Criteria for assessment of bridge aesthetic and visual quality

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Abstract. The bridge designers should find an ideal balance between structure, economy, buildability, aesthetics, durability and harmony with industrial or natural landscape. During the last years, the society has adopted documents providing procedures for evaluation of the impact of the structural appearance on surrounding landscape. The European Landscape Convention defines the landscape as an area perceived by people, whose character is the result of the action and interaction of natural and/or human factors. The Convention indicates the methods for clear and objective assessment of the landscape’s visual qualities. The esthetical qualities of bridge structures, appearance and attraction should satisfy not only the technicians - engineers and architects, but mostly the surrounding population. Each of these groups has a different perception of esthetical qualities of structure. Many authors have used different methods and criteria for assessment of bridge aesthetics. The aim of this paper is to provide an overview of the bridge aesthetic and visual quality assessment methods and criteria.

1. Introduction
Society estimate the landscape is an important part of the quality of his life. Evidence of this is the European Landscape Convention adopted by Council of Europe [1]. Convention covers natural, rural, urban and peri-urban areas, including inland water and marine areas. It concerns landscapes, which may be considered outstanding as well as usual or degraded landscapes. The aims of Convention are to promote protection, management and planning of the landscape as well as to organize cooperation of landscape issues.

The appearance of bridges is one of very important characteristic element of natural or urban landscape. The bridge transport infrastructure element must fit into surrounding environment and be elegant and functional (fig.1). Often, due to its size, bridges are the highly visible in neighboring area and could impact the environment in a positive or negative way. Therefore, the form and geometrical proportions, visual and aesthetic characteristics are important not only for bridge elements, but also for the general composition of whole structure.

Aesthetic impression of the bridge depends from his compositional harmony with the surrounding environment. Aesthetical and elegant bridge structure could be expressed as the right combination of several criteria, such as: scale, fit into surrounding area, functionality, efficiency, detailing, materials, near and distant views, views from bridge, light and shade, rhythm, artificial lightning, colour, etc. Therefore, one of the essential challenges for designers is the harmonization of the bridge structures in environment. The task of this paper is to provide an overview of the bridge aesthetic and visual quality assessment methods and criteria.
2. Evaluation of bridge aesthetic

The Roman architect Vitruvius, the most cited writer in this context, in his 10-volume essay “The Architecture” [2] formulates the basic principles for structural performance of structures: Firmitas – structural stability, Utilitas – appropriate spatial serviceability and durability, Venustas - attractive appearance, that are actual until today. Vitruvius underline that architecture includes both - structures and their placement. Vitruvius first defines that proportionality of building is the harmony of separate elements and compliance of separate parts and whole with accepted output size, so there could be a question of scale and proportions.

Tyrrell, in paper published in 1912 [3], in addition to the already mentioned principles: compatibility with the environment; exhibition of purpose and construction and pleasing appearance and proportions - added some additional principles for designing of aesthetic bridges: economical use of materials and appropriate but limited use of ornament.

Active discussions about the roll of architects and engineers in a bridge design process occurred in the thirties of the last century. There was concluded, that bridge form must come primarily from engineers but architects could be used as “artistic consultants” and some authors consider the negative role of architects by adding unless decoration on bridge structure front surfaces [4].

Several suggestions of bridge aesthetics are discussed by Gauvreau in [5]. Form Follows Function (structural efficiency is a sufficient condition for aesthetic significance) in bridge design context has become a motto of many articles about the bridge aesthetics. This is the view held by most American authors on aesthetics of bridges. Such opinion also has a Gottemoeller F. [6]. Gottemoeller with examples characterized features of good-looking bridges: simplicity, relative slenderness, continuous lines and clear force flow in structure. These characteristics author integrates in principles, as aesthetic purposes of design: simplicity, visible slenderness and transparency, structural clarity, diversity in unity and suitability (the bridge as a whole shall be clearly and logically relate to the surroundings). The author also refers to the term “structural art” developed by David Billington and the definition that works of structural art should combine three principles: economy, efficiency and elegance [7]. Gottemoeller in his publication describes possible points of view for bridge viewing – moving and fixed, as well as gives an understanding of the visual design elements to be determined by visual perception (line, contour, shape, colour and texture) and aesthetic characteristics which result from the visual design elements and are used to describe the visual composition (proportions, rhythm, order, harmonium, balance, contrast, scale and unity).

Leonhardt in [8] formulate ten criteria for aesthetically pleasing bridges: (1) fulfil the purpose/function, (2) proportions, (3) order, (4) clear form (form improvement), (5) integration in environment, (6) surface texture, (7) colour, (9) nature and (10) involvement in nature. These criteria become as guidelines for bridge designers, however the simple use of these guidelines will not result in a beautiful bridge. Similar conclusions in [9] are made by Christian Menn. He accented that the bridges are not alone-standing structures, but the component of surrounding landscape. Christian Menn emphasizes the bridge compatibility with the environment associated with the spatial components – scale, character of the landscape and topography, as well as man-made environment and time component – history and tradition of local bridge construction, technology and culture. It should also be noted that
the bridge design as an independent element of landscape can be characterized by the following criteria: efficiency of visual expression what might call the technical concept of efficiency, order and unity, which may be achieved by a clear and comprehensible construction scheme, artistic design, which can be achieved by means of visual expression of force flow, elements and cross sections, which reduces stresses, effects of light and shadow and finally with unconstructive elements and ornaments.

In order to be able to talk about the aesthetic quality of structure and landscape as a whole to achieve harmony between all elements (Fig.2).

![Figure 2. Classification of the elements of visual harmony.](image)

3. Visual assessment of bridges

The concept of “visual bridge assessment” generally looks in the concept of assessment of the technical condition of the bridge, which is also essential for the bridge evaluation. The literature more attention is paid to impact of bridge and road on the environment and their visual assessment. Issues regarding visual quality of the landscape and its assessment discussed in article of Terry C.Daniel [10]. Visual impact assessment process for road projects is given in the Visual Impact Assessment for Highway Projects (VIAHP) manual [11], [12]. The manual gives the principle steps of the road project impact assessment, but similar principles can also be used for the assessment of existing bridges:

1. determination of the affected environment, including bridge location and viewshed, taking into account the distance of viewer location from the bridge (Tab.1),

2. determination of main viewpoints (fixed or movable [6]), taking into account the view of the carriageway, crossed road and viewers (residents, recreationists or travellers),

3. assessment of bridge visual impact, including changes of visual environment and reaction of viewers:
   - 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 (degree of integration between bridge elements/design and scale/character of surrounding), taking into account that successful integration is based on the structural integrity and coherence (shape/scale, visual characteristics), relationship of bridge/elements and landscape elements and their action as integrated composition.

Visual quality is fundamentally characterized by three descriptions that are summarized in Table 2. Impact of building or road on the environment/landscape, based on several sources of literature [14], [13] can be estimated using [13] assessment methodology, which includes determination and evaluation of level of visual impact (Table 3) viewshed at different distances (see, Table 1) and visual sensitivity (Table 4).

Level of visual sensitivity is determined, taking into account land use and viewing distance of elements [13]. Visual effects can be determined in accordance with Table 4.
**Table 1.** Area of Primary View zone at various distances from the development [13].

| Distance from project area | Area of Primary View Zone |
|---------------------------|---------------------------|
| 1 km                      | 0.52 km²                  |
| 2 km                      | 2.09 km²                  |
| 3 km                      | 4.71 km²                  |
| 4 km                      | 8.38 km²                  |
| 5 km                      | 13.07 km²                 |
| 6 km                      | 18.85 km²                 |
| 7 km                      | 25.65 km²                 |
| 8 km                      | 33.51 km²                 |
| 9 km                      | 42.41 km²                 |
| 10 km                     | 52.36 km²                 |
| 11 km                     | 63.35 km²                 |
| 12 km                     | 75.40 km²                 |
| 13 km                     | 88.49 km²                 |
| 14 km                     | 102.62 km²                |
| 15 km                     | 117.81 km²                |

Primary View Zone is an arc suspended by 30 degree angle both sides of the horizontal control view line as well as 30 degrees above it.

**Table 2.** Visual quality [13].

| Visual quality   | Vividness | Intactness | Unity |
|------------------|-----------|------------|-------|
|                  | (The visual power or memorability of landscape components as they combine in distinctive visual patterns) | (The visual integrity of the natural and human-built landscape and its freedom from encroaching elements) | The visual coherence and compositional harmony of the landscape considered as a whole) |

Central view line
| Visual Properties | Visual Effect Levels |
|-------------------|----------------------|
| **Contrast**      |                      |
| Levels with elements in primary view zone | High Visual Effect | Moderate Visual Effect | Low Visual Effect | Very Low Visual Effect |
| High | Development elements do not borrow, form, shape, line, color or texture or scale from existing features of the visual setting and contrast levels are high with existing landscape and or… Active face of REA | It occupies more than 2.5% of the primary view shed | It occupies between 2.5 – 1% of the primary view shed | It occupies between 1- 0.5% of the primary view shed | It occupies less than 0.5% of the primary view shed |
| Moderate | Development elements borrow from some features of the visual settings in terms of form, shape, line pattern and or color and scale, reducing visual contrast with existing setting and or … newly rehabilitated pit area | It occupies more than 20% of the primary view shed, generally when in a foreground location | It occupies between 20 – 10% of the primary view shed | It occupies between 10 – 5% of the primary view shed | It occupies less than 5% |
| Low | Development elements borrow extensively from features in visual setting in terms of form, shape, line, pattern color and scale minimizing contrast with existing landscape and or… rehabilitated landscape pattern | The development occupies more than 40% of the primary view shed | The development occupies 40 - 30% of the primary view shed | The development occupies between 30 – 20% of the primary view shed | The development occupies less than 20% of the primary view shed |
Table 4. Visual Impact [13].

| Visual Effect | Visual Sensitivity    |
|---------------|-----------------------|
| High          | High Visual Impact    |
|               | Moderate              |
|               | Low                   |
| Moderate      | High/ Moderate Visual Impact |
|               | Moderate              |
|               | Low                   |
| Low           | Moderate/ Low Visual Impact |
|               | Moderate              |
|               | Low Visual Impact     |
| Very Low      | Low Visual Impact     |
|               | Very Low Visual Impact |

In order to evaluate the bridge and landscape interaction, should be set the criteria for landscape aesthetic evaluation. Prof. Nikodemus in his lecture course “Landscape Ecology” [14] has given the landscape evaluation principles: contour – geometric, natural, visual perception of topography – mountains, hills, flat land, scale – small or large scale, layout (groups) – harmonious, balanced, conflicting, chaotic, order – landscape harmony and proportions of landscape.

Although Lakovskis in his thesis [15] about ecological planning of landscape and methodological solutions for mosaic landscapes uses in evaluation of landscape the English rural commissions checklist of aesthetic assessment of landscape. Checklist includes the scale, transparency, diversity, etc. characteristics. In Finland, for evaluation of the bridge location landscape is used four class system [16]:

Class I very demanding considering the landscape and city view,
Class II demanding considering the landscape and city view,
Class III remarkable considering the landscape and city view,
Class IV ordinary considering the landscape and city view.

4. Criteria of aesthetic and visual assessment of bridges

For assessment of bridge aesthetic and visual quality as well as the evaluation of it visual effects is developed different methods and used different criteria in several countries. A study of assessment of bridge design is carried out by the Road Administrations of Nordic countries and universities in an international European Telecommunications Standards Institute project “Bridge Life Cycle Optimisation”. The life cycle optimisation considering all aspects of the life cycles, including: functionality, techniques, economics, aesthetics, repair etc. and developed methodology and life cycle cost (LCC) tool for Bridge management, which is used only for comparison of alternatives in new bridge design [16], [17], taking into account the landscape harmony. Also prof. Reich in his paper "A model of aesthetic judgment in design" [18] give example how to compare the cable bridge alternatives during design. As can be seen more attention for road and bridge aesthetic and visual quality is paid directly to comparison of alternatives. Reich considers that “…aesthetic analysis of existing bridges, providing relatively few basic concepts for use in design.” Many authors have similar view and therefore could not be found the methodology and criteria for aesthetic and visual evaluation of existing bridges.

Sarah Billington has touched the questions of pier aesthetic in his study "Improving Standard Bridges Through Aesthetic Guidelines and Attractive, Efficient, Concrete Substructures" [19]. The objectives of this research were to develop visual guidelines for improvement of the aesthetics and efficiency of widely used moderate - span bridges in Texas and provide useful guidelines and examples for improvement of the aesthetics and efficiency of substructures for standard bridge systems. This study was devoted to the application of precast and cast-in-place concrete piers.
There are no studies about aesthetic and visual aspects of bridges in Latvia. Taking into account the local conditions, the main attention should be devoted to evaluation of the existing bridge from point of view of improvement its visual and aesthetic quality and reduction of negative impact on the surrounding landscape. Proposed general scheme for assessment of aesthetic quality of existing bridges is shown in Figure 3.

**Figure 3.** Proposed general scheme for bridge assessment.

Before the start of the bridge evaluation action should be defined the requirements of assessment criteria. According to Aesthetic Guidelines for Bridge Design [20] assessment process could be divided in three levels, depending on the importance of bridge structure and number of specialists involved in design process. Depending on the importance of the bridges (table 4) bridges could be classified in four levels - A, B, C and D.

In [21] are given criteria for aesthetic and visual assessment of the bridge piers which could be adopted for assessment of all bridges:

1. Shape/form: bridge superstructure and substructure shape regardless of the material; proportions – balance and harmony between the elements; order – symmetry and lines, number of directions and edges.
2. Composition: character – impact on viewers; order in composition – view beneath the bridge (open view, restricted view, closed view). The principle also includes the effects on the landscape; proportions – impact on overall bridge appearance and landscape.

Adrian Lako in [22] divided structures into basic elements and detail elements, and for each type proposed different aesthetic quality characteristics:

- for basic elements: function, proportions, harmony, order and rhythm,
- for detail elements: contrast, texture, light and shadow.

Taking into account the scheme in figure 3 in this paper is developed the basic requirements for bridge aesthetic and visual evaluation, as well as the outlines for the basic requirements for the bridge and landscape interaction assessment (fig. 4 and fig. 5) and the proposal for landscape assessment by considering the evaluation of bridge location and evaluation process used in Finland [16] (figure 6).
Table 5. Bridge division for aesthetic and visual assessment.

| Level of aesthetic design | Level of bridge assessment |
|---------------------------|-----------------------------|
| Level A                   | For bridges with significant cultural or aesthetic importance | Level A | For bridges in the city, in the territory of National parks and areas with excellent landscapes |
| Level B                   | For regional structures | Level B | For overpasses over high intensity roads, bridges adjacent to recreation areas, bridge “families”, pedestrian bridges |
| Level C                   | For bridges with low-level aesthetic requirements | Level C | For few visible bridges, bridges over waterways, which are not used for recreation, overpasses over railways or low intensity roads. |
| Level D                   | For forest bridges | |

Figure 4. Visual assessment of bridges.
5. Conclusion

There are obtained various criteria and methods for evaluation of the bridge aesthetic and visual quality. Most of them have either an educational nature or intended for evaluation of design or design alternatives in preliminary stages. The paper provides the basic criteria which could be the basis for development of multi-criteria assessment methodology for evaluation of new and existing bridges.

Aesthetic is always subjective, but it may be establishing that a bridge is really expressive when its aesthetical quality is well recognized by civil engineering community. Therefore, in order to improve the aesthetic quality of bridges is necessary to systematise the criteria of aesthetic evaluation of bridges and develop the method of multi-criteria analysis for using in the design of aesthetically elegant bridges.

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References

[1] “European Landscape Convention,” *European Treaty Series* **176**, p. 7, 2000
[2] Vitruv, De Architectura Libri Decem, Marix, 2012
[3] H. G. Tyrrell, *Artistic bridge design: a systematic treatise on the design of modern bridges according to aesthetic principles*, Chicago: The Myron C. Clark Publishing Co, 1912
[4] D. Billington, “Bridge Aesthetics: 1925-1933,” Vienna, 1980
[5] P. Gauvreau, “The Three Myths of Bridge Aesthetics,” Vancouver, British Columbia, Canada, 2002
[6] F. Gottemoeller, *Bridgescape: the art of designing bridges*, Hoboken, New Jersey: John Wiley& Sons, Inc., 2004, p. 316
[7] B. D.P., *The tower and the bridge: the new art of structural engineering*, Princeton: Princeton University Press, 1985
[8] F. Leonhardt, *Briicken - Asthetik und Gestaltung* /Bridges -Aesthetics and Design, Stuttgart: Deutsche Verlags-Anstalt GmbH, 1982, p. 308
[9] C. Menn, “Fundamental considerations on the aesthetics of bridges,” in *The 14th IABSE Congress Civilisation through civil engineering*, New Delhi, 1992
[10] T. C. Daniel, “Whither scenic beauty? Visual landscape quality assessment in the 21st century,” *Landscape and Urban Planning*, **54**, no. 1–4, 2001
[11] U.S. Department of Transportation, “Guidelines for the Visual Impact Assessment of Highway Projects,” U.S. Department of Transportation, Washington, D.C., 2015
[12] U.S. Department of Transportation, “Guidelines for the Visual Impact Assessment of Highway Projects,” U.S. Department of Transportation, Washington, D.C, 1981
[13] INTEGRAL, landscape Architecture&Visual Planning, “Continuation of Boggabri Coal Mine, visual impact assessment,” Integral, Scarborough, 2010
[14] O. Nikodemus, lekciju kurs "Ainavu ekoloģija", Rīga: LU MOODLE, 2016
[15] P. Lakovskis, “Ainavu ekologiskā plānošana un tās metodoloģiskie risinājumi mozaīkveida ainavās,” Latvijas Universitāte, Rīga, 2013
[16] L. Salokangas, “ETSI Project - Bridge Life Cycle Optimisation Stage 3,” Aalto University, Helsinki, 2013
[17] L. Salokangas, “ETSI PROJECT (Stage 2) Bridge Life Cycle Optimisation,” Helsinki University of Technology, Helsinki, 2009
[18] Y. Reich, “A model of aesthetic judgment in design,” **8**, no. 2, 1993
[19] S. L. Billington, “Ferguson Structural Engineering Laboratory,” Ferguson Structural Engineering Laboratory, 1997. [Online]. Available: http://isel.engr.utexas.edu/component/publications/details/605153208. [Accessed 02 01 2017]
[20] O. o. B. a. Structures, Aesthetic Guidelines for Bridge Design, Minnesota: Minnesota Department of Transportation, 1995
[21] I. Rozentale, A. Paeglitis, “Aesthetic Requirements for Bridge Piers,” in *People, Buildings and Environment*, Lednice, Czech Republic, 2012
[22] Arian Lako; Markel Baballëku; Ira Kadare, “http://aace.al/event-2012/presentations/Aesthetic%20approach%20on%20some%20bridge%20design%20elements.pdf,” 2012. [Online]. [Accessed 11 03 2017]
[23] J. Radić, Z. Šavor, M. Küster Marić, “Aesthetics of Contemporary Arch Bridges,” 8th International Conference on Arch Bridges, Wroclaw, 2016
[24] Donald Appleyard, Kevin Lynch, John R. Myer, The View From the Road, Cambridge, MA: The MIT Press, 1965