Evaluation of Bridge and Landscape Interactions

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Abstract. The community has become more and more focused on preserving the natural landscape. That is an essential part of the quality of human life. Every member of society wants to enjoy a high-quality landscape. That is evidenced by the documents adopted in recent years, which set out how to evaluate the interaction between structures and landscape. The European Landscape Convention covers all areas with both natural and human-changed landscape. These paper analyses methods and criteria for the assessment of bridges as a component of the landscape, focusing on the possibilities and experiences of applying multi-criteria methods. Particular attention dedicated to the interaction between the bridge and the environment, the criteria and methods for its assessment, which is one of the stages of the visual (technical and visual) and aesthetic (separate elements and overall design) of the bridges, which includes both landscape and bridge impact assessment. Paper analysis the possible application of criteria and methods for evaluation of existing and new bridges as a part of the landscape.

1. Introduction

Society estimate the landscape is an essential part of the quality of his life and want to enjoy a high-quality landscape. Evidence of this is the European Landscape Convention, which covers natural, rural, urban and peri-urban areas, including inland water and marine areas. The Convention covers both the landscapes which considered as excellent and degraded landscapes. Convention aims to promote protection, management, and planning of the landscape as well as to organise cooperation of landscape issues [1].

One of the elements of the landscape is the bridge transport infrastructure element, which must be both functional and elegant. Often, due to its size, bridges are highly visible in the neighbouring area and could impact the environment positively or negatively. The aesthetic impression created by the bridge depends on how the bridge looks in compositional harmony with the surrounding environment. Interaction between the bridge structural solutions and environment is one of the leading architectural and aesthetic problems of bridge construction. Relationships between the bridge design aesthetic qualities and its impact on environment condition will be model with a mathematical model. Authors in paper [2] gives a general scheme for the evaluation of the aesthetic and visual qualities of bridges (Figure 1).

The purpose of this paper is to find out the criteria for the assessment of bridge and landscape interaction.

2. Landscape assessment

European Landscape Convention [1] defines a landscape as the territory within the meaning that people perceive it, and which is the natural or result of human activity and interaction: in urban and rural areas,
degraded or cared areas, gorgeous or casual places. The landscape, according to individual type, can be assessed by a value of specific criteria. That describes the visually aesthetic landscape quality, cultural and historical significance as a landscape ecosystem quality [3].

![Diagram](image)

**Figure 1.** A proposed general scheme for bridge assessment.

Studies of aesthetic quality in Latvia described for different landscape levels and types: natural elements as primary aesthetic sources; natural and rural landscapes; urbanized landscapes. Landscape researchers, geographers Olgert Nicodemus and Aija Melluma [4] have made a significant contribution to the study of the aesthetic quality of Latvian natural landscapes, emphasizing the importance of the subjective perception of the man in the interpretation of landscape aesthetics. Research on landscape aesthetic quality using the aesthetic quality assessment methodology was performed by Daiga Zigmunde [5], developing an evaluation method with criteria of aesthetic quality based on the basic principles of composition and evaluation criteria of aesthetic quality based on composition. Figure 2 shows the criteria for the aesthetic quality of the landscape and their assessment based on D Zigmunde's study [5]. Literature review shows that for landscape identification and classification there are many different methods and systems, that are widely discussed in the paper [6]. The author indicates 54 methods for landscape assessment used worldwide and indicates the simplest one. These methods identify the landscape quality mostly with natural components (geology, soil, etc.) and components characterising human intervention (land use, settlements, etc.). They also are suitable for landscape inventory and land use planning. In the paper [7], the use of the term "landscape" is limited to visual qualities. The methodology used by the authors [7] consists of 5 parts. First two parts refer to the criteria given in Figure 2. The evaluation of the landscape quality performs by the observer survey and evaluation by using an assessment of the intensity of landscape elements. The visual quality of the landscape consists of the evaluation of each component in the visual perception and relatively uniform landscapes classified by the geographic information system (GIS). In this study observers rated the photos, giving rating points, such as "best" +4 points, "worst" -4 points. As a result, an average visual quality index (AVQ index) determined for each landscape. Authors developed a scale of measurement of landscape attributes and elements, who will be used for the landscape aesthetic evaluation and based on the Regulations No.240 issued by Cabinet of Ministers of the Republic of Latvia “General Regulations for Planning, Use and Building of the Territory” [8]. The results in the form of criteria and scoring of aesthetic quality shown in Figure 2.
Figure 2. Criteria and scoring of aesthetic quality.

The evaluation of the landscape and bridge interaction is relatively complicated and based on different criteria. Flexible well-structured method with multiple decision-making criteria (MDMC) will solve this task. It has been developed many MDMC methods with different applications. An overview of the application of the MDMC methods for the period from 2000 to 2014 is found in [9]. Also other authors research of the MDMC methods [10], [11], [12], etc., shows that they have used similar approaches. This paper does not try to analyse in detail and compare MCDM methods, but looks at the possibility of its practical application in landscape evaluation. The MCDM method for each criteria include the "weight" that show the importance of criteria. Paper [7] describe one of the “weight" detection methods. In table 1 is showed the measurement scale from [7] with the “weight” corrections.

In table 1 and 2 given evaluations and the scale of measurements is not enough accurate because it is affected by the human subjective assessment and the large number of criteria that complicate the use of MDMC. To assess human action impact on the landscape, it should be assessed not only the landscape but also a bridge and landscape interaction.
Table 1. Scale of measurement of landscape attributes and elements [7] with corrections.

| Criteria                                                                 | Importance (“weight”) of criteria | Scoring                                                                 |
|--------------------------------------------------------------------------|-----------------------------------|-------------------------------------------------------------------------|
| Presence of water                                                        | 0.01                              | No water= 0; River= 1; Lake= 2; Dam=3; Large areas of water =4          |
| Water movement                                                           | 0.01                              | No movement= 0; Movement= 1                                             |
| Type of land use                                                          | 0.03                              | Non built-up territory = 1; Built-up territory = 2                      |
| Land use - non built-up territory                                        | 0.05                              | Forest area = 1; Agricultural use = 2; Public outdoor space = 3         |
| Percentage of land covered by vegetation                                 | 0.03                              | 0-25%= 0; 25-50%= 1; 50-75%= 2; 75-100%= 3                             |
| Type of vegetation                                                       | 0.03                              | Meadow plants or cereal crops = 1; Mix vegetation (bushes and trees)= 2; Trees= 3 |
| Horizon                                                                  | 0.01                              | Hidden= 0; Almost flat =1; Some small hills= 2                         |
| Presence of man-made elements with high influence (roads, bridges, objects with cultural heritage) | 0.02                              | None= 0; One element= 1; Two elements= 2; Three or more elements= 3 |
| Presence of building environment                                         | 0.02                              | No buildings= 0; Low-storey buildings (<3 storeys) = 1 ; Multi storey buildings (> 3 storey) = 2; Mixed buildings = 3 |
| Building density                                                         | 0.03                              | No buildings= 0; Individual buildings = 1; Low building density = 2; High building density = 3 |
| Land use - built-up territory - residential buildings                    | 0.05                              | No buildings = 0; Private house building = 1; Garden house building = 2; Country estate building = 3; Terraced house building = 4; Multi-apartment house building= 5 |
| Land use - built-up territory - public building                          | 0.05                              | No buildings = 0; Office buildings = 1; Building of business = 2; Building of tourism and recreational establishments, Building of cultural institutions = 3; Sport buildings = 4; Building of defence and security institutions= 5; Building of educational and scientific institutions, Building of health protection and social care institutions = 6 |
| Land use - built-up territory - industrial building                      | 0.05                              | No building = 0; Building of light industry undertakings = 1; Building of heavy industry and primary processing undertakings = 2; Building of agricultural production undertakings = 3; Extraction of mineral resources = 4; Building of waste management and recovery undertakings = 5 |
| Land use - built-up territory - technical building                       | 0.03                              | No building = 0; Building of light industry undertakings = 1; Building of heavy industry and primary processing undertakings = 2; Building of agricultural production undertakings = 3; Extraction of mineral resources = 4; Building of waste management and recovery undertakings = 5 |
| Number of colours                                                        | 0.05                              | One colour= 1; Two colours= 2; Three or more colours= 3                |
| Internal contrast                                                        | 0.05                              | Weak colour contrast= 0; Clear colour contrast= 1                      |
| Presence of alignments                                                   | 0.03                              | None= 0; Presence of alignments= 1                                     |
| Scale effect                                                             | 0.05                              | No element presents scale effect= 0; Presence of scale effect= 1        |
| Focal view                                                               | 0.05                              | No focal view = 0; Focal view = 1                                      |
| Mutual interaction forms of landscape elements (rhythm, proportion, harmony) | 0.15                              | Conforms to the overall nature of landscape= 2; Partially conforms = 1; Does not conforms = -1 |
| Scenery (accessibility, visibility, expressiveness)                      | 0.1                               | Good = 2; Medium = 1; Bad = -2                                         |
| Compositional quality of the scenery                                     | 0.1                               | Good = 2; Medium = 1; Low = -1                                         |
3. Bridge impact assessment

The question about the interaction of bridge and landscape already viewed in the Roman architect Vitruvius 10-volume essay “The Architecture” [13]. Vitruvius underline that architecture includes both - structures and their placement. Henry Grattan Tyrrell, in a paper published in 1912 [14], defining requirements for beautiful bridges mentioned compatibility with the environment. Also, Gottemoeller F. [15], Leonhardt F [16] in terms of aesthetically pleasing bridges mentions both integrations into the environment and the landscape. As mentioned [2] then directly Christian Menn emphasizes bridge compatibility with the environment associated with the spatial components – scale, a character of the landscape and topography.

Evaluation of bridge and environmental interactions closely linked to the visual quality of the landscape, characterized by three characteristics - vividness, intactness, unity, and harmony between all elements of the landscape, including the bridge. These characteristics discussed in the article [2]. Principles of Bridge Impact Assessment for Landscape based on the Principal Steps of the Visual Impact Assessment for Highway Projects (VIAHP) Handbook [17] are: 1. determination of the affected environment, 2. determination of main viewpoints, 3. assessment of bridge visual impact, including changes of visual environment and reaction of viewers such us impact on the landscape and vegetation, impact from bridge integration degree into street network or landscape, impact on the spatial urban or landscape context, impact on the surrounding character.

Selection of the viewing point/points is essential for determining the interaction between the bridge and the landscape. This issue extensively discussed in the article [18]. The authors note that there are no clear criteria for determining the point of view, but given the type of criteria types, as summarized in Table 2. Using images created with Google Map, Table 3 attempts to simulate the impact of distance on bridge perception based on Table [18].

| Division by Center | Division by Location of View | Viewpoint selection criteria |
|--------------------|-----------------------------|-----------------------------|
| Landscape resources | Inside View Point | The place where see excellent landscape resources |
| Users | Outside View Point | A central point inside of the area |
| Distance View/Middle | Prediction point of landscape change by distance |
| Distance/Close-range | |

| Division by View Point Use | Viewpoint selection criteria |
|----------------------------|-----------------------------|
| Reputational | A standard viewpoint to protect a good landscape |
| Formational | A standard point to form a good landscape |
| Management type | A standard point to manage a poor landscape |

The evaluation methodology for determining the visual impact of the bridge to the environment/landscapes can be used methodology given in [19], which includes determining of the impact levels of the visual resources depending on the percentage of visual characteristics occupied the basic viewing area from the primary viewshed.

Estimation of the bridges from the aesthetic and visual point of view can be based on the 4 class system used in Finland for evaluation of bridge site [20] supplemented by Class V without requirements [2] and assigning a rating of 5 - Class 1 to 1 Class 5.
Table 3. The appearance of the bridge depending on the distance of viewing point.

| Divide            | Distance                  | Visible landscape and bridge | Target area/distance (scheme and satellite view) |
|-------------------|---------------------------|-----------------------------|-----------------------------------------------|
| Close-range (a)   | Located in radius about of 200m of bridge | ![Close-range image] | ![Close-range target area] |
| Middle distance (b) | Located in radius about of 500m of bridge | ![Middle distance image] | ![Middle distance target area] |
| Distance view (c) | Located in radius about of 1km of bridge | ![Distance view image] | ![Distance view target area] |

A comparative assessment of landscape and bridge effects has been carried out using the methodology and evaluation system from [20], information of Table 1, and MCDM. The simple assessment scheme is shown in Figure 3. The results summarized in Table 4.

![Landscape and bridge impact assessment](image)

**Landscape assessment (Table 1)**

**Evaluation of bridge site**
- Class I – 5
- Class II – 4
- Class III – 3
- Class IV – 2
- Class V – 1

**Figure 3. Simple assessment scheme.**
Table 4. The results of the assessment.

| Landscape assessment | Bridge impact – 8.15 (max 10) | Bridge site – Class 1 – 5 |
|----------------------|-------------------------------|--------------------------|
| -1.83                |                               |                          |

Bridge over Lorupe ravine (photo R. Salcēvičs)

4. Conclusion
For measuring of industrial changed landscape quality could be used the MCDM method. For real use of MCDM method the number of criteria must be reduced and the criteria should be redefined. For the general evaluation of the bridge could be obtained a single evaluation scale, that could be used as the basis for the methodology for assessing of the visual, aesthetic and technical quality of the bridges in Latvia.

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