Digital Methods for Mapping Landscape Spaces in Landscape Design

Mei Liu[1], Steffen Nijhuis[2]

[1]Faculty of Architecture and The Built Environment/TU Delft, Delft/Netherlands · m.liu-1@tudelft.nl
[2]Faculty of Architecture and The Built Environment/TU Delft, Delft/Netherlands

Abstract: With the growth of digital technology, the possibilities increase for landscape architects to gain a deeper understanding of landscape compositions and their spatial-visual characteristics. Despite the fact that digital methods are acknowledged to be useful for thinking about landscape space, in practice their potential is often still underutilized in the spatial design process. In order to break down the barriers of using digital methods in the practice of landscape design, it is essential to develop applications that show their potential and added value in a practical design context. This paper aims to provide an overview of some useful applications of digital mapping methods to understand spatial-visual characteristics of landscape and their transformations in a hypothetical landscape design process.

Keywords: Mapping landscape space spatial-visual characteristics, landscape design, research through design, intersubjective approaches

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 spatial-visual characteristics of landscape spaces. Despite its importance, there are only a few attempts to implement and develop digital methods that help to understand and describe the visual manifestation of landscape space, how space is organized, 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 visualizations, and virtual reality (VR) environments (e. g. CANTRELL & MICHAELS 2010, CURETON 2016, WALLISS & RAHMANN 2016, BIANCHETTI 2017, LIN et al. 2018). They are essential means to present three-dimensional spatial characteristics of the landscape and mimic the existing landscape, or future landscape scenarios in the design process. Next to these visual representation tools, there are also some quantitative mapping methods using algorithms and indicators to acquire knowledge of spatial-visual landscape characteristics, for example GIS-based approaches, Space Syntax, and landscape metrics, etc. (e. g. WEITKAMP 2010, TUDOR 2014, WARNOCK & GRIFFITHS 2014, SWETNAM & TWEED 2018, WANG et al. 2019). These methods open up alternative ways to understand landscape spaces.

While digital methods are recognized to be useful for thinking about landscape space, their application in a practical design context is still lagging behind (NIJHUIS 2015). The uptake of

Journal of Digital Landscape Architecture, 5-2020, pp. 634-645. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-690-1, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537690065.

using digital methods in design processes is surprisingly slow and is often limited to basic visualizations when used. There seems to be a lot of confusion and unawareness about the use of digital methods for thinking about landscape space in the design process, and the possibility to gain a deeper understanding of spatial-visual characteristics and their transformations. In order to break down the barriers of using digital methods in landscape design, it is essential to develop applications that show their potential in a practical design context.

This paper explores some digital methods for mapping landscape space in the design process, as a means for thinking and communication about spatial-visual landscape characteristics. Central is a hypothetical design experiment to illustrate practical applications of spatial-visual mapping methods and tools in landscape design while exploiting their powerful integrating, analytical, and graphical capacities.

2 Methods

2.1 Mapping Methods and Tools

Visual landscape research integrates landscape architecture concepts, landscape perception approaches, and mapping methods and techniques (NIJHUIS et al. 2011). In the field of landscape perception research, there is a vast amount of theories, methods, and applications available that can be divided into two main discourses: expert approaches and public preference approaches (SEVENANT 2010). 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.

Research on visual landscape mapping can be categorized 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 the map view (NIJHUIS 2015). Qualitative approaches here are termed as the empirical interpretation of observation, while quantitative approaches gather numerical information or translate knowledge into numbers in order to describe and analyse certain phenomena more objectively. In NIJHUIS et al. (2011) the following methods for mapping spatial-visual landscape characteristics are identified:

- 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 (e. g. axial map based on Space Syntax).
- 3D landscapes: identifies the visual landscape from an observer's point of view, which utilizes two to three dimensional visualizations and addresses spatial-visual characteristics horizontally (e. g. landscape visualization, 3D modelling).
- Grid-cell analysis: evaluates the landscape by calculating different spatial properties by means of grid-shaped polygons or raster cells. The results of compartment analysis or 3D landscapes can be used as inputs (e. g. SegNet analysis, GIS-based point density analysis).
- 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 (e. g. GIS-based viewshed analysis, isovist analysis).

- 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 (e. g. Fragstats measurement).

Some of these methods are tested on their use in the hypothetical design experiment.

2.2 Research through Design

Design is a core activity of landscape architecture, and also regarded as a research strategy, often referred as "research through design" (DEMING & SWAFFIELD 2011, NIJHUIS & DE VRIES 2020). Research through design enables researchers to explore possibilities in a spatial and designerly way, and generate specific knowledge for design in the form of guidelines and design principles through design experiments and their evaluation. Six stages are typical for the design process (adapted from STEINITZ 1994, DIAZ & BELL 1997, NASSAUER & OPDAM 2008). This research conducts a design experiment while using multiple digital mapping methods and tools for getting a grip on landscape space in the design process (Figure 1).

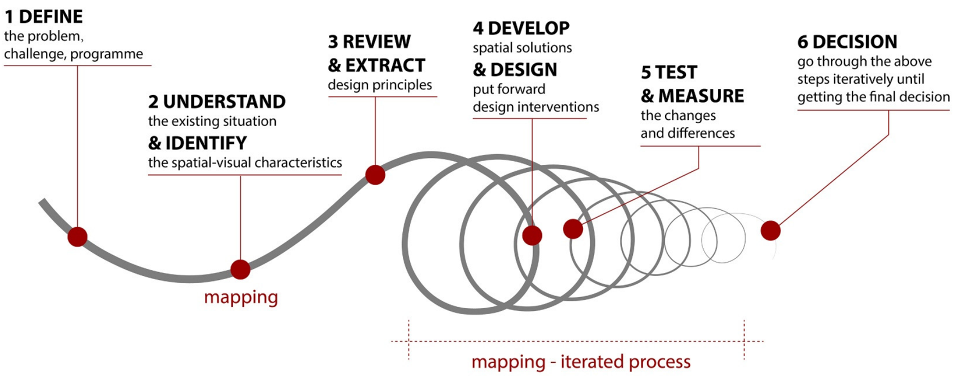

Fig. 1: The landscape design process in six steps

As an essential part of the process of design, mapping media such as drawings, models, and digital techniques are seen as indispensable means for understanding landscape space from multiple levels of scale.

2.3 The Hypothetical Design Assignment

In order to showcase the potential of mapping methods in the design process, the Vondelpark in Amsterdam is used as an experimentation site. The Vondelpark is a public urban park initially designed by the architect Jan David Zocher in 1865. Since 1996 the whole park has been designated as a National Monument, which nowadays welcomes more than 10 million visitors every year. The 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 (STEENBERGEN & REH, 2011). Thus, the 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 the Vondelpark (and its hypothetical changes) that serves as a basis for the computational analysis.

As cultural heritage, the Vondelpark suffers from problems related to climate change and the popularity of the park. Four main spatial challenges are urgent to be addressed, which 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 going-through cycling. Here a challenge is defined as the situation of being faced with something that needs great effort in order to address successfully. These challenges are addressed in the hypothetical design and used to display the potential of digital 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 organization of the park.

3 Results

3.1 Spatial-Visual Design Solution: A Hypothetical Plan for the Vondelpark

In order to address the challenges, the following interventions are proposed: 1) Creating landforms in open spaces to compensate for the subsidence and enabling higher groundwater tables (Challenge A); 2) Expanding water bodies to increase storage capacity, as well as to enhance the perception of the open-enclosed variation (Challenge B); 3) Creation of a new retention pond connected with the primary water system (Challenge B); 4) Establishing the visual connection between the Vondelpark and neighbourhoods by removing some vegetation to create vistas and accommodate way-finding (Challenge C); 5) A new cycle route from east to west to differentiate between pedestrians and going-through cyclers (Challenge D); 6) Opening spaces along the cycling route to accommodate distribution of visitors, but also to improve the perception of safety (Challenge D). Figures 2 and 3 present the translation of the proposed interventions into spatial design.

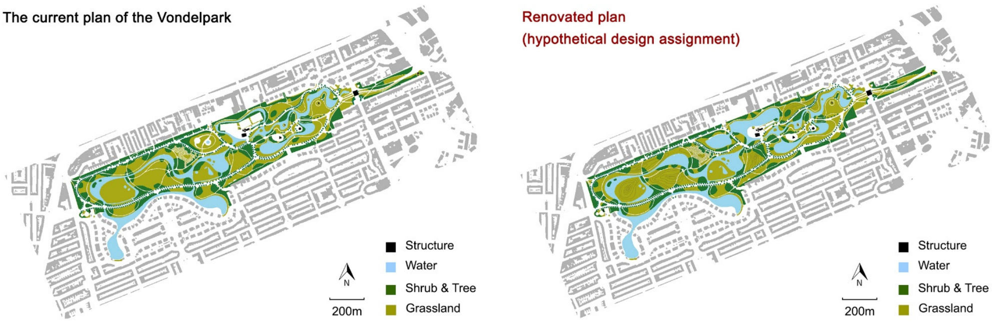

Fig. 2: The current plan (left) and the new plan of the Vondelpark (right)

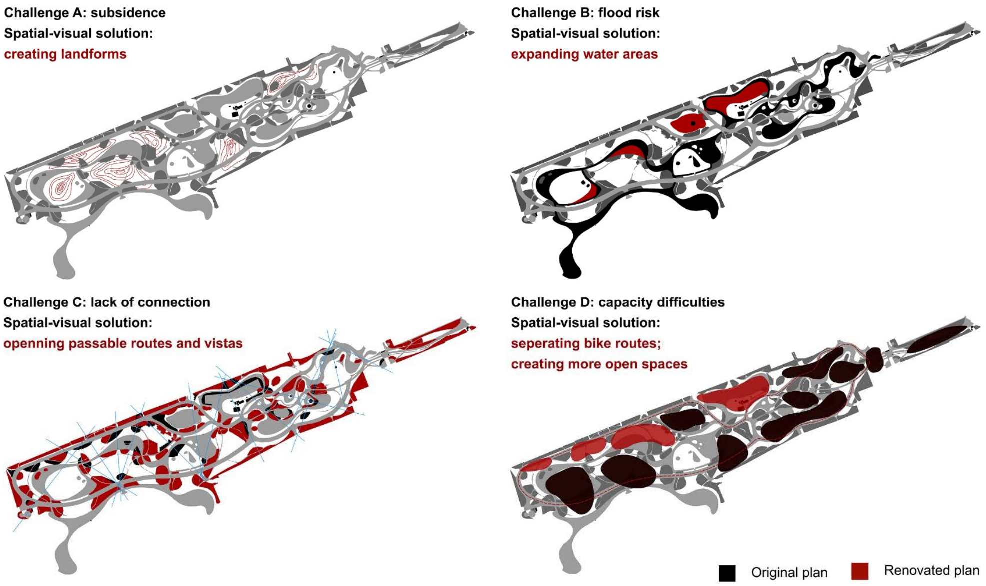

Fig. 3: Diagrams showing changes in the new plan following the hypothetical design assignment (Challenge A, B, C, D)

3.2 Mapping Spatial-Visual Characteristics of Landscape Spaces

In order to identify the spatial-visual consequences of the interventions to the Vondelpark, selected digital 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, making a pictorial landscape composition, and identifying dominant visual landscape elements, etc.

3.2.1 Compartment Analysis and Landscape Metrics (Challenge A & B)

To evaluate the impact of the topographic changes by the addition of landforms, compartment analysis is applied, which is helpful to represent the relationship between space and mass, and concludes 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. Figure 4 shows the cross sections of the terrain elevation in the current and new situation.

After calculating the proportion of land use in both plans, the water surface in the park increases from 17.2 % to 22.7 %, which indicates extra water storage capacity for rain water (Figure 5). In terms of spatial compositions, the open-enclosed variation along the water flow is emphasized at the same time.

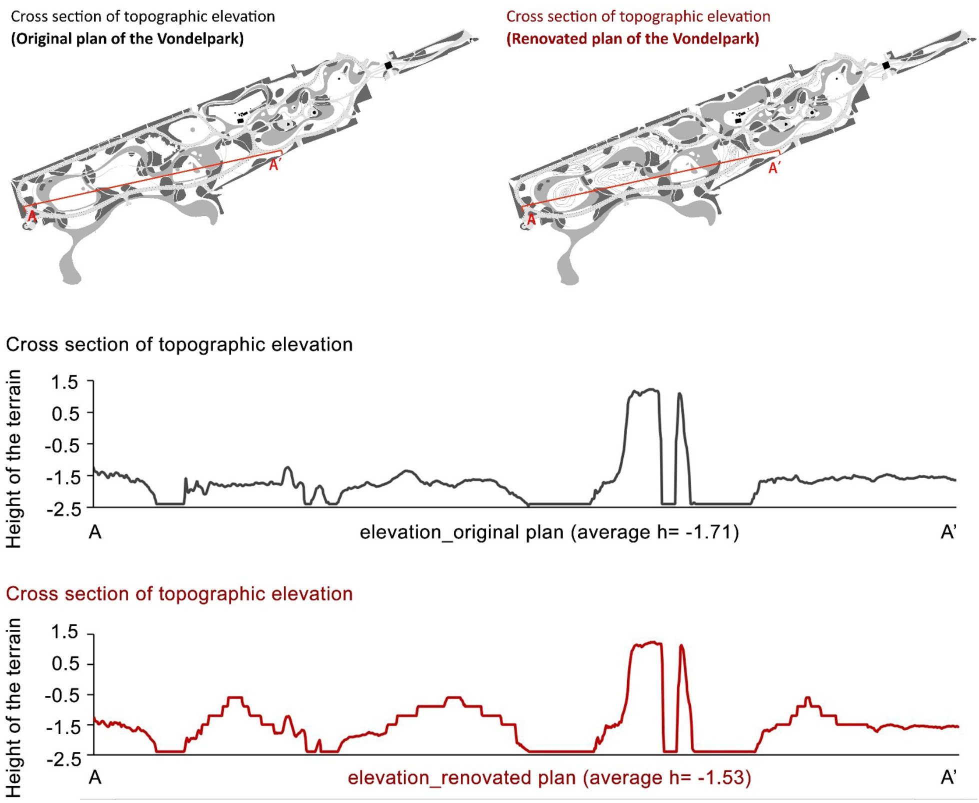

Fig. 4: Cross-section elevations A-A in the current plan and the new plan

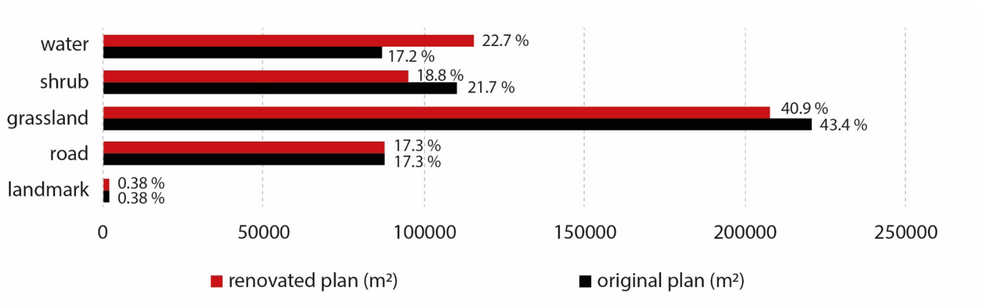

Fig. 5: Bar chart showing the proportion of land use in the current and new situation

To evaluate changes in the spatial pattern, landscape metrics are utilized. Indicators such as the Radius of gyration/Correlation length (GYRATE) and Proximity (PROX) (McGarigal & Marks, 1995) are used to provide information on the spatial composition of the park. Fragstats v4.2.1 is applied to measure these indicators based on the land-use grid map and transferred to ArcGIS to visualize. Figure 6 shows individual spaces that are connected and show a significant value of the radius of gyration, which indicates physical and visual continuity. Compared to the compact but discrete spaces, continuous and elongated spaces are joined. At the same time, the analysis of proximity shows that closed spaces from the same class show larger values. Even though they are not physically connected, they show structural adjacency. Spatial designers can use these clues as a basis to create continuity by providing transitional spaces or thresholds between contiguous spaces.

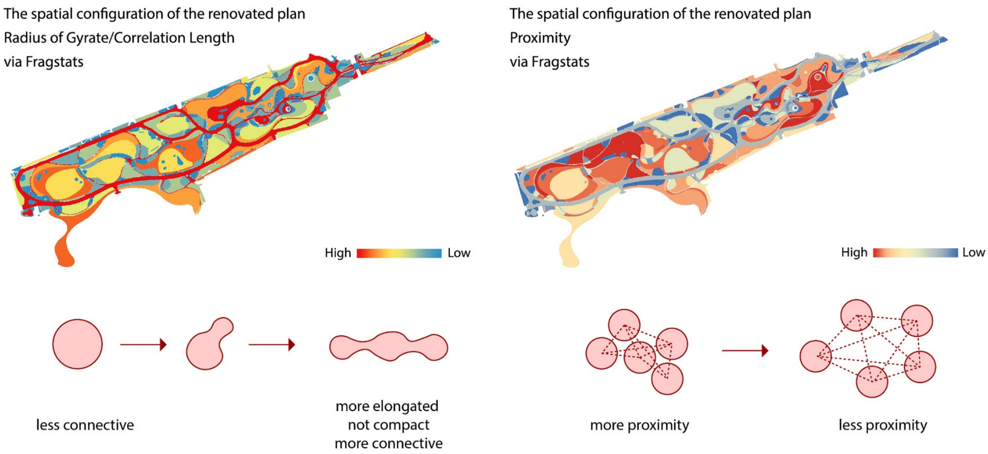

Fig. 6: Evaluation of the changes in the spatial pattern via Fragstats and ArcGIS: Radius of Gyrate (left) and Proximity (right)

3.2.2 Grid-Cell Analysis, Visibility Analysis, 3D Landscapes (Challenge C)

To strengthen visual connections between the Vondelpark and its urban context, some vegetation is removed (Figure 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 enclosure and states that a visual and physical enclosure can be characterized in every scene. Figure 7 shows open visual and open physical viewpoints along the path system, and calculates point densities based on the grid-cell analysis. Compared with the original situation, the new situation shows more integrated connectivity in all directions.

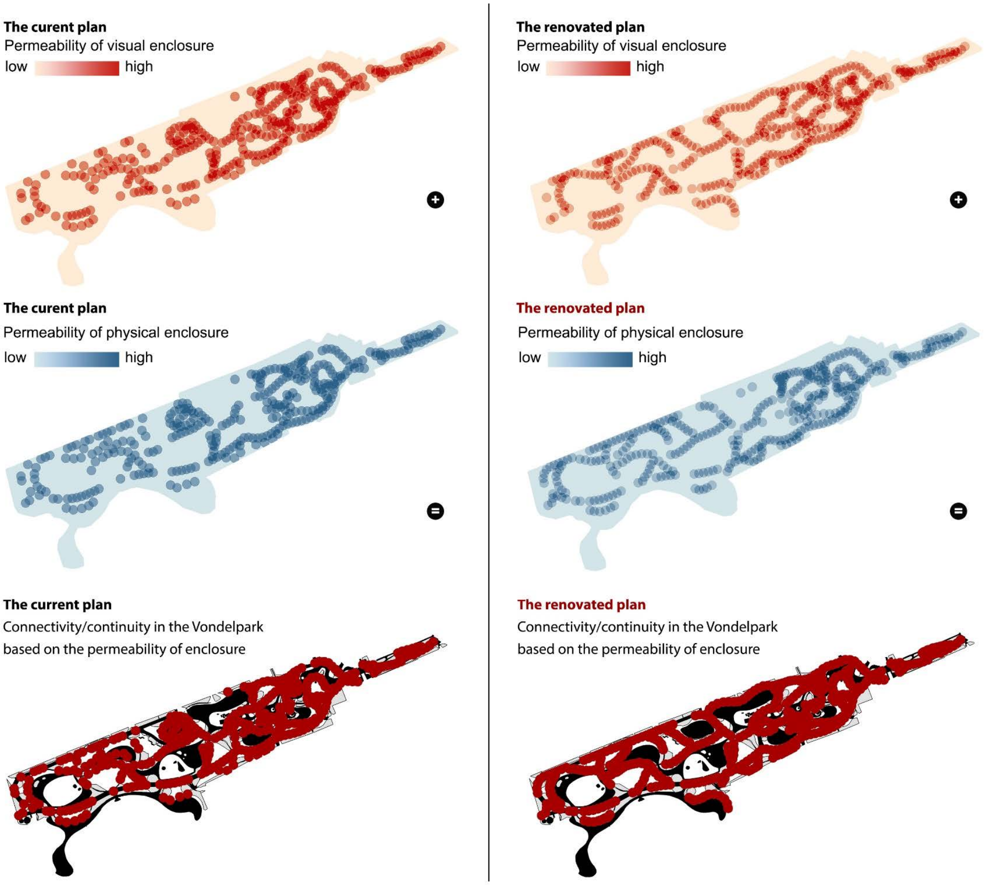

Fig. 7: Grid-cell analysis evaluating the connectivity in the current and new situation

The new vistas improve the complexity/diversity with open views and eye-catching landmarks from different directions. Visibility analysis and 3D landscape visualization 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 way-finding, 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 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.

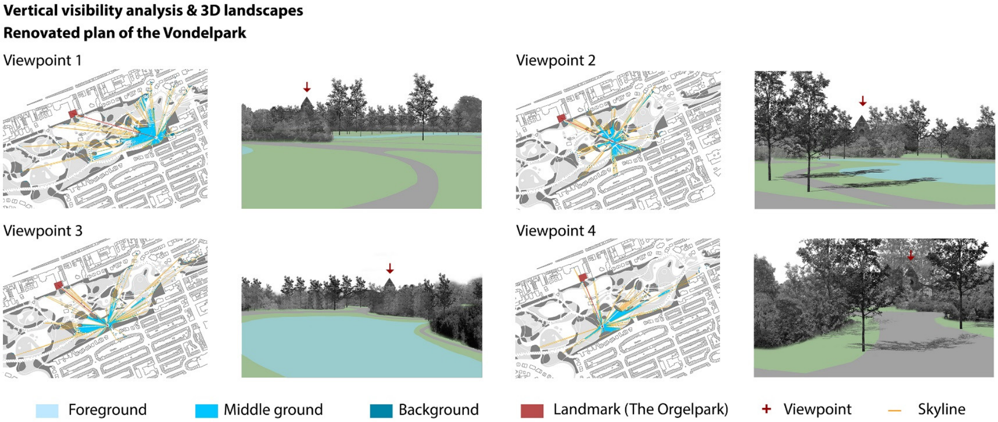

Fig. 8: Visibility analysis combined with 3D landscapes to show the complexity/diversity scenes in the landscape

3.2.3 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 mode will influence the visibility of spaces (WEITKAMP, 2010). Taking Path 1 as an example, the line chart in Figure 9 shows the visual character of sequential experience, with a horizontal visual angle of 124°, moving forward from east to west. The indicator used here is the amount of overlapping open space seen along the path in the current and new 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 (Figure 10). 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.

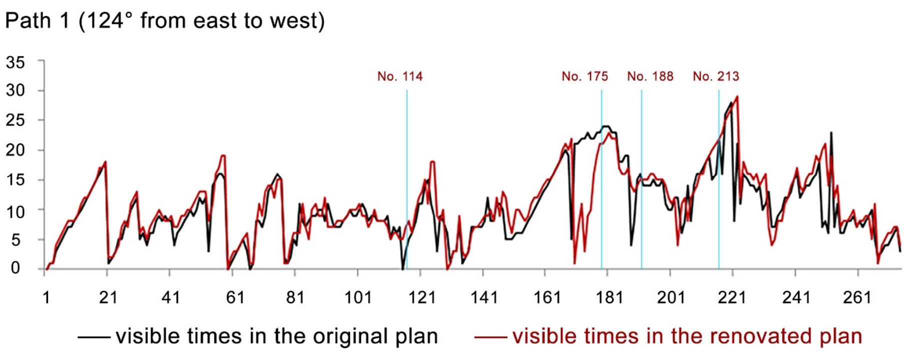

Fig. 9: Line chart presenting the visual character of the sequential experience along Path 1 of the existing and new situation

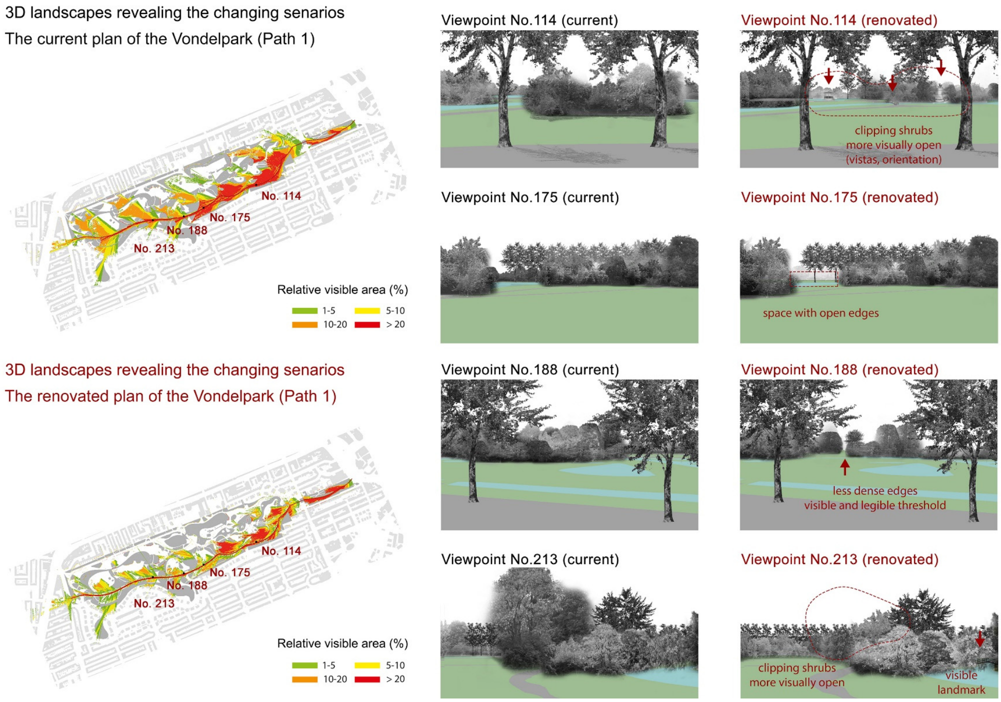

Fig. 10: Visibility analysis and 3D landscapes of the existing and new situation

4 Discussion and Conclusion

As exemplified by the presented design process, a combination of different mapping methods is not only used to get a grip on the spatial-visual character of the Vondelpark, but also to evaluate the consequences of the 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, 3D landscapes, grid-cell analysis, visibility analysis, and landscape metrics prove to be powerful means in *ex-ante* analysis and evaluation of the proposed spatial-visual organization. The methods are complementary, and especially in combination they help to think about and visualize landscape space in qualitative and quantitative ways.

Though the paper 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 11). The mapping results became part of the design iterations, in which the designer gains a better understanding of landscape space and makes changes and refinements accordingly.

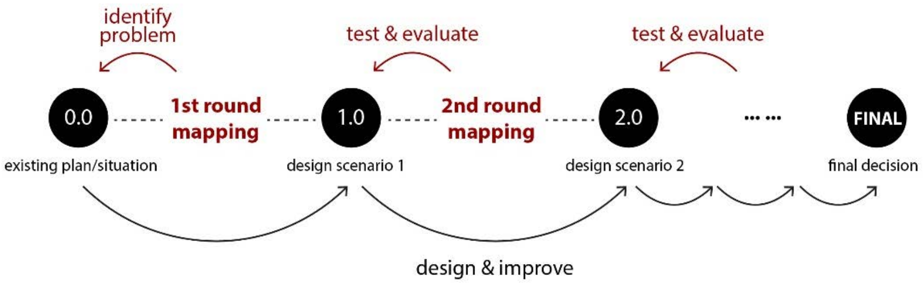

Fig. 11: Diagram showing the iterative design process of landscape design and the role of spatial-visual landscape mapping methods and tools

Digital methods for mapping landscape spaces are important for enhancing the advancement of landscape architecture and extending the toolbox of knowledge-based landscape design. This study showcases that (combinations of) digital mapping methods can be practically applied throughout the landscape design process. Although the implementation of digital mapping methods proved 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 in the design process. In addition, digital mapping methods do not replace traditional means such as hand drawn sketches and models, but are complementary tools for the landscape architect. Digital methods also have their limitations in terms of data acquisition, processing time, skills, etc. Further research is needed to identify and address practical hurdles of the implementation of digital tools in design. Therefore, educational and research institutions have an important role to play, they should take the lead in knowledge acquisition and development of a digital culture in landscape architecture.

References

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

CANTRELL, B. & MICHAELS, W. (2010), Digital Drawing for Landscape Architecture: Contemporary Techniques and Tools for Digital Representation in Site Design. John Wiley & Sons, Hoboken, NJ.

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

DEMING, M. E. & SWAFFIELD, S. (2011), Landscape Architectural Research: Inquiry, Strategy, Design. John Wiley & Sons, Hoboken, NJ.

DIAZ, N. M. & BELL, S. (1997), Landscape analysis and design. Creating Forestry for the 21st Century: The Science of Ecosystem Management. Island Press, Washington, DC, 255-270.

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. doi:10.1080/01426397.2013.773966.

EVERT, K. J., BALLARD, E. B., OQUINENA, I., SCHMERBER, J. M. & STIPE, R. E. (2010), Encyclopedic Dictionary of Landscape and Urban Planning. Multilingual Reference Book in English, Spanish, French, and German (2 Vols.).

HIGUCHI, T. (1988), The Visual and Spatial Structure of Landscapes. MIT Press, Cambridge.

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. doi:10.1016/j.eiar.2018.03.001.

MCGARIGAL, K. & MARKS, B. J. (1995), FRAGSTAT: Spatial Pattern Analysis Program for Quantifying Landscape Structure. United States Department of Agriculture, Pacific Northwest Research Station.

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

NIJHUIS, S. & DE VRIES, J. (2020), Research through Design in Landscape Architecture. Landscape Journal, 38 (1).

NIJHUIS, S. (2015), GIS-based Landscape Design Research. A+ BE| Architecture And The Built Environment, (13), 1-338.

NIJHUIS, S., LAMMEREN, R. VAN, ANTROP, M. (2011), Exploring visual landscapes. An introduction, Research in urbanism series, Vol. 2; 5-39. http://dx.doi.org/10.7480/rius.2.205.

ROBINSON, N. (2016), The Planting Design Handbook. Routledge Taylor & Francis, London/New York.

STEENBERGEN, C. & REH, W. (2011), Metropolitan landscape architecture. Bussum, Thoth.

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

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. doi: 10.1016/j.landusepol.2018.02.037.

TUDOR, C. (2014), An Approach to Landscape Character Assessment. Natural England.

VROOM, M. J. (2006), Lexicon of Garden and Landscape Architecture. Birkhäuser-Publishers for Architecture.

WALLISS, J. & RAHMANN, H. (2016), Landscape Architecture and Digital Technologies: Reconceptualising Design and Making. Routledge Taylor & Francis, London/New York.

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. doi: 10.1016/j.ecolind.2018.09.015.

WARNOCK, S. & GRIFFITHS, G. (2015), Landscape Characterisation: The Living Landscapes Approach in the UK. Landscape Research, 40 (3), 261-278. doi: 10.1080/01426397.2013.870541.

WEITKAMP, S. G. (2010), Capturing the view: a GIS-Based Procedure to Assess Perceived Landscape Openness (unpublished thesis). Wageningen University, Wageningen, the Netherlands.