Evaluation of Suspended Veneer Façade Criteria at the Construction Stage

Darius Migilinskas, Viačeslav Zigmund(✉), and Jurgita Antuchevičienė

Department of Construction Management and Real Estate, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Sauletekio ave. 11, Vilnius, Lithuania
viaceslav.zigmund@vilniustech.lt

Abstract. Construction uses different innovative solutions and advanced technologies to increase effectiveness, safety assessment, site preparation, logistic, save resources, reduce waste and reworks. One of the ways to find the best solution is introducing specific problem-based evaluation criteria and applying complex multi-criteria evaluation systems. The aim of the current research is to develop a multifaceted criteria system for evaluation of suspended veneer façade installation solutions by increasing effectiveness according to sustainability at the construction stage, including expert survey and determining relative significance (weights) of criteria. The authors suggested three groups of criteria, evaluating preparation for construction, installation and the result, each group consisting of eight criteria. Some criteria were analyzed together with the future application of decision system tools and building information modelling (BIM) for information management and data analysis. The determined criteria weights will be applied in ranking of alternative suspended veneer façade solutions by using multiple criteria decision-making methods.

Keywords: Veneer Façade · Construction · Criteria · Expert Evaluation · BIM

1 Introduction and Literature Review

All the time the construction process is improving a lot using various innovative solutions and advanced technologies to increase effectiveness of decisions, save resources [1], reduce wastes and reworks [2]. Some researchers and practitioners analyze different ways to find the solution by introducing specific problem-based evaluation criteria [3] or even whole multi-criteria evaluation systems for certain situations in construction [4]. The selection of criteria and evaluation system is important, but it is also important to have project data prepared for risk and alternative assessment.

The combination of Building Information Modelling (BIM) with precise project data, actual information and Multiple Criteria Decision Making (MCDM) methods for the efficient decision support was evaluated advanced BIM application for project information management. This integration faces some challenges, risks and can be deeply evaluated. The request for a solution for every stakeholder must be based not only on economic and technologic evaluation but also on sustainability principles [5], effective

J. A. O. Barros et al. (Eds.): MBMST 2023, LNCE 392, pp. 537–544, 2024.
https://doi.org/10.1007/978-3-031-44603-0_55

supply, reliable safety at works and trustable construction management. In best case, when this leads to development of innovative assessment index system for any scale of community decision [6] based on weighted systems of criteria for new construction or retrofitting projects. Some projects can be evaluated as a set of criteria based on energy performance of building and information before construction and after completion [7]. Another example of BIM integration with AHP (Analytic Hierarchy Process) method as a multi-criteria decision-making tool to save building energy and improve comfort was analyzed by Jalilzadehazhari and other researchers [8]. The detailed evaluations are connected to different types of buildings and Pavlovskis with other researchers analyze the possible solutions for the industrial buildings [3].

Best practices and different MCDM approaches can be used together with BIM for various evaluations in the construction industry [6]. It shows the transformation of construction process for better data management with possibility of information control between stakeholders and disciplines at different project stages for successful project implementation and BIM application [5]. BIM improves team collaboration, project efficiency, data accuracy and delivers better results in the construction process.

To evaluate the improved alternatives, it is necessary to analyse the construction project from perspective of time [2], cost and quality. The same attention to improvements is applied in construction of veneer façade. Suspended veneer façade is not only connected to construction, sustainability and durability, but requires a technical understanding of the processes to reach high aesthetics in modern city architecture. The construction of veneer façade is mostly based on a sustainable decision in building architecture project and has average application growth up to 8% [9]. Brick veneer façade constitutes 15%–25% of total construction costs [10]. But despite the costs veneer façade is a feasible solution for a building façade [11]. Moreover, it represents the key part of economic and environmental application not only in construction stage, but in the different stages of the lifecycle such as design and production [12]. An important part of risk is design errors which account for 60% of issues in construction of facades [10].

Veneer masonry façade has been applied in a different type of buildings in different regions worldwide due to aesthetic [13], energy savings [14], great variety of designs [9], environmentally friendliness [15], maintenance costs [16], the art form of brick expressionism [17], water absorption [18]. To select the best type of façade in terms of multiple aspects, a multifaceted criteria system should be developed. Safety management in construction sites must be evaluated as a very important criterion and all efforts must be made to reduce the safety hazards in the construction industry. The support for efficiency by government can be shown as good country efforts for safety risk management as advanced solution on site [19]. Construction documentation must be prepared for all project stages, but it is crucial to have it on time for construction works to save resources [20] and connect to construction site layout planning [21].

The aim of the current research is to develop a criteria system for evaluation of veneer façade solutions at the construction stage, including expert survey and determining relative significance (weights) of criteria. Methodology is presented in Sect. 2, criteria evaluation is described in Sect. 3. Conclusions and future research are presented in the last Section.

2 Methodology

The initial aim of the research is to prepare a criteria evaluation system for analysis of veneer façade alternatives in construction stage together with determination of criteria weights using expert evaluation method. The list of criteria was defined based on theoretical background from analyzed research [3, 11, 12] and practical approach as real project experience. The research methodology presented in Fig. 1. The equations applied for calculations as well as verifying compatibility of expert opinions are presented further.

Figure 1 shows the steps of criteria development and evaluation according to the description below:

Step 1. Identification of Evaluation Criteria;
Step 2. Developing an Evaluation Criteria System;
Step 3. Expert Survey to Estimate the Weights;
Step 4. Mean Values of Experts Scores are Determined;
Step 5. The Significance of the Criteria is Determined;
Step 6. Compatibility Assessment of Expert Opinions.

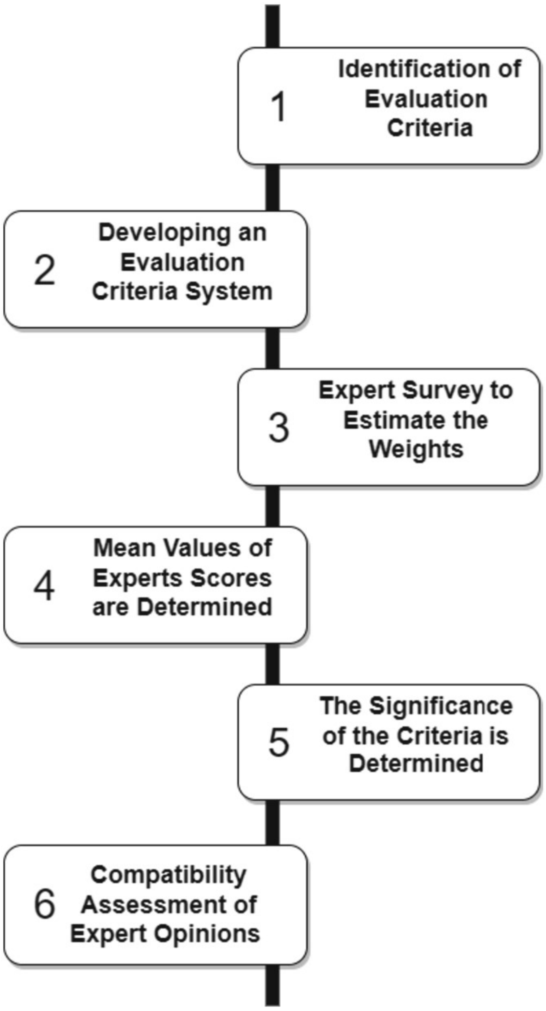

Fig. 1. The methodology of the research.

For evaluation of criteria relative significance (weights) w_j, the authors applied expert survey. The experts (r experts) were asked to rank the significance of criteria (n criteria) according to their opinion. The expert given ranks t_{jk} were further processed as follows [22].

Calculating the mean value of scores given by experts:

$$\overline{t_j} = \frac{\sum_{k=1}^{r} t_{jk}}{r}. \tag{1}$$

Calculating the weight of each criterion:

$$w_j = \frac{\overline{t_j}}{\sum_{j=1}^{n} \overline{t_j}}. \tag{2}$$

The Kendall coefficient of concordance is calculated for checking expert opinions compatibility [23]:

$$W = \frac{12\left(\sum_{j=1}^{n}\left(\sum_{k=1}^{r} t_{jk} - \frac{1}{n}\sum_{j=1}^{n}\sum_{k=i}^{r} t_{jk}\right)\right)}{r^2\left(n^3 - n\right)}. \tag{3}$$

The conclusion regarding compatibility is made after calculating the significance of concordance coefficient and comparing it with respective normative value:

$$\chi^2 = \frac{12\left(\sum_{j=1}^{n}\left(\sum_{k=1}^{r} t_{jk} - \frac{1}{n}\sum_{j=1}^{n}\sum_{k=i}^{r} t_{jk}\right)\right)}{rn(n+1)}. \tag{4}$$

3 Criteria Evaluation Results

The aim is to evaluate relative significance of three groups of criteria G_1 – Preparation for construction, G_2 – Installation and G_3 – Result, and relative significance of eight criteria in each group, describing effectiveness of suspended veneer façade construction. Some criteria are maximized because a higher value is better, and some criteria are minimized because a lower value is better. The groups and the criteria are presented in Tables 1, 2 and 3.

The research for evaluation of suspended veneer façade criteria at the construction stage applies expert survey to determine the relative weights of criteria based on the suggested three groups. Twelve experts were selected who work in the construction industry. Most of them have Master degree (66.6%) or PhD degree (16.7%), they are specialists as Project managers (58.3%) or Engineers (25.0%) and working in construction industry as Contractors (58.3%) or Procurement (25.0%). The detail distribution of experts is presented in Table 4.

The experts had to set scores to three groups of criteria established on the scale 1–3, where 1 means the lowest importance and 3 means the highest importance to an issue. Criteria ranked in each group set on the score scale 1–8, where 1 means the lowest and 8 means the highest importance to an issue. The results after the expert survey and respective calculations (Eqs. 1–4) are presented in Table 5.

Table 1. List of criteria – Preparation for construction group G_1.

Notation	Criterion	min/max
X_{11}	Site preparation for installation, m^2	min
X_{21}	Preparation of Workshop drawings, h	min
X_{31}	Scaffolding for installation, EUR	min
X_{41}	Formworks for lintels, EUR	min
X_{51}	Storage area, %	min
X_{61}	Paper drawing waste reduction (savings), EUR	min
X_{71}	Precision of material quantity calculation, %	max
X_{81}	Convenience for delivery of materials, points	max

Table 2. List of criteria – Installation group G_2.

Notation	Criterion	min/max
X_{12}	Safety measures, points	max
X_{22}	Delivery to installation place, EUR/m^2	min
X_{32}	Work expenditures for installation of m^2 of façade, labor hour	min
X_{42}	Quality control measures, h	min
X_{52}	Waste reduction in construction, %	max
X_{62}	Supply chain reliability, %	max
X_{72}	Installation energy consumption, kW/h	min
X_{82}	Water consumption, l/100 m^2	min

Table 3. List of criteria – Result group G_3.

Notation	Criterion	min/max
X_{13}	Construction mistake risk, points	min
X_{23}	Complexity of installation and reworks, points	min
X_{33}	Construction time, days	min
X_{43}	Construction costs, EUR	min
X_{53}	Process management, points	min
X_{63}	Visual façade quality, points	max
X_{73}	CO_2 emissions	min
X_{83}	The environmental result, points	max

Table 4. Distribution of experts.

By Degree	By specialty	By area of industry
PhD 16.7%	Project manager 58.3%	Contractors 58.3%
Master 66.6%	Engineer 25.0%	Procurement 25.0%
Bachelor 16.7%	Architect 16.7%	Designer 16.7%

Table 5. Weights of criteria.

Group	Weight/Rank	Criteria	Weight	Rank	Compatibility
G_1	0.24/3	X_{11}	0.17	2	$W = 0.34$ $33.21 > 20.28$ $(p = 0.005)$
		X_{21}	0.19	1	
		X_{31}	0.10	6	
		X_{41}	0.11	5	
		X_{51}	0.10	7	
		X_{61}	0.05	8	
		X_{71}	0.16	3	
		X_{81}	0.12	4	
G_2	0.40/1	X_{12}	0.18	1	$W = 0.49$ $47.94 > 20.28$ $(p = 0.005)$
		X_{22}	0.13	5	
		X_{32}	0.15	4	
		X_{42}	0.17	2	
		X_{52}	0.09	6	
		X_{62}	0.16	3	
		X_{72}	0.06	7/8	
		X_{82}	0.06	7/8	
G_3	0.36/2	X_{13}	0.15	4	$W = 0.36$ $35.71 > 20.28$ $(p = 0.005)$
		X_{23}	0.16	2/3	
		X_{33}	0.16	2/3	
		X_{43}	0.17	1	
		X_{53}	0.14	5	
		X_{63}	0.12	6	
		X_{73}	0.04	8	
		X_{83}	0.06	7	

4 Conclusions

The developed multifaceted criteria system describing the efficiency of suspended veneered façade solutions during the construction phase was submitted to experts for evaluation. According to an experts' survey, the most important group of criteria is G_2 – Installation, the secondly ranked group is G_3 – Results, and the least important is G_1 – Preparation for construction group. The relative importance of the criteria in the groups is widely distributed, from 0.04 to 0.19, but the concordance of expert opinions is very high with a reliability of $p = 0.005$.

Future research on suspended veneer façade installation method will be based on precise BIM model quantities. The developed criteria system and determined criteria weights will be applied for ranking of alternatives by using MCDM methods and BIM integration.

References

1. Nikmehr B, Hosseini MR, Wang J, Chileshe N, Rameezdeen R (2021) BIM-based tools for managing construction and demolition waste (CDW): a scoping review. Sustainability 13(15):8427. https://doi.org/10.3390/su13158427
2. Khalesi H, Balali A, Valipour A, Antucheviciene J, Migilinskas D, Zigmund V (2020) Application of hybrid SWARA–BIM in reducing reworks of building construction projects from the perspective of time. Sustainability 12(21):8927. https://doi.org/10.3390/su12218927
3. Pavlovskis M, Migilinskas D, Antuchevičienė J, Urba I, Zigmund V (2017) Problems in reconstruction projects, BIM uses and decision-making: Lithuanian case studies. Procedia Eng. 208:125–128. https://doi.org/10.1016/j.proeng.2017.11.029
4. Carbonari A, Corneli A, Di Giuda GM, Ridolfi L, Villa V (2019) A decision support system for multi-criteria assessment of large building stocks. J. Civ. Eng. Manage. 25(5):477–494. https://doi.org/10.3846/jcem.2019.9872
5. Tan T, Mills G, Papadonikolaki E, Liu Z (2021) Combining multi-criteria decision making (MCDM) methods with building information modelling (BIM): a review. Autom. Constr. 121:103451. https://doi.org/10.1016/j.autcon.2020.103451
6. Chen ZS, Yang LP, Rodríguez RM, Zhu Z, Pedrycz W, Skibniewski MJ (2022) BIM-aided large-scale group decision support: optimization of the retrofit strategy for existing buildings. Appl. Soft Comput. 131:109790. https://doi.org/10.1016/j.asoc.2022.109790
7. Migilinskas D, Balionis E, Džiugaitė-Tumėnienė R, Šiupšinskas G (2016) An advanced multi-criteria evaluation model of the rational building energy performance. J. Civ. Eng. Manage. 22(60):844–851. https://doi.org/10.3846/13923730.2016.1194316
8. Jalilzadehazhari E, Vadiee A, Johansson P (2019) Achieving a trade-off construction solution using BIM, an optimization algorithm, and a multi-criteria decision-making method. Buildings 9(4):81. https://doi.org/10.3390/buildings9040081
9. Kanig M, Glock G (2019) Innovative binder technology for masonry building. Mauerwerk – Eur. J. Masonry 23(1):55–61. https://doi.org/10.1002/dama.201800032
10. Carretero-Ayuso MJ, Sáez-Pérez MP (2021) Construction flaws in facing brick facades and the risk of associated litigation. J. Build. Eng. 33:101633. https://doi.org/10.1016/j.jobe.2020.101633
11. Leśniak A, Balicki J (2016) Selection of façades finishing technology for a commercial building using multi-criteria analysis. Entrepr. Bus. Econ. Rev. 4(2):67–79. https://doi.org/10.15678/EBER.2016.040206

12. Zigmund, V., Antuchevičienė, J., Migilinskas, D.: The Selection of a masonry façade installation method for a building at the design stage. In: New Trends in Construction Management, pp. 101–119. Cracow University of Technology, Cracow (2023). ISBN 9788367188395
13. Martins A, Vasconcelos G, Campos Costa A (2017) Brick masonry veneer walls: an overview. J. Build. Eng. 9:29–41. https://doi.org/10.1016/j.jobe.2016.11.005
14. Mas Á, Vercher J, Cubel F, Gil BE, Lerma C (2018) Design and construction recommendations for connections arrangement in anchored veneers with continuous air cavity. Revista de la Construcción 17(1):137–148. https://doi.org/10.7764/RDLC.17.1.137
15. Ingrao C, Scrucca F, Tricase C, Asdrubali F (2016) A comparative Life Cycle Assessment of external wall-compositions for cleaner construction solutions in buildings. J. Clean. Prod. 124:283–298. https://doi.org/10.1016/j.jclepro.2016.02.112
16. Tam VWY, Le KN, Wang J (2018) Cost implication of implementing external facade systems for commercial buildings. Sustainability 10(6):1917. https://doi.org/10.3390/su10061917
17. Jaeger F (2019) The Art of Masory. Mauerwerk – Eur. J. Masonry 23(1):51–54. https://doi.org/10.1002/dama.201900001
18. Kahangi Shahreza S, Niklewski J, Molnár M (2022) Novel water penetration criterion for clay brick masonry claddings. Constr Build Mater 353:129109. https://doi.org/10.1016/j.conbuildmat.2022.129109
19. Chatzimichailidou YM (2022) Using BIM in the safety risk management of modular construction. Saf. Sci. 154:105852. https://doi.org/10.1016/j.ssci.2022.105852
20. Yije K, Sangyoon C, Seungyeon C (2022) BIM data requirements for 2D deliverables in construction documentation. Autom Constr 140:104340. https://doi.org/10.1016/j.autcon.2022.104340
21. Zavari M, Shahhosseini V, Ardeshir A, Sebt MH (2022) Multi-objective optimization of dynamic construction site layout using BIM and GIS. Journal of Building Engineering 52:104518. https://doi.org/10.1016/j.jobe.2022.104518
22. Palevičius V, Burinskienė M, Antuchevičienė J, Šaparauskas J (2019) Comparative study of urban area growth: determining the key criteria of inner urban development. Symmetry 11:406. https://doi.org/10.3390/sym11030406
23. Kendall MG, Gibbons JD (1990) Rank correlation methods, 5th edn. Oxford University Press, New York