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A Framework for Visual Nuisance Evaluation in Metro Railway Systems

C. Pyrgidis, D. Georgiadis, A. Anagnostopoulos and E. Manthos

Laboratory of Highway Engineering, Department of Civil Engineering, Aristotle University of Thessaloniki, Greece

Abstract

Metro railway systems constitute essential components of sustainable urban mobility. Besides their transport function, they can influence the visual quality and identity of urban environments. However, the perception of visual quality remains largely subjective, while objective assessment criteria are still limited. Furthermore, unlike technical and operational characteristics, which are commonly evaluated through established standards, the visual nuisance lacks universally accepted assessment criteria. To address this gap, this paper proposes a quantitative methodology for evaluating the visual nuisance of metro railway systems. The methodology builds upon previous visual nuisance assessment frameworks developed for urban mass transportation systems. The proposed approach assigns evaluation criteria to key metro structural elements and combines them into a Visual Nuisance Index. The methodology is applied to selected stations of the Athens Metro system, demonstrating its ability to provide a systematic and comparable assessment of visual nuisance. The framework may be applied during procurement and bidding processes, design assessment, and the evaluation of improvement measures in metro systems.

Keywords: visual nuisance, metro railway systems, passenger perception, visual nuisance index, railway aesthetics, bid assessment, metro stations.

1 Introduction

In contemporary metropolitan environments, metro railway systems constitute essential components of sustainable urban mobility and strongly influence both the functionality and the visual quality of modern cities [1]. Beyond their transportation role, metro infrastructures shape the urban identity, environmental quality, and aesthetic perception of the urban landscape through their stations, entrances, platforms, passenger circulation areas, signage systems, and rolling stock [2-3].

Recent research highlights that the visual environment of public transport infrastructure significantly affects passenger perception, travel experience, and urban identity [4]. Architectural quality, spatial organization, openness, lighting conditions, material selection, public art, and visual coherence have been identified as important parameters influencing the perceived visual nuisance of transport environments [5]. Conversely, visually intrusive infrastructure, excessive visual clutter, poorly integrated structural elements, and incoherent spatial interventions may negatively affect both the urban landscape and users' psychological perception [6].

Metro railway systems can be considered as major urban public spaces where millions of passengers interact daily with the built environment [7-8]. Consequently, the aesthetic performance of metro infrastructure has become an increasingly important issue in urban transport planning, architecture, and infrastructure design [9]. Modern metro stations are expected to combine operational efficiency with high-quality architectural design, accessibility, visual clarity, and integration with the surrounding urban context [10]. Previous research has shown that spatial organization, signage systems, and the integration of infrastructure with the surrounding urban context strongly affect visual perception and aesthetic experience [11-12]. Furthermore, the audiovisual environment of rail transit spaces, including visual interference, noise exposure, and spatial openness, plays a significant role in shaping user's experience [13].

The increasing use of metro systems for urban mobility highlights the importance of evaluating visual aesthetics and visual nuisance, as passengers interact daily with the built environment of metro infrastructure. Recent studies emphasize that metro aesthetics, public art, architectural design, signage systems, and visual communication significantly influence passenger experience, urban identity, and the perceived visual quality of transport infrastructure, while poorly integrated infrastructural elements may increase visual nuisance and negatively affect the urban landscape [14].

Given the increasing importance of visual quality in metro environments, the question of how visual nuisance can be systematically assessed becomes particularly relevant. A review of existing visual nuisance assessment methodologies highlighted two major methodological gaps:

- the perception of visual quality remains largely subjective, while objective assessment criteria are still limited, and
- unlike technical and operational characteristics, which are commonly evaluated through established standards and performance indicators, the visual nuisance lacks universally accepted assessment criteria. In addition, visual nuisance is rarely assessed by a dedicated regulatory framework or supervisory authority during the planning, design, and approval stages of transport infrastructure projects.

Existing visual nuisance assessment studies have mainly focused on surface and elevated urban transport systems, such as tramways, monorails, and Bus Rapid Transit (BRT) systems [15-17], while limited attention has been given to metro railway systems. The proposed framework builds upon the visual nuisance assessment approaches developed by Pyrgidis et al. [15-17], assigning evaluation criteria to key metro structural elements and combining them into a Visual Nuisance Index (VNI).

The methodology is based on the identification of the key structural elements affecting visual nuisance, their classification into aesthetic categories according to the visual performance of alternative design solutions, and the application of weighting coefficients reflecting their relative influence on passenger perception and urban visual quality. The weighting coefficients were established through expert-based questionnaire surveys involving specialists in transport and railway infrastructure.

The developed approach is applied to selected stations of the Athens Metro system. The proposed framework may be used during procurement and bidding procedures, at the design stage of new metro systems, for the evaluation of existing systems, and for the assessment of improvement measures. can provide to transport authorities and designers a quantitative tool for evaluating visual nuisance and supporting the aesthetic integration of metro infrastructure within the urban environment.

2 Methodological Framework for Visual Nuisance Evaluation of Metro Railway Systems

The proposed methodological framework aims to establish a quantitative and systematic approach for the evaluation of visual nuisance in metro railway systems. The framework assumes that the overall visual quality of a metro system is determined by the combined influence of its structural components. The methodology integrates qualitative characteristics with quantitative evaluation criteria to reduce subjectivity and enable comparative assessment between alternative design solutions and infrastructure configurations. As mentioned before, the proposed framework builds upon the visual nuisance assessment approaches developed by Pyrgidis et al. [15-17] for urban mass transportation systems (tram, monorail, and bus rapid transit), adjusted specifically to the operational and visual characteristics of metro railway systems.

Initially, the main structural elements (SE) affecting visual perception within metro environments were identified. Subsequently, aesthetic categories (AC) and weighting coefficients were assigned to each structural element according to their visual significance and influence on passenger perception and urban integration. Finally, evaluation parameters were integrated into a unified assessment algorithm for the calculation of the final Visual Nuisance Index (VNI).

2.1 Structural elements of a metro railway system and related aesthetic solutions

The proposed framework comprises seven structural element (SE) categories, each including a set of coded alternative aesthetic solutions. The structural elements, which were considered to contribute to the visual nuisance caused by a metro railway system, are the following [3]:

- Station entrances
- Passenger Corridors
- Ticketing & Fare Control Facilities
- Platforms
- Signage & Passenger Information
- Exterior Appearance of Trains
- Interior Appearance of Trains

An aesthetic category (AC) value was assigned to each solution according to its contribution to aesthetic quality enhancement and visual nuisance reduction. Specifically, the proposed AC scale consists of five categories (O, A, B, C, and D), ranging from complete concealment of the structural element (Category O) to the least effective aesthetic treatment (Category D). The AC values assigned to the aesthetic solutions were subsequently used to characterize the corresponding SE categories. The resulting classification framework is presented in the following table.

Code	**Structural element/ Aesthetic solution**	**AC**
1	Structural element 1: Station entrances	
1.1	Landmark / minimally intrusive entrances	O
1.2	Glass entrance structures	A
1.3	Integrated reinforced concrete entrances	B
1.4	Non-integrated reinforced concrete entrances	C
2	Structural element 2: Passenger Corridors	
2.1	Artistic murals / artworks	A
2.2	Marble or tiled wall finishes	B
2.3	Cultural or tourism advertising panels	C
2.4	Commercial advertising panels	D
3	Structural element 3: Ticketing & Fare Control Facilities	
3.1	Modern automated machines with reduced metallic appearance	A
3.2	Modern automated machines with visible metallic appearance	B
3.3	Older-generation ticketing machines	C
4	Structural element 4: Platforms	
4.1	Modern open platforms with artistic wall interventions	A
4.2	Modern open platforms without artistic interventions	B
4.3	Older platforms with artistic interventions	B

4.4	Modern platforms with obstructive columns and no artistic treatment	C
4.5	Older platforms with obstructive columns and no artistic treatment	D
5	Structural element 5: Signage & Passenger Information	
5.1	Integrated signage and information systems	A
5.2	Non-integrated signage and information systems	B
6	Structural element 6: Exterior Appearance of Trains	
6.1	Contemporary curved design with neutral colors	A
6.2	Moderate exterior design quality with contrasting colors	B
6.3	Older train design with sharp geometry and strong contrasts	C
7	Structural element 7: Interior Appearance of Trains	
7.1	Spacious contemporary interiors without advertising	A
7.2	Moderate visual clutter with limited advertisements	B
7.3	High visual clutter, strong metallic appearance, older information systems	C

Table 1: Aesthetic classification of structural elements and design solutions in metro systems.

Each AC was associated with a qualitative description and a corresponding number of Visual Nuisance Points (VNP), as presented in Table 2. The assigned VNP values reflect the relative degree of visual nuisance generated by each aesthetic solution category, ranging from complete concealment of the structural element (VNP = 0) to increased visual intrusion caused by visually obstructive or non-essential elements (VNP = 4).

AC	Description	VNP
O	Full concealment of the structural element (e.g., iconic entrances, visually unobtrusive structures)	0
A	Limited visibility with high visual quality (e.g., transparent materials, artistic design treatments)	1
B	Partial visibility mitigation or moderate aesthetic treatment (e.g., tiled finishes, neutral architectural integration)	2
C	Fully visible element with limited visual quality consideration (e.g., exposed concrete surfaces, non-integrated equipment)	3
D	Increased visual obstruction and aesthetic degradation (e.g., advertisements, opaque barriers, oversized elements)	4

Table 2: Visual Nuisance Points (VNP) scale for the proposed aesthetic categories.

2.2 Weighting coefficients of structural elements

The structural elements of metro systems do not contribute equally to visual perception and visual nuisance. Therefore, weighting coefficients (w_i) were assigned to each SE through an expert-based weighting procedure. A structured questionnaire was distributed to professors and senior researchers with expertise in railway systems, urban design, and transport engineering. Participants were asked to assess the relative contribution of each structural element to the overall visual nuisance generated by the metro system using a scale ranging from 3 (lowest impact) to 10 (highest impact). The lower bound was intentionally set above zero to reflect the assumption that all structural elements contribute, to some extent, to the visual perception of the urban environment. Consequently, the assessment reflected the relative magnitude of visual nuisance rather than its absence. Following data collection, the mean score for each structural element was calculated and normalized by dividing it by the minimum reference value. The resulting weighting coefficients were rounded to the nearest decimal place.

Table 3 presents the weighting coefficients (w_i) and the corresponding threshold values adopted for the examined structural elements under the minimum and maximum Visual Nuisance Point (VNP) scenarios, representing the most adverse and most favorable conditions, respectively. The weighting factors reveal that station entrances, platform environments, passenger circulation areas, and the exterior appearance of trains constitute some of the most influential structural elements affecting the overall visual perception of metro infrastructure.

The threshold values for the Visual Nuisance Index (VNI) were determined through the weighted calculation of the values under both scenarios, resulting in an index range between 0.84 and 3.18.

SE	**W_i**	**Minimum VNP Scenario**	**Maximum VNP Scenario**
Station entrances	2.5	0	3
Passenger corridors	2.3	1	4
Ticketing and fare control facilities	2.1	1	3
Platforms	2.5	1	4
Signage & Passenger Information	2.0	1	2
Exterior appearance of trains	2.3	1	3
Interior appearance of trains	2.0	1	3
Total / Thresholds	15.7	0.84	3.18

Table 3: Weighting coefficients (w_i) and corresponding VNP threshold values for the examined structural elements.

To standardize the assessment framework and improve the comparability, the final VNI values were further normalized, resulting in a normalized index range between 0 and 1. Based on the equal interval classification of the normalized VNI range, three distinct qualitative classes of visual nuisance were defined, categorizing the VNI into low, moderate, and high visual nuisance levels.

Equation 1 presents the proposed Visual Nuisance Index (VNI) developed to assess the level of visual nuisance caused by the operation of a metro system, while Table 4 presents the corresponding qualitative visual nuisance categories.

$$VNI_{metro} = \mathrm{k}_1 \left(\frac{\sum_{i=1}^{n} w_i VNP_i}{\sum_{i=1}^{n} w_i} - \mathrm{k}_2 \right) \tag{1}$$

Where:

- VNI is the Visual Nuisance Index of the examined metro system;
- VNP_i is the Visual Nuisance Points assigned to each structural element i, depending on the qualitative category of the adopted aesthetic mitigation solution;
- Wi is the weighting factor expressing the relative influence of structural element i on the overall visual nuisance generated by the metro system;
- n is the total number of evaluated structural elements;
- k1 is a normalization coefficient, equal to 0.427;
- k2 is a normalization coefficient, equal to 0.84.

VNI range	**Visual nuisance category**	**Evaluation**
0.00 – 0.33	Category I: Low Visual Nuisance	The metro system causes limited visual nuisance, while the adopted design and aesthetic mitigation measures are considered highly effective.
0.34 – 0.66	Category II: Moderate Visual Nuisance	The metro system causes moderate visual nuisance due to the partial visual impact of structural elements, requiring localized aesthetic improvement measures.
0.67 – 1.00	Category III: High Visual Nuisance	The metro system causes significant visual nuisance, strongly affecting the visual perception of users and requiring extensive corrective aesthetic interventions.

Table 4: Qualitative classification of the normalized Visual Nuisance Index (VNI) for metro systems.

3 Assessment of Visual Aesthetics and Nuisance in the Athens Metro

3.1 Case study rationale

The proposed visual nuisance assessment framework that was developed and presented before was applied to the Athens Metro system. The aim of this case study is to evaluate the visual performance of the metro infrastructure and to examine the degree to which the system contributes either positively or negatively to the urban environment and the passenger experience.

The Athens Metro was selected as the case study since it represents one of the most significant public transport infrastructures in Southeastern Europe and forms the backbone of the metropolitan transport network of Athens, exceeding 240 million passenger boardings in 2024 [18]. Beyond its transportation function, the system exerts a substantial influence on the urban identity and visual image of the urban environment due to the high passenger volumes, the extensive integration of stations within the urban fabric.

Three of the busiest metro stations were selected for analysis. More specifically, the stations of (a) Syntagma, (b) Attiki, and (c) Monastiraki. The selected stations are highlighted within the overall Athens Metro network in Figure 1.

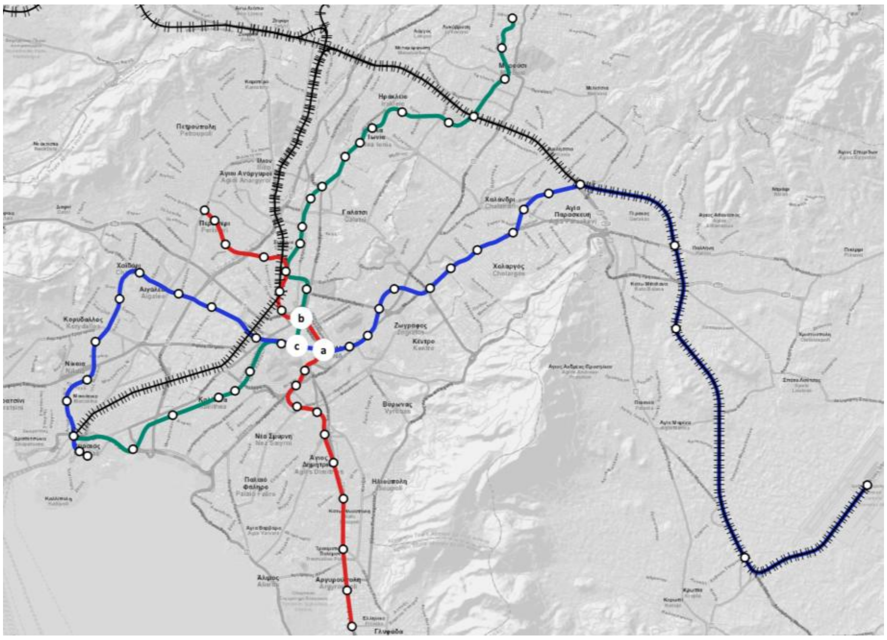

Figure 1: Athens Metro network and location of the selected case study stations: (a) Syntagma, (b) Attiki, and (c) Monastiraki.

3.2 Evaluation procedure

The evaluation procedure followed the proposed visual nuisance assessment framework developed in the previous sections. Initially, the structural elements (SEs) of the selected metro stations were identified and classified into the seven predefined categories of the framework. Subsequently, an aesthetic category (AC) was assigned to each structural element according to the design characteristics, architectural integration, materiality, spatial organization, and degree of visual intrusion observed during the field assessment.

The three selected stations present substantially different spatial and operational characteristics, allowing the examination of diverse visual conditions within the Athens Metro system. Syntagma station was evaluated more favorably due to its high level of spatial integration, contemporary design approach, extensive use of transparent materials, artistic interventions, and coherent passenger information systems. In contrast, Attiki station exhibited increased visual nuisance associated with limited architectural integration, older infrastructure elements, visually intrusive structural components, and a less coherent spatial organization. Monastiraki station presented an intermediate case, combining relatively high architectural quality and cultural integration with moderate levels of visual clutter generated by passenger circulation areas and station access configurations.

Differences were also observed between older and newer generations of rolling stock operating on the Athens Metro. Newer trainsets exhibited more integrated exterior and interior design characteristics, reduced visual clutter, and improved passenger information systems, resulting in lower perceived visual nuisance. In contrast, older rolling stock presented less coherent aesthetic integration and a stronger visual presence. The rolling stock fleet operating on the examined lines consists of first-generation trains (42.4%), second-generation trains (31.8%), and third-generation trains (25.8%). A weighted average visual nuisance value of 2.17 VNP was estimated for the rolling stock component.

Based on the assigned AC categories, the corresponding Visual Nuisance Points (VNP) were determined for each structural element and subsequently combined with the weighting coefficients (w_i) of the framework in order to estimate the overall visual nuisance performance of each station. Table 5 summarizes the assigned aesthetic categories (AC) and corresponding Visual Nuisance Points (VNP) for the examined structural elements of the selected stations.

SE	$\mathbf{w_i}$	**Station**					
		Syntagma		Attiki		Monastiraki	
		AC	VNP	AC	VNP	AC	VNP
Station entrances	2.5	O	0	A	1	B	2
Passenger corridors	2.3	A	1	B	2	A	1
Ticketing and fare control facilities	2.1	B	2	B	2	B	2
Platforms	2.5	B	2	B	2	B	2
Signage & Passenger Information	2.0	A	1	A	1	A	1
Exterior appearance of trains	2.3	B*	2.166	B*	2.166	B*	2.166
Interior appearance of trains	2.0	B*	2.166	B*	2.166	B*	2.166

* Weighted average classification of multiple rolling stock generations.

Table 5: AC classification and corresponding VNP values for the selected Athens Metro stations.

3.3 Results

Utilizing Equation 1, the VNI was calculated for the examined stations, resulting in values of 0.26 (26%) for Syntagma station, 0.39 (39%) for Attiki station, and 0.40 (40%) for Monastiraki station. These values indicate that Syntagma station presents the lowest relative level of visual nuisance among the examined cases, whereas Attiki and Monastiraki stations exhibit moderate visual nuisance levels.

Based on the calculated values and the classification, Syntagma station is classified within the low visual nuisance category (category I), indicating the most favorable visual performance among the examined cases. In contrast, Attiki and Monastiraki stations are classified within the moderate visual nuisance category (category II). However, their VNI values remain close to the threshold separating the two categories, suggesting that relatively limited aesthetic interventions could further improve their visual performance and allow their classification within the I category.

4 Conclusions

Metro railway systems constitute essential components of sustainable urban mobility. Besides their transport function, they can influence the visual quality and identity of urban environments. However, the perception of visual quality remains largely subjective, while objective assessment criteria are still limited. Furthermore, unlike technical and operational characteristics, which are commonly evaluated through established standards and performance indicators, the visual nuisance lacks universally accepted assessment criteria

This paper presented a structured methodological framework for the evaluation of visual nuisance in metro railway systems. The framework was developed through the classification of metro structural elements into aesthetic categories and the assignment of Visual Nuisance Points (VNP) and weighting coefficients reflecting their relative contribution to overall visual perception. The proposed Visual Nuisance Index (VNI) enables the quantitative estimation of the visual performance of metro systems and facilitates comparisons between different stations and infrastructure configurations. The weighting factors revealed that station entrances, platform environments, passenger circulation areas, and the exterior appearance of trains constitute some of the most influential structural elements affecting the overall visual perception of metro infrastructure

The application of the methodology to selected stations of the Athens Metro system demonstrated the practicality and effectiveness of the proposed framework. The analysis showed that stations characterized by higher levels of architectural integration, artistic interventions, coherent signage systems, transparent materials, and improved spatial organization present lower levels of visual nuisance. Conversely, visually intrusive infrastructure elements, older structural components, and increased visual clutter were associated with higher visual nuisance levels.

The proposed framework may be used during procurement and bidding procedures, at the design stage of new metro systems, for the evaluation of existing systems, and for the assessment of improvement measures. It can provide to transport authorities and designers a quantitative tool for evaluating visual nuisance and supporting the aesthetic integration of metro infrastructure within the urban environment.

However, the present research does not come without limitations. The proposed framework has not yet been extensively applied in practice, and therefore additional case studies are required to evaluate its robustness, general applicability and transferability.

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