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SUPPORT FOR MAKING DESIGN DECISIONS IN RENOVATION OF HISTORIC BUILDING

WSPOMAGANIE DECYZJI PROJEKTOWYCH W REMONCIE OBIEKTU ZABYTKOWEGO

A b s t r a c t

The design and implementation of building structure renovation works allow for a selection of constructional and material solutions, as well as organisational issues. Proper selection should take into account many different technical and economic factors, and in the case of historic buildings – conservation factors as well. This leads to suggesting various solutions. Choosing a solution should not be intuitive, but based on a multi-criteria analysis using simple or complex decision-making models. This paper discusses two constructional solutions for a flat roof in a historic building subject to renovation. An AHP method-based multi-criteria analysis has been carried out for both of them. This analysis allows for the assessment and selection of a proper solution.

Keywords: historic building renovation, multicriteria analysis, the AHP method

S t r e s z c z e n i e

W projektowaniu i realizacji remontów obiektów budowlanych istnieje możliwość wyboru rozwiązań konstrukcyjno-materiałowych, a także organizacyjnych. Właściwy wybór powinien uwzględniać wiele różnych czynników natury technicznej, ekonomicznej, a w przypadku obiektów zabytkowych – konserwatorskiej. Prowadzi to do proponowania rozwiązań wariantowych. Wybór rozwiązania nie powinien być intuicyjny, lecz wsparty analizą wielokryterialną wykorzystującą proste lub złożone modele decyzyjne. W artykule przedstawiono dwa rozwiązania konstrukcyjne stropodachu w remontowanym obiekcie zabytkowym, dla których przeprowadzono analizę wielokryterialną z zastosowaniem metody AHP, pozwalającą na ocenę i wybór rozwiązania.

Słowa kluczowe: remont obiektu zabytkowego, analiza wielokryterialna, metoda AHP

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1. Introduction

Currently, we are observing an increasing level of interest from investors in historic building renovations. However, works of this type constitute a great challenge due to specific technological requirements, untypical conditions for execution of construction works and necessary high expenses. Therefore, proposed design and implementation concepts should be well thought out, suggested solutions should be varied, and evaluation and selection should take into account various factors. A multi-factor analysis is used in the decision-making process in various issues and is supported by different, more or less complex and popular methods [5].

Owing to the National Fund for the Revalorisation of Historic Buildings and Monuments in Krakow established in 1985, intensive revalorisation works are carried out every year in more than 100 historic buildings in the capital city of Małopolska. In 2012 this programme covered 167 objects, and the Fund appropriated 42,497,731.37 PLN for their renovation. These buildings included Fort no. 2 "Kościuszko", in which renovation works were carried out at Curtain V-I p [1, 4, 6].

The purpose of this work is to analyse and assess the concept of design solutions for the roof of fort curtain subject to renovation. Considering this, the article specifies the rules for the adaptation of historic works of military defence, which should be taken into account in design concepts. Building characteristics presented in this paper have been complemented with photographs showing the progress of construction works, as observed by authors. Two roof design proposals provided in this work have been assessed with a multi-criteria analysis using the AHP method.

2. The rules for adaptation of historic works of military defence

Many different spatial forms and structural solutions of fortification buildings have developed due to ceaseless changes in defence methods, progress in military technology and the existence of many schools of fortification and evolution of *architectura militaris* through centuries. This is also the reason why there are no applicable standards or rules for maintenance and adaptation of these objects. The issue of managing fortress complexes is an extensive matter that requires analyses in many fields of science, including the construction industry, architecture, economy, sociology, ecology, management, etc.

To simplify, we can make a few assumptions which affect the adaptation of fortress complexes. Among them we distinguish [3]:

- structural characteristics of after-fortress management guidelines resulting from the original defensive function of facility,
- preservation and technical state of facility elements,
- rules regarding protection of the value of historic facilities,
- obligatory educational and scientific functions, which should be provided by a facility,
- current legal and functional status of a fortification,
- contemporary technical and functional requirements set to building structures.

The priority in the adaptation of historic fortification is to protect them against damage whilst ensuring authentic structure of facilities. It is preferred to choose such facility adaptation method, which will guarantee:

- all-year-round facility use,
- economic calculation taking into account the costs of carrying out conservation work,
- functional programme for the use of the whole fortification,
- public availability of the facility.

In the article, the authors devote special attention to the issue of designing greenery around the facility, and to the roles it played throughout the cycle of facility service life, and the need to hide structures of this type e.g. by planting greenery directly connected with them.

Greenery surrounding forts today has little to do with historic styles. Without constant maintenance, soil fortifications turn into areas covered with wild vegetation. For the purposes of maintaining the facility as an exhibition, the most important task is to cut down trees and shrubs, and to repair damage caused by roots. During structure clearing, it is also a requirement to isolate and properly secure foliage of special historic value. While preparing an adaptation project for a given historic structure, it is extremely important to carry out historical research in order to determine the functions held by greenery in a given facility, and to make a decision regarding the extent of its reconstruction.

The study contains comparing the alternative solution, chosen from many analyzed proposals in [7], with an executed(in real) solution suggested by the designer. To the evaluation was used multicriteria analysis. This method has a lot of varieties and more and more universally is being used for analysis of different engineering problems and the decision [8, 13, 14]. The finding has historic buildings serving the decision-maker responsible for the compliance of the concept with the requirements concerning the renovation above all. Performed solving the designer is supposed to take into account a lot of important measurable and immeasurable requirement/factors to a given historic building and economic possibilities of the institutional investor.

3. Facility characteristics

Fort no. 2 “Kościuszko” is one of the oldest defensive structures of the Krakow Stronghold. It was established from 1850–1854 as a citadel fort with its centre formed by the mound built by Poles in honour of Tadeusz Kościuszko. The building is untypical of an Austrian school of fortifications due to the preservation of the mound which constitutes the central element of the whole complex. The fort plan is close to hexagonal with corner bastions. Three huge bastions were built from the west and two smaller ones from the east. The structure lacks redoubt, which was a typical element of forts at that time. Its function was performed by brick wall which was built around the Mould, surrounded by a courtyard and a cylinder of neck barracks. The fort has been included in the list of fixed vintage buildings of the City of Krakow on January 2, 1968, ref. no. A-308.

The fort section subject to renovation is Curtain V-I, constituting the southern part of fortification line. From the western side, the curtain is adjacent to Bastion V and Caponier, and from the east, it borders on the entrance road to the fort courtyard. Originally, it consisted of two longitudinal walls, each ca. 1.15m-thick, distant from each other from 12.8 m at the bastion to 14.6 m in the area of not existing now entrance gate. Inside the curtain, at both its ends, there were also rooms with barrel vaults. From the fort courtyard side there was also a ramp shielded by the wall, leading to the curtain crown.

Prior to the commencement of the works, the space between the curtain walls was filled with soil, and the curtain crown covered with growing trees and shrubs (Fig. 1). The outside walls were damaged in many places, and before the soil removal it was impossible to evaluate the current state of the inside walls preservation. It was also impossible to determine precisely the building foundation depths and the technical state of the foundation walls.

Fig. 1. Northern façade of the facility before commencement of works

The design allows for using the space between the curtain walls for commercial purposes by creating the Tadeusz Kościuszko Conference and Exhibition Centre (Fig. 2) [6]. As a result of space development between the curtains and making a flat roof restoring original curtain topping form, functional space will be created on three storeys (cellar, ground floor and first floor) connected by two stairways, with mezzanine above first floor. Designed flat roof will have the form of an observation deck, which will be available through the restored ramp (Fig. 3).

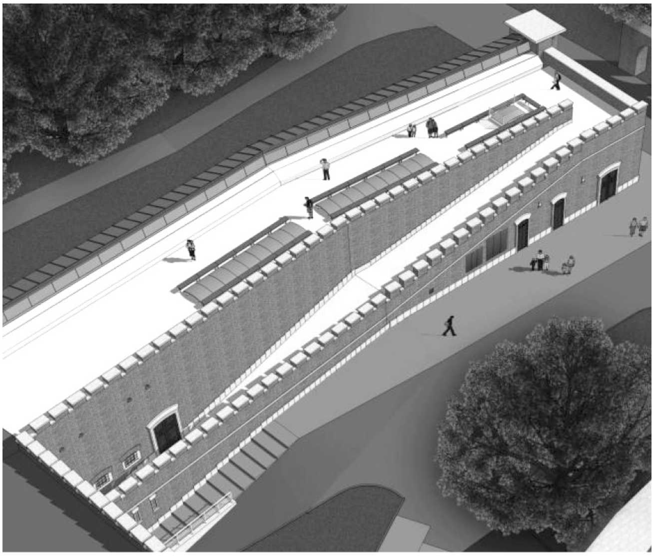

Fig. 2. Facility visualisation

Fig. 3. Northern façade – May 2013

Additionally, it is planned to develop the area adjacent to the fort. In the courtyard between the curtain and rotunda there will be a pedestrian and vehicular traffic route with a parking lot and station with bicycle stands. From the northern façade side, there will be a green area with a playground for children.

Kościuszko Mound Committee is the investor and future user of the curtain. The Committee finances this project, supported by the European Union and National Fund for the Restoration of Krakow's Historic Monuments. Gross investment value is 7,920,501.19 PLN. The project preparation is carried out by Pracownia Konserwacji Zabytków "Arkona" ["Arkona" Historic Buildings Conservation Office], while Skanska S.A. [a joint-stock company] is responsible for its implementation. The works are planned from July 2011 until December 2013.

4. Analysis and evaluation of design solutions

The scope of analysis includes two proposals for the design of a flat roof in the renovated building [7], which will be subject to multi-criteria assessment carried out using the AHP method [2, 10].

Flat roof design suggestions

The first of the analysed structures is a design solution for a flat roof made as an observation deck (Fig. 4) [11]. For the purposes of the performed analysis, this solution will be marked A.

The second variant is an intensive green flat roof with vegetation including sedums, grasses and herbs, which is made in a reversed layout (Fig. 5) [12]. Layer structure for selected green roof type has been designed on the basis of system solutions from Optigrün International AG [9]. This solution will be marked B.

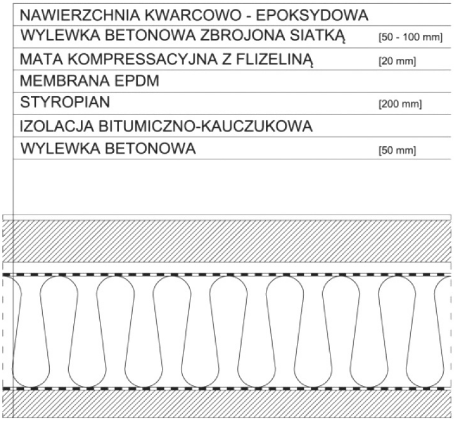

Fig. 4. Flat roof layer structure

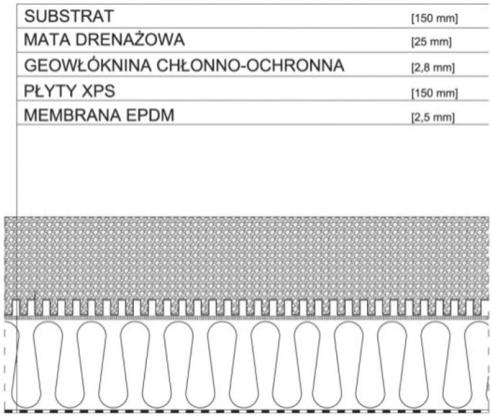

Fig. 5. Green flat roof layer structure

Multi-criteria analysis

Completed multi-criteria analysis involves the assessment of presented solutions considering specific factors. We distinguish several stages in it:

1. Preparing the list of criteria to be applied to assess presented solutions.
2. Assessing criteria significance using the AHP method:
   - creating matrix of comparisons in pairs,
   - calculating local priorities – determining largest own value of matrix and own vector corresponding to it,
   - checking evaluation compliance by determining compliance index and ratio,
   - computing global priorities.
3. Evaluation of decision-making options.
4. Presentation of results in form of a GSM matrix.

Comparative criteria. The first stage involved preparing a list of factors, which would be used to consider two decision-making options. These factors were divided into two groups – internal (Table 1) and external (Table 2).

Evaluation of criteria and decision-making options. It involves creating proper matrixes of comparisons in pairs – external and internal factors assessed according to general purpose of the analysis, that is selection of the best constructional solution in given conditions, and analysed solutions compared as regards individual factors.

When comparing individual elements, we use the relative preference scale created by Saaty, in which we distinguish five basic situations, matched by a numerical scale [2]. These are: equivalence (numerical equivalent 1); weak preference (3); significant preference (5); distinct preference (7); absolute preference (9). Among these, there are also indirect preferences – 2, 4, 6, 8. This allows us to prepare the following matrixes.

$$A^w = \begin{bmatrix} 1 & 5 & 5 & 5 & 3 & 5 \\ \frac{1}{5} & 1 & 1 & 1 & \frac{1}{3} & 3 \\ \frac{1}{5} & 1 & 1 & 1 & \frac{1}{3} & 3 \\ \frac{1}{5} & 1 & 1 & 1 & \frac{1}{5} & 3 \\ \frac{1}{3} & 3 & 3 & 5 & 1 & 5 \\ \frac{1}{2} & \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & \frac{1}{5} & 1 \end{bmatrix} \qquad A^z = \begin{bmatrix} 1 & 1 & \frac{1}{3} & \frac{1}{3} & \frac{1}{5} & \frac{1}{3} \\ 1 & 1 & \frac{1}{3} & \frac{1}{3} & \frac{1}{5} & \frac{1}{3} \\ 3 & 3 & 1 & 3 & \frac{1}{3} & 3 \\ 3 & 3 & \frac{1}{3} & 1 & \frac{1}{3} & \frac{1}{3} \\ 5 & 5 & 3 & 1 & 1 & 3 \\ 3 & 3 & \frac{1}{3} & 3 & \frac{1}{3} & 1 \end{bmatrix}$$

$$A^1 = \begin{bmatrix} 1 & 9 \\ \frac{1}{9} & 1 \end{bmatrix} \quad A^5 = \begin{bmatrix} 1 & \frac{1}{3} \\ 3 & 1 \end{bmatrix} \quad A^{3'} = \begin{bmatrix} 1 & \frac{1}{3} \\ 3 & 1 \end{bmatrix}$$

$$A^2 = \begin{bmatrix} 1 & \frac{1}{7} \\ 7 & 1 \end{bmatrix} \quad A^6 = \begin{bmatrix} 1 & \frac{1}{7} \\ 7 & 1 \end{bmatrix} \quad A^{4'} = \begin{bmatrix} 1 & 5 \\ \frac{1}{5} & 1 \end{bmatrix}$$

$$A^3 = \begin{bmatrix} 1 & 3 \\ \frac{1}{3} & 1 \end{bmatrix} \quad A^{1'} = \begin{bmatrix} 1 & 3 \\ \frac{1}{3} & 1 \end{bmatrix} \quad A^{5'} = \begin{bmatrix} 1 & \frac{1}{9} \\ 9 & 1 \end{bmatrix}$$

$$A^4 = \begin{bmatrix} 1 & \frac{1}{3} \\ 3 & 1 \end{bmatrix} \quad A^{2'} = \begin{bmatrix} 1 & 5 \\ \frac{1}{5} & 1 \end{bmatrix} \quad A^{6'} = \begin{bmatrix} 1 & \frac{1}{5} \\ 5 & 1 \end{bmatrix}$$

where:

A^w – evaluation of internal factors,
A^z – evaluation of external factors,
$A^1, \ldots, A^6$ – assessment of solutions as regards internal factors,
$A^{1'}, \ldots, A^{6'}$ – assessment of solutions as regards external factors.

Local and global priorities. Local priorities are determined for all obtained matrixes by way of determining highest own values for matrixes λ_{max} (5) and corresponding to them own vectors w (4). Values obtained in this way are used to determine global priorities, which are the basis for choosing the best solution. Individual values are determined using methods developed by Saaty [e.g. 2,10]:

$$A = \begin{pmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{pmatrix}$$

$$a_i^* = \sqrt[n]{\Pi_{j=1}^{n} a_{ij}}, \quad i = \overline{1,n} \tag{1}$$

$$a_i^* = \sqrt[n]{\Pi_{j=1}^{n} a_{ij}}, \quad i = \overline{1,n} \tag{2}$$

$$a^* = \sum_{i=1}^{n} a_i^* \tag{3}$$

$$w_1 = \frac{a_i^*}{a^*}, \quad i = \overline{1,n} \tag{4}$$

$$\lambda_{\max} = \sum_{j=1}^{n} a_j^* w_j \tag{5}$$

Using the obtained matrix own values, we check if the received results are correct. In order to do that, we determine compliance index C.I. (6) and compliance ratio C.R. (7) – if they are less than 0.1, the completed assessment may be deemed correct (method details are available e.g. in literature items [2, 10]). In case of higher values, the decision-making problem should be rethought and the evaluation should be repeated.

$$\text{C.I.} = \frac{\lambda_{\max} - n}{n - 1} \tag{6}$$

$$\text{C.R.} = \frac{\text{C.I.}}{\text{R.I.}} \tag{7}$$

where:

n – matrix dimension,

R.I. = 1.24 for $n = 6$.

In this case, we received C.I. 0.6, C.R. 0.05 for matrix of internal factors and C.I. 0.09, C.R. 0.08 of matrix of external factors.

The last stage of computations is to determine global priorities, meaning the sum of products of priorities for each branch of considered decision-making options for the purposes of the pondered general problem. In the case of the issue analysed by us, cumulative tables are prepared which contain evaluation of both variants regarding internal (Table 1) and external (Table 2) factors.

GSM matrix. The obtained results are shown in a four-field GSM matrix (Fig. 6), in which both flat roof solutions are shown in the form of points in two-dimensional space. The horizontal axis is the evaluation of internal factors, and the vertical axis is the evaluation of external factors. A is the symbol of the flat roof made according to the original design, and B is the green flat roof proposed by the author.

Table 1

Evaluation of internal factors

Internal factors		Criterion priority	Evaluation of variant A	Modified* evaluation factors A	Evaluation of variant B	Modified* evaluation factors B
1	Structure construction cost	0.44	0.90	0.396	0.10	0.044
2	Structure construction time	0.09	0.13	0.012	0.87	0.078
3	Requirements regarding employee qualifications	0.09	0.75	0.068	0.25	0.023
4	Requirements regarding construction site layout	0.09	0.25	0.023	0.75	0.068
5	Structure stability	0.25	0.25	0.063	0.75	0.188
6	Structure aesthetics	0.04	0.13	0.005	0.87	0.035
SYNTHETIC EVALUATION			∑	0.567	∑	0.436

* Product of criterion priority and evaluation of variant

Table 2

Evaluation of external factors

External factors		Criterion priority	Evaluation of variant A	Modified* evaluation factors A	Evaluation of variant B	Modified* evaluation factors B
1’	Availability of constructional materials	0.06	0.75	0.045	0.25	0.015
2’	Availability of qualified staff	0.06	0.83	0.050	0.17	0.010
3’	Requirements regarding the structure use and making	0.24	0.25	0.060	0.75	0.180
4’	Users’ interest and evaluation	0.12	0.83	0.100	0.83	0.020
5’	Conservator’s guidelines	0.35	0.1	0.035	0.83	0.315
6’	Situation in construction industry	0.17	0.17	0.029	0.75	0.142
SYNTHETIC EVALUATION			∑	0.319	∑	0.682

* Product of criterion priority and evaluation of variant.

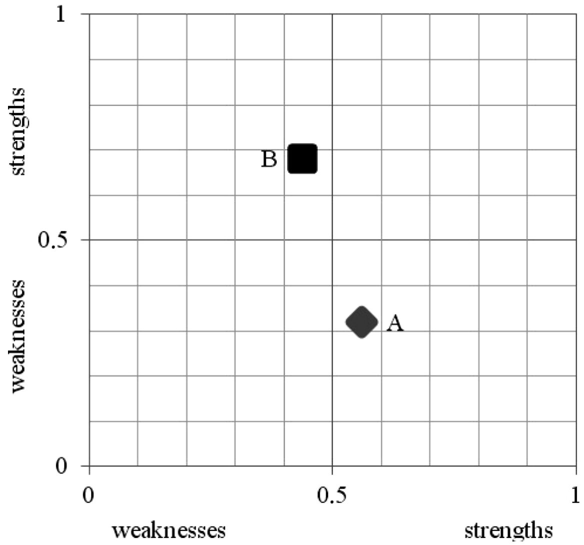

Fig. 6. GSM matrix

5. Conclusions

Results obtained from an analysis carried out using the AHP method are not unequivocal. Analysis of the decision-making options regarding internal factors gives results in favour of solution A, that is the flat roof made according to the prepared building permit design. However, the difference between evaluations of both projects is insignificant. In the case of analysis for external factors, difference in evaluations is much more considerable. Evidently, solution B prevails, that is the reversed intensive green roof.

The following have greatest impact on the obtained results: for internal factors – the structure construction cost (criterion weight 0.44) and its stability (criterion weight 0.25), and for external factors – conservator's guidelines (criterion weight 0.35) and requirements regarding the structure use and keeping (criterion weight 0.24). It's worth observing that in the case of prevailing internal factors, we receive certain divergence – the design solution is predominant as regards costs, however the green solution has been deemed more durable. There are no such differences in the case of external factors – most important factors have been assessed to be in favour of the green roof. The obtained results agree with the general analysis of both solutions [5], which has taken into account weight, cost and time of making individual structures, and also historical study of the building.

In situations like the selection of the flat roof solution demonstrated in this study, the investor faces difficult choices with regard to economic aspects, aesthetic values and striving for preserving historical conformity of the facility with its original state. Curtain subject to renovation is expected to serve commercial purposes as potential location for conferences and meetings, therefore, according to the author, external factors should play a greater role in the selection of a constructional solution. Although uncommon in Poland, a green roof may increase the building's attraction, which should translate into greater interest in using this new commercial space. This sort of operation is observed in the case of the construction of the University Library building in Warsaw for example, where a decision has been made to incur much higher expenses, which are expected to translate into an increase of investors' interest and profits from using the space for commercial purposes. One of the elements aimed at increasing the building value is a grand-scale design of the garden on the building roof.

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