (2009). *Mapping Urban Form: Morphology studies in the contemporary urban landscape.* Delft University of Technoloy, Delft, the Netherlands.
Plexida, S. G., Sfougaris, A. I., Ispikoudis, I. P., & Papanastasis, V. P. (2014). Selecting landscape metrics as indicators of spatial heterogeneity: A comparison among Greek landscapes. *International Journal of Applied Earth Observation and Geoinformation, 26,* 26-35.
Pont, M. B., & Haupt, P. (2010). *Spacematrix: Space, Density, and Urban Form.* Rotterdam: nai010.
Popelka, S., & Brychtova, A. (2013). Eye-tracking Study on Different Perception of 2D and 3D Terrain Visualisation. *The Cartographic Journal, 50(3),* 240–246.
Portman, M. E., Natapov, A., & Fisher-Gewirtzman, D. (2015). To go where no man has gone before: Virtual reality in architecture, landscape architecture and environmental planning. *Computers, Environment and Urban Systems, 54,* 376-384.
Punia, M., & Pandey, D. (2006). 3D landscape modelling using JAVA 3D/VRML. *Journal of the Indian Society of Remote Sensing*, *34(4),* 397-403.
Punter, J. V., & Carmona, M. (1996). Design policies in English local plans: the search for substantive principles and appropriate procedures. *Urban Design International, 1(2),* 125-143.

Qin, X., Gao, L., & Shen, Y. (2016). Road Landscape Space Enclosure Scale and Sequence Characteristics Based on Human Aesthetic Perception and Psychological Experience. *Journal of Testing and Evaluation, 44(2),* 734-743.

Qiu, Y., Gao, J., & Zhan, Q. (2011). The Study of Landscape Visual Impact Assessment in Mountain Tourism Area. *2011 International Conference on Management and Service Science.* Wuhan.

Queensland Government. (2013). *Road Landscape Manual. Environmental Protection (2nd edition).* Retrieved from https://www.tmr.qld.gov.au/-/media/busind/techstdpubs/Environment-management/Road-Landscape-Manual.

Raaphorst, K., Roeleveld, G., Duchhart, I., van der Knaap, W., & van den Brink, A. (2018). Reading landscape design representations as an interplay of validity, readability and interactivity: a framework for visual content analysis. *Visual Communication, 19(2),* 163-197.

Rega, C. (2014). *Landscape planning and rural development: key issues and options towards integration.* London, New York, NY: Springer.

Ren, X., & Kang, J. (2015). Interactions between landscape elements and tranquillity evaluation based on eye tracking experiments. *The Journal of the Acoustical Society of America*, *138(5),* 3019–3022.

Repton, H. (1803). *The Theory and Practice of Landscape Gardening.* Cambridge, MA: The Riverside Press.

Robinson, N. (2004), The Planting Design Handbook. London: Ashagte Publishing.

Ronnen, G., Demura, Y., Kawasaki, M., & Higuchi, T. (2005). *Visual Perception of Landscape - from Kyoto city to its surrounding Mountains.* Retrieved from https://www.jsce.or.jp/library/open/proc/maglist2/00897/2005/pdf/B42D.pdf.

Rowley, J. & Hartley, R. (2006). *Organizing Knowledge. An introduction to managing access to information.* London: Ashgate Publishing.

Salat, S. (2011). *Cities and forms: on sustainable urbanism.* CSTB Urban Morphology Laboratory. Paris: Hermann.

Sang, Å. O., & Tveit, M. S. (2013). Perceptions of stewardship in Norwegian agricultural landscapes. *Land Use Policy, 31,* 557-564.

Sang, N., Hägerhäll, C., & Ode, Å. (2015). The Euler character: a new type of visual landscape metric? *Environment and Planning B: Planning and Design, 42(1),* 110-132.

Sang, N., Miller, D., & Ode, Å. (2008). Landscape metrics and visual topology in the analysis of landscape preference. *Environment and Planning B: Planning and Design*, *35(3),* 504–520.

Sanoff, H. (1991). *Visual research methods in design.* Hoboken, New Jersey: John Wiley & Sons.

Schroth, O. (2010). *From information to participation: interactive landscape visualization as a tool for collaborative planning.* ETH Zürich: VDF Hochschulverlag AG.

Schroth, O., Pond, E., Muir-Owen, S., Campbell, C., & Sheppard, S. R. (2009). *Tools for the understanding of spatio-temporal climate scenarios in local planning: Kimberley (BC) case study.* Zurich: Swiss National Sciences Foundation.

Secor, A. (2010). Social surveys, interviews, and focus groups. In B. Gomez, & J. P. Jones, (Eds.), *Research methods in Geography: A Critical Introduction.* Hoboken, New Jersey: Wiley.

Sevenant, M. (2010). *Variation in landscape perception ad preference. Experiences from case studies in rural and urban landscapes observed by different groups of respondents.* (Unpublished thesis). Department of Geography, Ghent University, Ghent, Belgium.

Shach-Pinsly, D., Fisher-Gewirtzman, D., & Burt, M. (2011). Visual exposure and visual openness: an integrated approach and comparative evaluation. *Journal of Urban Design, 16(2)*, 233-256.

Shi, S., Guo, Z, & Chen, L. H. C. (2014). How does enclosure influence environmental preferences? A cognitive study on urban public open spaces in Hong Kong. *Sustainable Cities and Society, 13,* 148-156.

Sijmons, D. F. & Van Dorst, M. J. (2014). The Emotional Landscape. In Sijmons, D. F., Hugtenburg, J., van Hoorn, A., & Feddes, F. (Eds.), *Landscape and Energy, Designing Transition.* Rotterdam: NAi010 publishers.

Simonds, J. O. (1961). *Landscape architecture: the shaping of man's natural environment.* New York: McGraw-Hill.

Simonds, J. O. (1997). *Landscape architecture : a manual of site planning and design.* New York: McGraw-Hill.

Simova, P., & Gdulova, K. (2012). Landscape indices behavior: a review of scale effects. *Applied Geography, 34,* 385-394.

Simpson, J., Freeth, M., Simpson, K. J., & Thwaites, K. (2019). Visual engagement with urban street edges: insights using mobile eye-tracking. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 12(3),* 259-278.

Smardon, R. C., Palmer, J. F., & Felleman, J. P. (1986). *Foundations for visual project analysis.* New York, NY: Wiley.

Smith, J. W. (2015). Immersive virtual environment technology to supplement environmental perception, preference and behavior research: a review with applications. *International journal of environmental research and public health, 12(9),* 11486-11505.

Stahl, S. A. (2005). Four problems with teaching word meanings. In H. Elfrieda & M. Kamil (Eds.), *Teaching and learning vocabulary: Bringing research to practice* (pp. 95-114). L. Erlbaum Associates, Groningen.

Stamps, A. E. (2004). Mystery, complexity, legibility and coherence: A meta-analysis. *Journal of Environmental Psychology, 24(1),* 1-16.

Stamps, A. E. (2005). Visual permeability, locomotive permeability, safety, and enclosure. *Environment and Behavior, 37(5),* 587-619.

Stamps, A. E. (2008). Some findings on prospect and refuge: I. *Perceptual and motor skills, 106(1),* 147-162.

Stamps, A. E., & Nasar, J. L. (1997). Design review and public preferences: effects of geographical location, public consensus, sensation seeking, and architectural styles. *Journal of environmental psychology,17(1),* 11-32.

Steenbergen, C. M., & Reh, W. (2003). *Architecture and landscape. The design experiment of the great European gardens and landscapes.* Basel, Boston, Berlin: Birkhäuser.

Steenbergen, C. M., & Reh, W. (2011). *Metropolitan landscape architecture: Urban parks and landscapes.* Bussum: Thoth publishers.

Steenbergen, C. M., Meeks, S., & Nijhuis, S. (2008). *Composing landscapes: analysis, typology and experiments for design.* Basel, Boston, Berlin, Switzerland: Birkhäuser.

Steinitz, C. (1990). Toward a sustainable landscape with high visual preference and high ecological integrity: the loop road in Acadia National Park, USA. *Landscape and urban planning, 19(3),* 213-250.

Steinitz, C. (1994), A Framework for Theory and Practice in Landscape Planning. *Ekistics, 61(364-365),* 4.

Stiles, R. (1994). Landscape theory: a missing link between landscape planning and landscape design?. *Landscape and urban planning*, *30(3),* 139-149.

Stoecklein, M. C. (2011). *The complete plant selection guide for landscape design.* Purdue University Press.

Stokes, E. C., & Seto, K. (2018). Characterizing and measuring urban landscapes for sustainability. *Environmental Research Letters, (14).*

Sunak, Y., & Madlener, R. (2016). The impact of wind farm visibility on property values: A spatial difference-in-differences analysis. *Energy Economics*, *55*, 79-91.

Surová, D., Pinto-Correia, T., & Marušák, R. (2014). Visual complexity and the montado do matter: landscape pattern preferences of user groups in Alentejo, Portugal. *Annals of forest science, 71(1),* 15-24.

Sutton, R. K. (1992). Understanding the Visual Language of Design: A Hierarchical Approach to Gestalt Formalism. *Landscape Architecture Program: Faculty Scholarly and Creative Activity, 9.*

Swetnam, R. D. & Tweed, F. S. (2018), A Tale of Two Landscapes: Transferring Landscape Quality Metrics from Wales to Iceland. *Land Use Policy, 76,* 565-576.

Tabrizian, P. (2018). *Integrating Geospatial Computation, Virtual Reality and Tangible Interaction to Improve Landscape Design and Research* (PhD thesis). North Carolina State University, Raleigh, North Carolina, United States.

Talen, E. (2006). Design for diversity: evaluating the context of socially mixed neighbourhoods. *Journal of Urban Design, 11(1),* 1-32.

Ţălu, M., Ţălu, Ş., Adam, E. I., & García, G. V. (2016). ArchiCAD landscape modelling employed in designing a small garden. *Acta Technica Napocensis: Civil Engineering & Architecture*, *59(2).*

Tebyanian, N. (2020). Application of Machine Learning for Urban Land-scape Design: A Primer for Landscape Architects. *Journal of Digital Landscape Architecture,* 217-226.

Telega, A. (2016). Urban Street Network Analysis Using Space Syntax in GIS - Cracow Case Study. *2016 Baltic Geodetic Congress (BGC Geomatics), 282–287.*

The University of British Columbia. (2020). *How Virtual Reality Can Aid Land-Based Resource Management and Operation Planning.* Retrieved from https://forestry.ubc.ca/research/how-virtual-reality-can-aid-forest-operations/.

Thiel, P. (1961). A sequence-experience notation. *Town Planning Review, 32(1),* 33.
Thiel, P. (1981). *Visual awareness and design: an introductory program in conceptual awareness, perceptual sensitivity, and basic design skills*. Seattle, MA: University of Washington Press.
Thwaites, K. (2001). Experiential Landscape Place: an exploration of space and experience in neighbourhood landscape architecture. *Landscape Research, 26(3),* 245-255.
Thwaites, K., Helleur, E., & Simkins, I. M. (2005). Restorative urban open space: Exploring the spatial configuration of human emotional fulfilment in urban open space. *Landscape Research, 30(4),* 525-547.
Torreggiani, D., Ludwiczak, Z., Dall'Ara, E., Benni, S., Maino, E., & Tassinari, P. (2014). TRuLAn: A high-resolution method for multi-time analysis of traditional rural landscapes and its application in Emilia-Romagna, Italy. *Landscape and urban planning, 124,* 93-103.
Trancik, R. (1986). *Finding lost space: theories of urban design.* Hoboken, New Jersey: John Wiley & Sons.
Tudor, C., & Natural England. (2014). *An Approach to Landscape Character Assessment*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/691184/landscape-character-assessment.pdf.
Turner, M. G. (1990). Spatial and temporal analysis of landscape patterns. *Landscape Ecology, 4(1),* 21–30.
Turner, M. G., & Gardner, R. H. (1991). *Quantitative methods in landscape ecology.* New York, NY: Springer.
Turner, M. G., Gardner, R. H., Dale, V. H., & O'Neill, R. V. (1989). Predicting the spread of disturbance across heterogeneous landscapes. *Oikos, 55,* 121-129.
Turner, M. G., O'Neill, R. V., Gardner, R. H., & Milne, B. T. (1989). Effects of changing spatial scale on the analysis of landscape pattern. *Landscape ecology, 3(3-4),* 153-162.
Tveit, M. (2009). Indicators of visual scale as predictors of landscape preference; a comparison between groups. *Journal of Environmental Management*, *90(9),* 2882–2888.
Tveit, M. S., & Ode, Å. (2014). Landscape assessment in metropolitan areas - developing a visual indicator-based approach. *SPOOL, 1(1).*
Tveit, M., Ode, Å., & Fry, G. (2006). Key concepts in a framework for analysing visual landscape character. *Landscape research, 31,* 229–255.
Tversky, B. (1993). Cognitive maps, cognitive collages, and spatial mental models. *In European conference on spatial information theor*y (pp. 14-24). Berlin, Heidelberg: Springer.
U.S. Department of Transportation. (2015). *Guidelines for the visual impact assessment of highway projects.* Retrieved from https://www.environment.fhwa.dot.gov/env_topics/other_topics/VIA_Guidelines_for_Highway_Projects.pdf.
Ulrich, R. S. (1977). Visual landscape preference: A model and application. *Man-Environment Systems, 7(5),* 279-293.
Urban, D., & Keitt, T. (2001). Landscape Connectivity: A Graph-Theoretic Perspective. *Ecology, 82(5),* 1205–1218.
Urech, P., Girot, C., Dissegna, M. A., & Grêt-Regamey, A. (2020). Point Cloud Modeling as a Bridge between Landscape Design and Planning. *Landscape and Urban Planning.*
Uttley, J., Simpson, J., & Qasem, H. (2018). Eye-tracking in the real world: Insights about the urban environment. In *Handbook of Research on Perception-Driven Approaches to Urban Assessment and Design (pp. 368-396)*. Hershey, Pennsylvania: IGI Global.
Uuemaa, E., Antrop, M., Marja, R., Roosaare, J., & Mander, Ü., 2009. Landscape Metrics and Indices : An Overview of Their Use in Landscape Research Imprint/Terms of Use. *Living Reviews in Landscape Research*, *3*, 1–28.
Van Bilsen, A. (2008). *Mathematical explorations in urban and regional design* (Doctoral thesis). Delft University of Technology, Delft, the Netherlands.
Van den Berg, A. E. (1999). *Individual differences in the aesthetic evaluation of natural landscapes* (Doctoral thesis). Groningen, Rijksuniversiteit Groningen.
Van der Hoeven, F., & Nijhuis, S. (2011). Hi Rise, I can see you! Planning and visibility assessment of high building development in Rotterdam. *Research in urbanism series*, *2*, 277-301.
Van der Valk, A. (2002). The Dutch planning experience. *Landscape and urban planning, 58(2-4),* 201-210.
Van Eetvelde, V., & Antrop, M. (2009). A stepwise multi-scaled landscape typology and characterisation for trans-regional integration, applied on the federal state of Belgium. *Landscape and Urban Planning*, *91(3),* 160–170.

Van Nes, A. (2011). The one and two dimensional isovists analyses in space syntax. In S. Nijhuis, R. Lammeren, & F. D. Hoeven (Eds.), *Exploring the Visual Landscape. Advances in Physiognomic Landscape Research. Research in Urbanism Series 2* (p. 163-183). Amsterdam: IOS Press.
Vroom, M. J. (2006). *Lexicon of Garden and Landscape Architecture.* Basel: Birkhäuser.
Walliss, J. & Rahmann, H. (2016). *Landscape Architecture and Digital Technologies: Re-conceptualising Design and Making.* London, New York: Routledge Taylor & Francis.
Wang, C., Li, X., Yu, H., & Wang, Y. (2019). Tracing the Spatial Variation and Value Change of Ecosystem Services in Yellow River Delta, China. *Ecological Indicators, 96,* 270-277.
Warnock, S. & Griffiths, G. (2015). Landscape Characterisation: The Living Landscapes Approach in the UK. *Landscape Research, 40(3),* 261-278.
Wasserman, J. (2012). A World in Motion: the creative synergy of Lawrence and Anna Halprin. *Landscape Journal, 31(1-2),* 33-52.
Weinstoerffer, J., & Girardin, P. (2000). Assessment of the contribution of land use pattern and intensity to landscape quality: use of a landscape indicator. *Ecological Modelling, 130(1-3),* 95-109.
Weitkamp, G., Bregt, A., van Lammeren, R., & van den Berg, A. (2007). Three sampling methods for visibility measures of landscape perception. *International Conference on Spatial Information Theory* (pp. 268-284). Berlin, Heidelberg: Springer.
Weitkamp, S. G. (2010). *Capturing the view: a GIS-Based Procedure to Assess Perceived Landscape Openness* (Unpublished thesis). Wageningen University, Wageningen, the Netherlands.
Wernke, S. A., Kohut, L. E., & Traslaviña, A. (2017). A GIS of affordances: movement and visibility at a planned colonial town in highland Peru. *Journal of Archaeological Science*, *84*, 22-39.
Wiens, J. A. (2002). Central concepts and issues of landscape ecology. *Applying landscape ecology in biological conservation* (pp. 3-21). New York, NY: Springer.
Wissen Hayek, U., Müller, K., Göbel, F., Kiefer, P., Spielhofer, R., & Grêt-Regamey, A., (2019). 3D Point Clouds and Eye Tracking for Investigating the Perception and Acceptance of Power Lines in Different Landscapes. *Multimodal Technologies and Interaction, 3(2),* 40.
Wissen, U., Schroth, O., Lange, E., & Schmid, W. A. (2008). Approaches to integrating indicators into 3D landscape visualisations and their benefits for participative planning situations. *Journal of Environmental Management*, *89(3),* 184-196.
Wright, G. (1974). Appraisal of visual landscape qualities in a region selected for accelerated growth. *Landscape Planning, 1,* 307–327.
Yahia, M. W., & Johansson, E. (2014). Landscape interventions in improving thermal comfort in the hot dry city of Damascus, Syria -- The example of residential spaces with detached buildings. *Landscape and Urban Planning*, *125*, 1-16.
Yahner, T. G., Korostoff, N., Johnson, T. P., Battaglia, A. M., & Jones, D. R. (1995). Cultural landscapes and landscape ecology in contemporary greenway planning, design and management: a case study. *Landscape and urban planning, 33(1-3),* 295-316.
Zhang, L., Wang, Z., & Da, L. (2019). Spatial characteristics of urban green space: a case study of Shanghai, China. *Applied Ecology and Environmental Research, 17(2),* 1799-1815.
Zube, E. H., Sell, J. L., & Taylor, J. G. (1982). Landscape perception: research, application and theory. *Landscape planning, 9(1),* 1-33.

Curriculum Vitae

Mei LIU

- **1989**
  Born in Harbin, China
- **2008 - 2012**
  Bachelor of Agriculture at the department of Landscape Architecture, Northeast Forestry University, Harbin, China
- **2012 - 2015**
  Master of Landscape Architecture at the department of Urban Planning and Management, Harbin Institute of Technology (Shenzhen), Shenzhen, China
- **2013 - 2014**
  Master of Landscape Study at the department of Landscape Architecture, The University of Sheffield, Sheffield, UK
- **2015 - present**
  PhD candidate at the chair of Landscape Architecture, Department of Urbanism, Faculty of Architecture and Built Environment, Delft University of Technology, Delft, The Netherlands

Mei Liu was born in Harbin (China) in 1989. In 2008, she started studying Landscape Architecture in Northeast Forestry University, where graduated with a diploma of Bachelor of Agriculture in 2012. For the coming year she started her Master of Landscape Architecture at the department of Urban Planning and Management in Harbin Institute of Technology in Shenzhen (China). After studying two semesters she went abroad to the UK and participated another master track Landscape Studies in the University of Sheffield. In 2015, she finished her master thesis 'Assessment of Aesthetic Preferences in Relation to Vegetation-Created Enclosure in Chinese Urban Parks' with distinction and obtained both master degrees. In the same year, she came to Delft University of Technology with scholarship from CSC (Chinese Scholarship Council) and started her PhD in the Section of Landscape Architecture at the Faculty of Architecture and the Built Environment (The Netherlands). She has expertise mainly in digital mapping methods and tools, spatial-visual landscape characterisation, and visual landscape preference studies. She participated in several international conferences and presented her research, published journals.

Publications

Journal Article:

- Liu, M., & Nijhuis, S. (2020), Digital Methods for Mapping Landscape Spaces in Landscape Design. *Journal of Digital Landscape Architecture, 5,* 634-645.
- Liu, M., & Nijhuis, S. (2020). Mapping landscape spaces: Methods for understanding spatial-visual characteristics in landscape design. *Environmental Impact Assessment Review*, *82*, 106376.
- Liu, M., & Schroth, O. (2019). Assessment of Aesthetic Preferences in Relation to Vegetation-Created Enclosure in Chinese Urban Parks: A Case Study of Shenzhen Litchi Park. *Sustainability*, *11*(6), 1809.

Conference Presentation:

- Liu, M. (2019, September). Digital Methods for Mapping Landscape Space. In *ECLAS and UNISCAPE Annual Conference 2019* (p. 29). Ås, Norway.
- Liu, M. (2019, September). Mapping Methods and Tools for Spatial-visual Characteristics of Landscape Space. In *IFLA 2019*. Oslo, Norway.
- Liu, M. (2018, October). Mapping and Understanding Urban Space. In *2018 Venice Architecture Biennale 'Free Space' Workshop TAU City Centre*. Venice, Italy.
- Liu, M. (2017, September). Interpretation, Measurement and Evaluation of Spatial-visual Landscape Characteristics in Landscape Design. In *Creation/Reaction: ECLAS 2017 Conference.* London, UK.

20#20

Mapping Landscape Spaces

Understanding, interpretation, and the use of spatial-visual landscape characteristics in landscape design

Mei Liu

Landscape design focuses on the construction and articulation of outdoor space and results in landscape architectonic compositions. In order to communicate about three-dimensional forms and functions, vocabulary, representations, and tools (in terms of spatial-visual characteristics) are of fundamental importance for landscape architects to describe, interpret, and manipulate landscape spaces. While combining design vocabulary and landscape indicators, qualitative and quantitative mapping approaches, visual representation and interpretation methods, this research aims to provide a framework for describing, understanding, and communicating about spatial-visual characteristics in landscape design. A pilot study is used to explore the potential of specific mapping approaches, such as compartment analysis, 3D landscapes, grid-cell analysis, landscape metrics, visibility analysis, and eye-tracking analysis, which are employed to address spatial-visual phenomena like sequence, orientation, continuity, and complexity. Hypothetical design experiments are conducted to evaluate the feasibility and effectiveness of spatial-visual mapping in the design process. Interviews with designers are carried out to reflect on techniques for mapping spatial-visual characteristics in the daily practice of landscape architecture. This research opens a way in which to apply visual landscape research in the process of landscape design and supports the development of multidisciplinary approaches. By expanding the spatial-visual mapping toolbox, designers can engage in issues of landscape development, transformation, and preservation while providing realistic and instrumental clues for interventions in urban landscapes.

A+BE | Architecture and the Built Environment | TU Delft BK