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THE IMPACT OF LAKESHORE MODIFICATIONS AND CONSTRUCTIONS ON VISUAL LANDSCAPE QUALITY: A MIXED METHODS STUDY

Xuecheng CAI [1]✉, Zsombor BOROMISZA [1], Zhenming CAI [2]

[1] *Department of Landscape Protection and Reclamation, Hungarian University of Agriculture and Life Sciences, Villányi út 35-43, H-1118 Budapest, Hungary*
[2] *Institute of Culture, Guizhou Academy of Social Sciences, Shuoshi Lane 19, 550002 Guiyang City, Guizhou Province, China*

Highlights:
- the visual quality of the lakeshore landscape is significantly degraded by the intervention of construction activities;
- modification and construction activities in lakeshore areas can cause chaotic landscape views, destruction of vegetation, and increased artificial shoreline;
- large-scale land cover changes and vegetation loss from construction activities are the primary drivers affecting lakefront landscape visual quality;
- selection of construction materials and control of construction duration play an important role in reducing the visual impact on the lakeshore landscape;
- testing and applying different evaluation methods provides a more comprehensive understanding of the factors contributing to visual intrusion and their impacts on receptors.

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Abstract. Lakeshore areas continue to be threatened by increasing human activities and land use. Development and large construction projects in lakeshore areas affect both the lake's ecological condition and its landscape quality and aesthetics. To minimize and prevent the occurrence of significant visual impacts, it is important to understand and evaluate the magnitude of damage and the factors contributing to such impacts from development activities. In this study, a mixed methods approach is used to assess the visual impact of modifications and constructions on the lakeshore landscape. This includes (1) an objective landscape indicator-based assessment method to measure the extent of construction and modification impacts on the visual landscape, and (2) a visual perception-based assessment method to capture receptors' evaluations of the visual landscape changes and visual impact factors on the lakeshore. Integrating the results from both methods yields a comprehensive assessment of visual impact. The results of both assessment methods indicate that the visual quality of the lakeshore landscape declined significantly during the construction phase. In addition, this study concludes that this mixed approach to visual impact assessment has greater advantages than a single approach and provides more dimensional information, criteria, and perspectives.

Keywords: lakeshore landscape, visual impact, landscape aesthetics, impact evaluation.

✉Corresponding author. E-mail: *chercaicai@gmail.com*

1. Introduction

Lakes have rich ecological resources and valuable aesthetic values and are often considered attractive destinations for tourism, leisure, and recreational activities. The lakeshore area is the most popular site for visitors and settlements, but are also the most vulnerable to the negative effects of human pressure (Furgała-Selezniow et al., 2020). Over the past 30 years, tourism development and construction along Hungarian lakeshores have steadily expanded, which has resulted in more than half of the lakeshore areas being occupied by man-made structures and a large proportion of semi-natural land being converted to tourism-related land use (Furgała-Selezniow et al., 2022). Socio-economic considerations often take priority over environmental concerns in lakeshore development (Lindsay et al., 2002). In recent years, the Hungarian government and the National General Directorate of Water Management (OVF) have continued to increase their investments and initiatives in the development of the lake areas. This has directly led to an increase in built-up areas and construction activities in the lakeshore areas, as well as changes in the shoreline.

Modification of the lakeshore may result in substantial changes in its character as it is subjected to multiple pressures and the quality of habitats may be threatened (Latinopoulos et al., 2018). Shoreline alteration and changes in riparian land use can pose risks to aquatic ecosystems and result in the loss of the naturalness of the lakes (Carpenter et al., 2007). Changes in the vegetation cover, natural state, habitat quality, and the richness of species are negatively associated with the developing activities in and around the lakeshore areas (Hall & Härkönen, 2006). Numerous research studies have examined the influence of lakeshore modifications on flora and fauna. However, the impact of intervention activities on the landscape aesthetic and aspects of visual amenities is still insufficiently recognized. In particular, the impact of developing projects and intensive construction activities on the visual quality and the aesthetics of the lake landscapes are rarely investigated. Lakeshore zones are extremely fragile environments, not only in an ecological sense but also visually (Smardon, 1988). Development activities and external interferences can lead to degradation of landscape resources (Cui et al., 2021), interrupt the visual information and scenic beauty of the surrounding area (Krause, 2001). An increasing number of new land uses are being imposed on the natural landscape, often resulting in large-scale facilities that dominate the visual scene (Werner & Zander, 2001). This study focuses on the effects of lakeshore construction activities and disturbances on visual landscape quality.

1.1. Visual impact assessment

Since the 60s, landscape visual quality assessment and visual impact assessment (VIA) have become a vital research composition component in the field of landscape architecture and environmental science (Palmer, 1983; Wu et al., 2006). Visual impact relates to the changes in the views of the landscape and the effects of those changes on visual amenity and visual receptors. Visual impact assessment predicts and assesses the intensity of potential aesthetic or visual impacts of developed projects or proposed development activities in a particular area (Canter, 1996). This is accomplished by evaluating how the views and visual zone may be affected by changes in the visual content or changes in features because of the introduction of new elements and loss of the existing elements in the landscape (Landscape Institute & Institute of Environmental Management & Assessment [LI & IEMA], 2013). According to Qi et al. (2013), "color, texture, uncoordinated volume, and occlusion of the visual zones might cause visual impacts in the landscapes." VIA has been widely used in studies of the visual impact of large sized objects in the landscape, such as; wind farms, power stations, and hydropower plants, etc. (Spielhofer et al., 2021; Wróżyński et al., 2016). It is also often used in site selection of new architecture or farm buildings in rural areas (Hernández et al., 2004), to estimate the scenic beauty (Frank et al., 2013; Schmid, 2001), to evaluate the visual impact of the highway construction (Jiang et al., 2015) and exposed pit mines (Misthos et al., 2020). In recent years, a number of researchers have focused on the visual impact of tall buildings on the lake landscapes and have argued that specific mid-range views can be effective in limiting the visual impact of tall buildings (Lin et al., 2018). Some studies evaluated the aesthetic value of waterfront landscapes with varied embankment types from the perspective of landscape preference (Cai & Boromisza, 2020; Hu et al., 2019).

1.2. Mixed methods for VIA

In the past, common methods applied to landscape aesthetics and visual aspects were primarily based on and survey of public perceptions and preferences (Li et al., 2021). These methods are based on the feelings, judgments, and reactions of the interviewees. Evaluations also usually differ in the different occupations, backgrounds, and ages of the interviewees. The subjective specificity of such perception-based assessment methods and the lack of standard evaluation procedures result in their inability to be systematically quantified and less convincing. Over the last decade, GIS, remote sensing and 3D graphics software have become important supporting tools that are widely used for objective visual landscape quality evaluation and visibility analysis (Atik et al., 2017; Daniel, 2001). Landscape metrics and spatial metrics provide opportunities for objectivity and standardization of assessments. Most visual evaluation metrics are related to the physical characteristics and state of the landscape (Palmer, 1983). Frank et al. (2013) suggested that the landscape metrics-based assessment is an effective method for environmental impact assessment and landscape aesthetic assessment, which can provide an informative context for survey sites that responds to physical landscape conditions, land use change and landscape character. Landscape spatial indicators are practically useful. They can facilitate landscape preference studies by enabling faster and easier evaluation through reference to landscape metrics. (de la Fuente de Val et al., 2006; Frank et al., 2013; Dupont et al., 2017).

Bamberger (2012) argued that there is rarely a single assessment method that can fully capture all the complexity of a project functioning in a physical space. A mixed approach allows the strengths of different approaches to be captured and useful information to be integrated. An integrated approach leverages different assessment tools and perspectives to help evaluate and monitor the quality and changes of development activities on the visual landscape. The adoption of a mixed approach can therefore generate new insights and comprehensive understanding through the results of different methods (Bamberger, 2012; Hattam et al., 2015).

In this paper, an objective landscape metrics-based assessment method (LMBA) and a subjective visual perception-based assessment method (VPBA) will be used to evaluate the visual impact of the construction and modification on the lakeshore landscape respectively. Both applied approaches considered the visual quality of the landscape as a matter of interaction between physical landscape features and visual perception processes, but with different attention to landscape quality and receptors (Daniel, 2001). The LMBA approach is first applied to quantify the magnitude of the visual impact and cumulative effect of the lakeshore landscape, which will be measured and calculated through a set of assessment indicators with the help of GIS tools and temporal-spatial datasets. The VPBA method will then investigate receptors' evaluations and perceptions of changes in the visual landscape quality of the lakeshore, and identify the impact factors during the construction phase. Lastly, to compare the visual impact values assessed by the two methods and validate their relevance. The final visual impact level for each lakeshore site will be determined by combining the results of the two assessment methods.

2. Case study and methods

2.1. Study area and project overview

Lake Velence is the second largest natural lake and a popular tourism destination in Hungary. It is situated in Fejér County, at the foot of the Velence Hills, between Budapest and Lake Balaton (Papp, 1995). Lake Velence has an area of 26 square kilometers and an average depth of 1.6 meters. On the western side of the lake lies a 4.2 km^2 nature reserve that is part of a Ramsar Convention site. The total length of the lake shoreline is 40.67 km (Boromisza, 2012). Since 1970, several interventions and bank stabilization works have been carried out along the shores of Lake Velence. From the early 1990s to 2019, the proportion of natural shoreline around Lake Velence decreased from 55% to 42% of the total length. At the same time, tourism-oriented land use has been increasing in the shore areas. The development of Lake Velence has focused on the creation and expansion of tourism infrastructure and structures (Gábor, 2016).

According to an official online announcement from the Hungarian water authorities (https://magyarepitok.hu/) in May of 2016, Lake Velence was planned to undertake a comprehensive lakeshore renovation and modification program starting at the end of 2017, with a tender fund for 14 billion forints from EU funds within the framework of KEHOP (Environmental and Energy Efficiency Operational Program). The project was expected to be completed in 2022. A total of 29 kilometers of shoreline will be renovated in the Lake Velence Complex Shore Renovation Program initiative. A new waterfront promenade and tailings pond will be constructed, dredging of the lake bottom will also take place, and emphasis will be placed on the development of recreational services and areas (e.g., additional bike paths and beaches).

2.2. Sample plots

Six representative plots along the lake were selected as sample sites for the visual impact assessment (Figure 1). Each of the selected study sites underwent different types of construction operations and modifications during the lakeshore reconstruction program, including pavement renewal, tailings disposal, embankment reconstruction, bank wall demolition, material stockpiling, and construction of a new promenade. The 100-meter riparian zone along the shoreline of Lake Velence serves as a focal point of our research, as these areas were predominantly semi-natural or characterized by low human activity prior to modification. All designated study plots represent typical sections of the lake shoreline, measuring 300 meters in length and 100 meters in width. Ground-level photographs taken from a human perspective were used for the public participation survey, with the camera position positioned in the middle of each plot.

2.3. Landscape metrics-based assessment

A set of relevant metrics was applied to measure visual impacts of the construction and lakeshore modifications. The selection of metrics focused on the spatial effects of construction activities on physical landscape conditions and land cover changes, and the cumulative impacts resulting from the duration of construction.

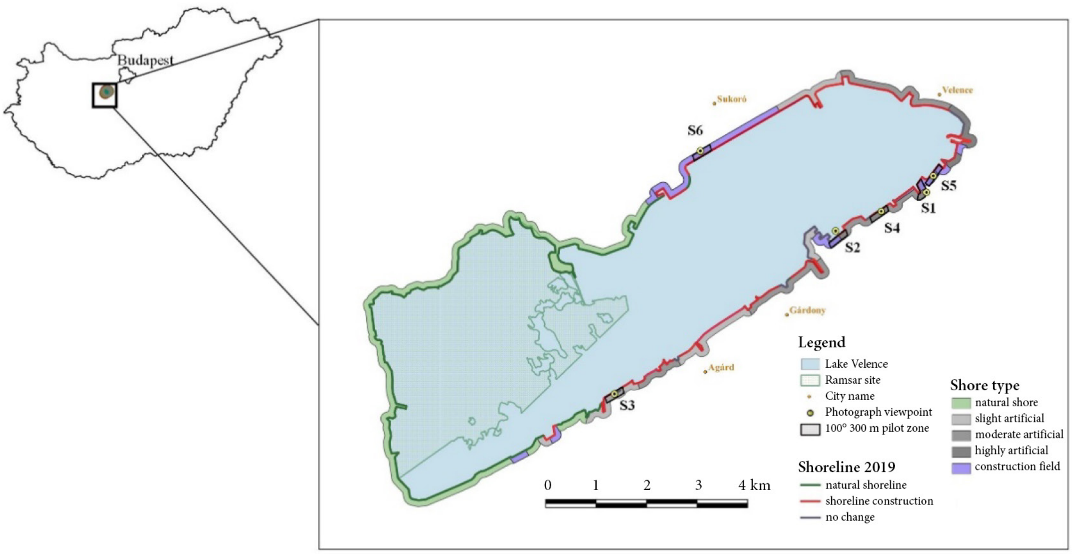

Figure 1. Study area

Previous studies have identified naturalness (Frank et al., 2013), landscape structure, and vegetation cover (Wang et al., 2016) as essential criteria for the assessment of landscape aesthetic quality. These factors are found to be closely correlated with scenic beauty, landscape preference, and visual landscape quality. Furthermore, LI and IEMA (2013) concluded that minor impacts on highly sensitive areas may be more critical than major impacts on less sensitive areas. Landscape sensitivity is therefore a crucial factor in assessing visually disturbed landscapes, as even slight disturbances can have significant adverse effect on areas with high sensitivity and naturalness.

We analyzed and measured the spatial land cover of the study sample plots using QGIS 2.18 (QGIS Development Team, 2016), based on 20-m resolution aerial imagery and raster orthophotography acquired in 2016 and 2019. First, we digitized land cover maps of the plots for the pre-construction (2016) and during construction (2019) periods by drawing polygons on two time-representative vector layers. The land cover analysis and measurements primarily included built-up areas, patch areas, bare land, and grassland. Afterwards, we calculated the differences in vegetation cover and the exposed construction area between the two time points. These differences represent the magnitude of land cover change.

Additionally, we monitored the duration of construction and disturbance conditions at the study sites during the 2016–2022 period through field surveys and the historical imagery tool in Google Earth.

Each indicator component has independent evaluation standards (Table 1). The rating scale for each indicator consists of four classes, from 1 to 4. The state of the landscape and naturalness level in the pre-construction period determines the scoring for the corresponding degree of the landscape sensitivity. The parameters obtained from the geoprocessing survey and monitoring are the basis for the corresponding scoring for each indicator (Table 1). The final impact value for each study site, calculated through the landscape metrics-based assessment (V_{LMBA}), is given by Equation (1):

$$V_{LMBA} = S_{LS}\left(\sum S_{MC}\right)\times S_{DE}, \tag{1}$$

where S_{LS} is the score of the sensitivity of the target area; S_{DE} represents the length of the construction duration; S_{MC} means the magnitude of the land cover changes, which was a combination of the degree of the exposed construction area (S_{CA}) and the degree of vegetation degradation (S_{VD}).

Table 1. Metrics for visual impact assessment of lakeshore modification

Categories	Landscape indicators	Description	Score (S)
Landscape sensitivity (LS)	Sensitivity/ Site condition before construction	low sensitivity (highly artificial lakeshore)	1
		slightly sensitive (semi artificial)	2
		moderate sensitivity (semi natural lakeshore)	3
		highly sensitive (nature conservation)	4
Magnitude of the land cover change (MC)	Construction area (CA) and Vegetation cover degradation area (VD)	small area (<20%)	–2
		medium (20%–50%)	–4
		medium-large (50%–70%)	–6
		Large (>70%)	–8
Duration effect (DE)	Duration of construction work	temporary (<6 months)	–1
		medium term (6–12 months)	–2
		medium-long term (12–24 months)	–3
		long term (>2 years)	–4

2.4. Visual landscape quality evaluation based on public perceptual attributes

An online photo-based questionnaire survey was conducted to involve participants in assessing the visual aesthetic quality of lakeshore landscapes under different conditions. Participants evaluated the aesthetic value of the lakeshore landscape using ground-level photographs from two periods: T1 (pre-construction) and T2 (during construction). The differences in evaluation scores between the two periods indicates the degree of influence of external interventions and modifications on visual quality.

Six sets of comparative photographs were used in the questionnaire survey (Figure 2), taken in June 2016 and late May 2019. All photographs used were intended to accurately document changes in site conditions and visual content, both before and during construction. Each group of comparative photos was taken with the exact viewpoint and at the same angle. To minimize the effects of color contrast and weather differences, the overall tone and sky color of each photo group were adjusted using Photoshop.

The first part of the questionnaire collected basic information about the respondents, including occupation, place of residence, and previous visits at Lake Velence. Afterward, respondents rated each scenario using the comparative photographs on a scale from 1 (least beautiful) to 5 (most beautiful). In the final session, participants were asked to select three main negative factors for each site from a list of 10 visual impact elements (Table 2). Overall, the visual influences were grouped into four categories: land cover change, intrusion of volumetric objects, high-contrast materials, and surroundings.

We sent the questionnaire via email and Facebook local groups individually to the participants. A total of 52 valid responses were completed. Among them, 80.41% of the respondents had visited lake Velence once or more times. The participants consisted of three different representative public groups (Figure 2), including planning and landscape professionals (37.5%), local residents and members of neighborhood associations around the lake (41.35%), and the tourists and outdoor enthusiasts (21.15%).

Note: a = T1 (before construction), b = T2 (under construction). S1 – pavement renewal site, S2 – new tailings pond site, S3 – reconstruction of embankment and pavement, S4 – demolition site, S5 – stockpile field, S6 – new promenade construction segment.

Figure 2. Comparison photo sets used in the online survey

Table 2. Categories of visual impact factors

Code	Element	Category
LC1	Damaged vegetation, plants degradation	Land cover change
LC2	Unpaved pavement, granular base, bare ground	
IV1	Stockpile of construction materials (soil, sand, gravel, rocks)	Invasion of volumetric objects
IV2	Machine (excavator)	
IV3	Public facilities (roadblock, iron fence, pole, trash bin)	
EM1	Hard paving (cement pavement, concrete shore wall)	Exposure to high-contrast building materials
EM2	Plastic cloth cover	
SE1	Water	Surrounding environment and other factors
SE2	Buildings	
SE3	Other factors	

2.5. Comparing and integrating the assessment results of the VPBA and LMBA methods

Based on the preliminary assessment results, we identified no clear positive visual impacts from construction operations and shoreline modifications at all survey sites in Lake Velence, either from the landscape metrics-based assessment or the public perception-based assessment. In the VPBA approach, the potential impact values depend on the mean differences of the aesthetic ratings between the two periods (before and during construction activities), with values ranging from 0 (no impact) to 4 (highest negative impact). The final impact values from the LMBA method range from 0 (no impact) to –128 (highest negative impact), indicating the extent to which construction affects the visual quality of the lakeshore.

To compare and verify the differences between the two methods, the final impact values were grouped into five levels: a (no impact), b (minor negative impact), c (moderate negative impact), d (significant negative impact), and e (major negative impact). The degree of visual impact is determined by the range of grade values corresponding to the final assessment values for each survey site (Table 3).

Table 3. Definition of visual impact degree of two assessment approaches

Range of V_{VPBA}	Range of V_{LMBA}	Impact description	Degree of visual impact (DVI)	Final degree of impact (FDI)
T1 – T2 = 0	0	no change	a (0)	0 = A
T1 – T2 = 0.1 – 1	–1 to –32	slight negative impact	b (1)	1 – 2 = B
T1 – T2 = 1.1 – 2	–32 to –64	moderate negative impact	c (2)	3 – 4 = C
T1 – T2 = 2.1 – 3	–65 to –96	significant negative impact	d (3)	5 – 6 = D
T1 – T2 = 3.1 – 4	–97 to –128	major negative impact	e (4)	7 – 8 = E

Note: V_{VPBA} – the aesthetic value difference between the two periods obtained through perceptual evaluation. V_{LMBA} – total impact value based on landscape metrics assessment.

Once the degree of visual impact (DVI) is assessed, each impact level is assigned a value from 0 to 4. Here, 0 represents a and 4 represents e. The final degree of impact (*FDI*) is then obtained by combining the results of the two methods, as expressed by the following equation:

$$FDI = DVI_1 + DVI_2, \quad (2)$$

where DVI_1 indicates the degree of visual impact obtained through the landscape metrics-based assessment method; DVI_2 represents the impact rating obtained through the visual perception-based assessment method. The final calculated impact value (*FDI*) can also be divided into five levels (from A to E), where A means no impact, E represents the highest impact level (Table 3).

2.6. Statistical analysis

A Wilcoxon signed-rank test was applied to examine the significance of differences in overall perceived aesthetics ratings of all survey sites between the two time periods (pre-construction and during construction), and individually test the significance of the difference in the perceived rating of each survey site in the two time periods. We also used the non-parametric method, Spearman's rank correlation coefficient (r_s) to examine the correlation between the impact results of the six survey sites obtained from the two approaches (visual perception-based assessment and landscape metrics-based assessment). All the above analyses were performed using software SPSS (v25.0, IBM Corp., Armonk, NY, USA).

3. Results

3.1. Evaluation results of the landscape metric-based assessment

The LMBA approach is primarily based on the objective identification of landscape characteristics, describing and measuring changes in landscape composition and quality through changes on a spatial-temporal scale. The main result of the assessment is a qualitative description of each of the landscape indicators listed in Table 1.

Among all the investigated sites, the results assessed with the LMBA method (Figure 3, Table 4) showed that Site 5 (stockpile site) received the highest negative visual impact score (V_{LMBA} = –48), which was the most significantly impacted by the shore modifications and construction operations. Followed by Site 2 (tailings pond) and Site 6 (promenade construction site), with scores of –36 and –27 respectively. From the field surveys and examination of HD aerial photographs of changes in landscape features, it was found that these high impact sites have moderate to large land cover changes caused by construction operations. All these scenes are in a continuous process of medium to long-term disruption.

3.2. Assessment of lakeshore visual landscape quality by public participants

Based on 52 valid responses, perceived aesthetic quality declined at all survey sites during the construction period (T2) compared with the pre-construction period (T1). This

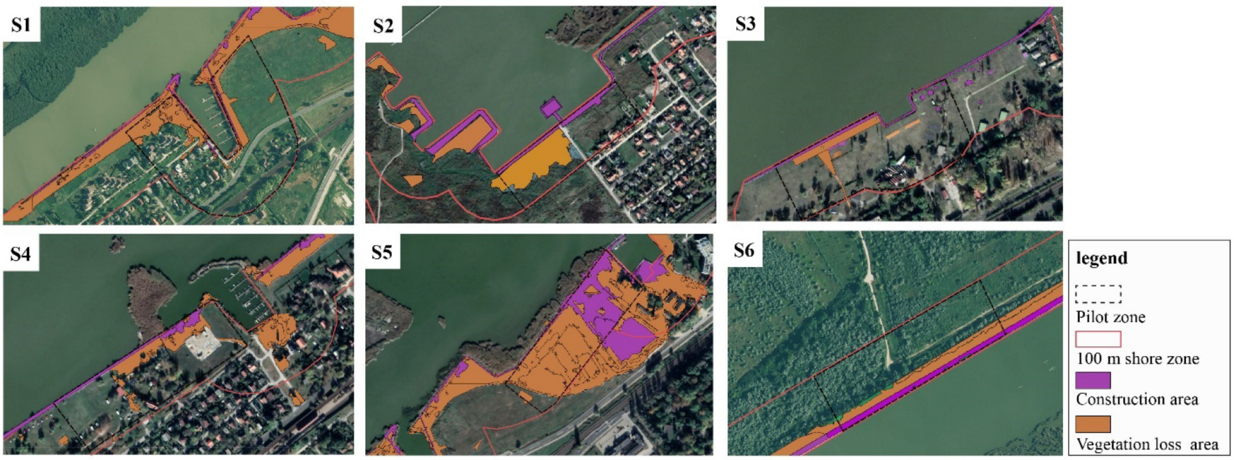

Figure 3. Land cover change in the study pilot sites

Table 4. Measurement of the landscape metrics

Categories	S1	S2	S3	S4	S5	S6
Landscape sensitivity (LS)	slight	moderate	slight	slight	moderate	moderate
Magnitude of the land cover change (MC)	medium	medium-large	small	small	large	medium
Duration effect (DE)	medium term	long term	medium term	temporary	long term	medium-long term
V_{LMBA}	–8	–36	–4	–4	–48	–27

difference was confirmed by a Wilcoxon signed-rank test ($Z = -12.277$, $p < 0.01$). As shown in Table 5, the perceived aesthetic scores and median scores at all survey sites during the construction period (T2) were significantly lower than the perceived aesthetic scores of the previous landscape (T1). The lakeshore modifications and associated construction activities led to a significant decline in the visual quality of the landscape. The largest mean decreases in aesthetic ratings between the two periods occurred at the stockpile site (S5), followed by the site where the embankment and pavement were reconstructed (S3), and the new tailings pond site (S2). However, the promenade construction site (S6) showed the smallest change in aesthetic ratings between the two periods.

The perception-based survey indicated that the public's ratings of disturbed lakeshore scenes were closely related to the visual quality of the pre-construction landscape. More picturesque scenes were found to be more visually fragile, and even minor disturbances or intrusions could cause substantial declines in perceived visual quality. For example, S5 received the highest aesthetic rating (mean = 4.19) among all surveyed sites before construction (T1), but dropped dramatically to 2.10 during the construction (T2). In contrast, Site 6, which had the lowest pre-construction rating, declined less than other sites and received relatively higher scores during construction, resulting in the smallest change in perceived visual quality between the two periods.

3.3. A comparison and integration of the evaluation results of the VPBA and LMBA methods

Spearman's rank correlation coefficient was computed to assess the relationships between the VPBA method, the LMBA method, and the landscape indicators applied in the LMBA. Table 6 shows the correlation between the results of the visual perceptual assessment and the landscape metrics-based assessment, indicating that there is no statistically significant correlation between the evaluation results. It is noteworthy that no significant correlations were found between the results of the visual perception assessment and the indicators (landscape sensitivity, land cover change, and construction duration) applied in the LMBA.

A comparison of the LMBA and VPBA results (Table 7) showed that half of the sites had identical visual impact ratings from the two methods. Differences in the degree of visual impact assessment are observed at S2, S3, and S6, and the visual impact ratings of S2 and S6 obtained from the landscape metrics-based assessment are higher than the visual perception evaluation.

Combining the visual impact values from the two assessment methods, Table 7 shows the final aggregate rating results (FDI), with Sites 2 and 5 receiving the highest visual impact grades, both rated D, indicating a significant negative visual impact.

Table 6. Correlations between values from LMBA and VPBA assessment methods and the applied indicators

	V_{VPBA}	LS	MC	DE
V_{LMBA}	0.433	–0.949**	0.906*	0.953**
V_{VPBA}	1	–0.211	0.477	0.572

Note: N = 6, ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Table 7. Impact level ratings for six survey sites based on different methods

Method	Degree of visual impact					
	S1	S2	S3	S4	S5	S6
DVI1	b	d	b	b	d	c
DVI2	b	c	c	b	d	b
FDI	B	D	C	B	D	C

Note: DVI1 – degree of visual impact evaluated based on landscape metrics, DVI2 – degree of visual impact of the assessment based on visual perception, FDI – final degree of visual impact from the integrated methods. The visual impact degrees range from A to E (a–e = results from different assessment methods; A–E = final evaluation results; A/a = no change; B/b = slight negative impact; C/c = moderate negative impact; D/d = significant negative impact; E/e = major negative impact). Values shown reflect only the categories observed.

Table 5. Visual quality ratings of the survey sites in different times

Sample site	T1 (Before)		T2 (During)		Difference		Z	P value of Wilcoxon Signed Ranks Test
	Mean	Median	Mean	Median	Mean	Median	T2-T1	T2-T1
S1	3.58	3.5	2.00	2	1.58	2	-5.369^b	0.000
S2	3.60	4	1.92	2	1.67	2	-5.321^b	0.000
S3	3.65	4	1.79	1	1.87	2	-5.512^b	0.000
S4	3.52	3.5	2.65	2.5	0.87	1	-3.611^b	0.000
S5	4.19	4	2.10	2	2.10	2	-6.172^b	0.000
S6	3.48	4	2.67	3	0.81	1	-3.060^b	0.002

Note: N = 52, the rating of the aesthetic value based on a scale from 1 (least beautiful) to 5 (most beautiful). ^{b} based on positive ranks, $p < 0.05$ indicates statistically significant change.

3.4. Visual impact factors during the construction phase

Participants identified the elements that negatively affected the change in the visual quality of the lakeshore landscape during the construction phase. According to the results received (Table 8), the highest percentage of factors contributing to the negative visual impact was the damaged vegetation (LC1) at about 22%, followed by 18.4% of the stockpiles (IV1), and around 17.4% of unpaved pavement or bare land (LC2).

Among the general impact categories (Figure 4), 39.4% of responses related to land cover change (LC), 34.5% to volumetric intrusions (IE), and 15.5% and 11.9% to high-contrast materials (EM) and peripheral elements (SE), respectively.

In follow-up interviews, participants expressed concerns about construction activities on the lakeshore, dissatisfaction with the loss of green space and the cluttered environment, and noted that the hardened shoreline was a serious problem, all of which seriously affected the visual amenity and peaceful atmosphere of the lake view. Additionally, the visual stimuli of lakeshore construction and modification for receptors were mainly reflected in the intrusion of incongruous objects into the scene (piles of construction materials and heavy equipment) and textural contrasts (e.g., granular base paving, turf scars from crushing operations). All these factors reduced the aesthetics and visual comfort and disrupted the connection between the receptors and the lakeshore landscape. The intrusion of new objects or colors disrupted the landscape composition and structure of the natural lakeshore. These stimuli reduced the visual quality by blocking or interrupting prominent lakeshore landscape axes and viewsheds.

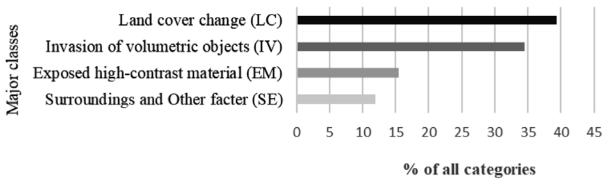

Figure 4. Ranking of major negative visual impact categories

4. Discussion

Modification and construction activities in lakeshore areas can directly lead to landscape fragmentation, vegetation degradation, dull landscapes, and an increase in artificial structures and hardscape along the shore. On a European scale, the European Water Framework Directive (WFD, 2000/60/EC)[1] can be regarded as the most important legislative instrument developed by the EU in the water sector. It is mainly concerned with the integrated assessment of the condition, protection and management of water bodies (including lakes and lake shores) in the EU (Farmer, 2001). Despite the EU-level regulations, the lack of an effective local and regional regulatory system has allowed intensive development activities to continue unabated. The assessment of environmental and visual impacts is often neglected. An integrated approach could be useful for assessing and monitoring the visual intrusion of development activities along the lakeshore, while also aiding in understanding and mitigating their impact on visual quality.

4.1. Visual impacts caused by lakeshore modifications

Visual stimulus from construction activities on the Velence lakeshore mainly appears as the intrusion of incongruous objects (piles of construction materials and heavy equipment), changes in texture (e.g., granular base paving, turf scarring from grubbing operations), and cluttered scenes, all of which reduce the aesthetic and visual amenity of the lakeshore landscape and disrupt the visual continuity

[1] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

Table 8. Percentage of the negative visual impact factors at the survey sites

Factor categories	Composition of negative factors at each site						Overall ranking
	S1 (%)	S2 (%)	S3 (%)	S4 (%)	S5 (%)	S6 (%)	% of all categories
LC1	27.1	17.4	18.7	27	25.8	17.9	22.0
IV1	13.5	22.2	25.2	0	25.8	22.4	18.4
LC2	23.3	0	7.7	24.8	34.8	19.4	17.4
EM1	10.5	6.6	5.2	24.1	6.8	12.7	10.7
IV3	12.1	12.6	5.2	14.6	0	13.4	9.7
SE3	13.5	7.8	9	5.1	6.8	9.7	8.6
IV2	0	26.3	0	0	0	0	5.1
EM2	0	0	26.5	0	0	0	4.8
SE1	0	0.6	2.6	4.4	0	4.5	2.0
SE2	0	6.6	0	0	0	0	1.3

Note: LC – land cover change, IV – invasion of volumetric object, EM – explosion of high-contrast material, and SE – surroundings and other factors.

between the receptors and the landscape. The intrusion of new objects may continue to alter parts of the shoreline landscape or entire structures, reducing visual quality by blocking or interrupting prominent natural landscape axes and viewsheds.

4.2. Landscape metrics for assessing disturbed landscape

In order to more accurately measure the changes in the physical landscape during the construction phase, we applied indicators that are highly relevant to the disturbance environment for testing and calculations. We recognize that the construction activities in lakeshore areas are neither transient nor isolated. They often have a linear characteristic, leading to continuous and sequential visual influences on the lake scenarios and the receptors. The current study does not account for the impact of landscape coherence on the visual quality of the lakeshore. Linear construction operations, like shore-wall renewal, drainage ditch, promenade construction, and marina development, require specific indicators and criteria for measuring the visual impacts.

Lakeshore modifications continue to have intensified impacts after construction, resulting in long-term effects on aesthetic value. This is particularly relevant due to increased human activity and land use pressure. Other potential indicators could be included in the framework of measurement indicators in the future, such as land use change (LC) and landscape coherence.

4.3. Overall appraisal of the LMBA method and the VPBA method

Comparing the objective landscape metric-based assessment (LMBA) approach with the subjective visual perception-based assessment approach (VPBA), we identified that there were some common factors driving the results of both assessment approaches. The destruction and alteration of land and vegetation cover are the factors that reduce the aesthetic value and visual quality of the landscape, from both visual and physical landscape perspectives. The results of the LMBA method and the VPBA method in evaluating visual impact were consistent and mutually complementary. Both approaches considered the visual quality of the landscape as a matter of interaction between physical landscape features and visual perception processes, but with different attention to landscape quality and receptors (Daniel, 2001).

In the LMBA approach, such remote and geoprocessing methods allow for accurate physical measurement and monitoring of land cover/land-use change through GIS software. In practical terms, it is more reliable and efficient. The applied landscape indicators account for spatial and temporal variations in landscape quality, which provide a multi-dimensional assessment of sites with temporary visual impacts. However, one limitation of the LMBA approach is the measurement of small-scale visual distractors. Small-scale objects are difficult to capture using GIS tools or aerial imagery due to their limited spatial extent: examples include building materials and heavy construction equipment. Although these objects can cause strong color contrasts or volume intrusion, their impact is often minor or undetectable from a spatial perspective. They may still significantly affect the visual experience of receptors.

The VPBA method records and visualizes landscape features and visual content at key landscape locations using photography over different time points. In addition, visual perception surveys can collect and reflect receptors' intuitive responses to landscape changes. This approach also helps identify specific factors that may disturb visual quality.

However, we found that there are some limitations in assessing the visual quality of a landscape from ground photographs or aerial imagery solely, as the scale of objects may be diminished by changes in the angle and color of the photos, and there may be discrepancies between assessments through photographs and field survey. Currently, these two methods have been applied only during the construction phase. Ongoing monitoring of the lakeshore's visual quality after construction is essential.

5. Conclusions

This study assessed the visual quality of lakeshore landscapes during construction phases, comparing the LMBA method and the VPBA method for visual impact assessment. The results indicate a significant degradation of landscape visual quality during construction. This is primarily due to visual stimuli, such as large-scale land cover changes and vegetation degradation caused by construction operations. While the evaluation results of the two methods did not show significant correlations, they offer different perspectives and criteria for assessing visual impact on lakeshore landscapes. The case study of the Velence Lakeshore demonstrates that the results of the two evaluation methods are not conflicting but rather complement and cross-reference each other. These methods and templates may be applied for monitoring and assessing the visual quality and impact of other lakeshore landscapes with similar development contexts.

To ensure the preservation of lakeshore landscape conditions and to mitigate the visual impact of construction processes, planning for lake regions should prioritize both the protection of spatial patterns and the anticipation of potential visual impacts of construction projects on observers. Major installations and developments require advanced impact assessments and continuous monitoring. After construction, disturbed areas should be replanted with native vegetation along the construction site edges to minimize visual impact and erosion. Moreover, attention should be paid to controlling the duration of construction projects and carefully selecting and using construction materials. Engaging local communities in governance and lakeshore development planning is recommended. This can be achieved by raising awareness of visual impact and integrating mitigation measures into the initial construction plans, and including maintenance protocols for future projects.

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