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Research paper

Impact of decision model structure on the selection of a telecommunications tower footing reinforcement alternative

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Abstract: In recent years, we have been able to observe a dynamic development of MCDA (multi-criteria decision analysis) methods, which have become widely used in various sectors, including construction. These methods are characterised by simplicity and one of their key advantages is their simple modelling of non-linear dependencies within decision problems and their analysis under the conditions of incomplete, uncertain and hard-to-measure information. The universality and simple use of these methods does not, however, free the decision-maker from the necessity to adopt the proper approach to modelling and analysing specific decision problems. To highlight the fact that it is the character of the problem that should determine the selection of the method of analysing it and not the other way around, the authors assessed the AHP (Analytic Hierarchy Process) and the ANP (Analytic Network Process) method in terms of verifying the impact of the different decision model structures on analysis outcomes and analysed their sensitivity to input data changes. This analysis was based on the example of selecting a telecommunications tower footing reinforcement alternative. The findings confirmed the significant impact of decision model structure on the ranking of the analysed alternatives.

Keywords: MCDA (multi-criteria decision analysis), AHP (Analytical Hierarchy Process), ANP (Analytical Network Process), civil engineering, footing reinforcement, telecommunications towers

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1. Introduction

In recent years, we have been able to observe a dynamic development of discrete MCDA (multiple-criteria decision analysis) methods, which considerably expand the scope of applying operational research in various fields of human activity [2,3,7,11].

MCDA methods can generally be categorised as belonging to one of the following groups [2,5]:

- methods based on aggregating ratings into the form of a synthetic criterion
- methods based on outranking
- other methods

The first group of methods is characterised by either a top-down or bottom-up approach and is rooted in the American school of multi-attribute decision-making support. Methods from this group use a typology of models that represent a given decision problem in the form of simpler elements, wherein decision alternatives are then separately assessed using specific criteria and the resultant information is aggregated. These methods are known for their compensation property, i.e. the possibility of returning a different result for an alternative that became worse as a result of lower ratings relative to other alternatives in a specific criterion due to ratings for other criteria being higher. This group of methods includes the ANP, AHP, MACBETH (Measuring Attractiveness by a Categorical Based Evaluation TecHnique) and DEMATEL (DEcision Making Trial and Evaluation Laboratory) methods.

The second group of methods, contrary to the first, uses a bottom-up approach and is derived from the European school of multi-attribute decision support. The outranking relations that are used in these methods are built upon a complete set of partial relations that refer to selected characteristics of each decision alternative. Thanks to these methods, we can define representation and dominance thresholds. They also employ concordance between partial ratings or the lack of said concordance. These methods include: ELECTRE (Fr. ELimination Et Choix Traduisant la REalia) and PROMETHEE (Preference Ranking Organisation METHod for Enrichment Evaluations).

The third group includes all methods that are not linked with either of the groups mentioned above and the methods that only partially use their characteristic mechanisms. Here one should particularly note the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and VIKOR (abbreviation from Serbian: višekriterijumska optymizacija i kompromisno rešenje) methods.

The variety of MCDA methods makes it difficult to choose the right method to analyse a specific decision problem and requires a level of understanding between the decision-maker and analyst [11].

These methods have their strong and weak points, which should be accounted for in their application. To highlight the weight of the problem, we can find several publications on assessing MCDA methods in the literature, viewed in the context of their effective application in solving specific classes of decision problems [4,6,10], but that nevertheless do not exhaust the issue. One alternative to the difficult selection of a specific method is the concept of integrated MCDA analysis, which is based on using several methods (either separately or in a hybrid combination) to analyse a problem and use their results in the inference process [1].

To continue the discussion on the problem of assessing and choosing MCDA methods to solve specific decision problems, the authors analysed the specificity of two popular and widely recognised MCDA methods: AHP (Analytic Hierarchy Process) [8] and ANP (Analytic Network Process) [9]. The object of the assessment of these two methods was the problem of the structurisation of the problem in the form of a decision model, which determines how it is analysed. As highlighted in [2], the choice of decision model structure can significantly affect the results of analysing a given decision problem. As many decision-makers do not, in practice, ascribe much significance to structurising problems when using the abovementioned methods, the authors based their argument on the practical example of selecting an alternative of the footing of a telecommunications tower located in Wierzbięcice, in the municipality of Nysa, Poland.

2. Analysis of the selection of an alternative of the footing of a telecommunications tower

2.1. Overview of the decision problem

The problem in question concerns the selection of an alternative of the reinforcement of a steel framework telecommunications tower located in Wierzbięcice in the municipality of Nysa, Poland. The tower is a part of the Wierzbięcice Radio Base Station and is the property of Tauron Dystrybucja S.A. Due to the planned modernisation of the station and its associated extension of the tower's antenna infrastructure, which will increase applicable loads, it was recommended to reinforce the tower's body and its foundations. The following footing reinforcement alternatives were subjected to analysis: V1 additional footing pads, V2 micropiles, V3 reinforced concrete slab. The alternatives were rated via the use of seven criteria: C1 completion time, C2 amount of excavated soil to dispose of, C3 amount of necessary machinery, C4 cost, C5 temporary stabilisation, C6 work complicatedness, C7 formal and legal requirements.

2.2. Decision model alternatives

The problem of selecting an alternative of the reinforcement of the footing of a telecommunications tower located in Wierzbięcice was analysed using four decision models, applying the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) methods. They belong to a group of methods based on aggregating preferences in the form of a synthetic criterion and are based on very similar calculation algorithms. The key difference between them is the structure of the decision model. In the AHP method, this model has a hierarchical structure, which features only ordered, unidirectional relations between each hierarchy level. In the ANP method, this model takes

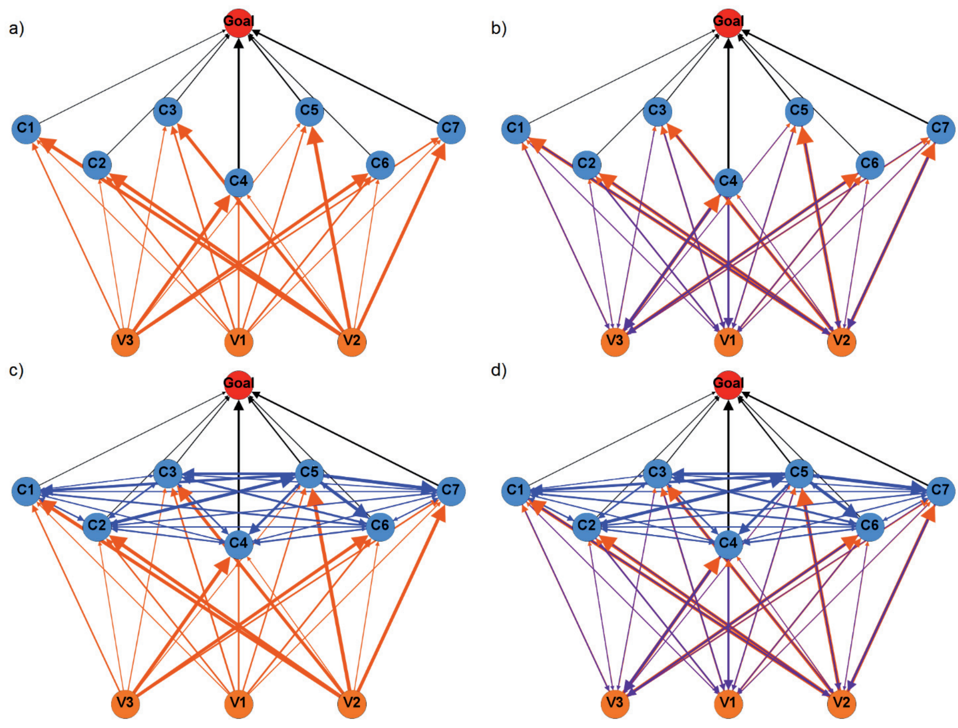

Fig. 1. Decision models used to analyse the problem. a) hierarchical model, b) model that accounts for feedback between criteria and alternatives, c) model that accounts for interdependencies between criteria, d) model that accounts for feedback between criteria and alternatives and interdependencies between criteria.

on the form of a network structure, which has no defined order of elements and the dependencies between them can be bidirectional. It also features mutual relations between each criterion. The objective of the analysis was to demonstrate the impact of the decision model's structure on the selection of an optimal solution to the decision problem in light of the previously presented criteria. The analysis utilising different decision models can allow us to verify whether a model structure that accounts for dependencies between criteria and feedback changes the final outcome. The four decision models used to analyse the presented problem have been presented in Fig. 1. Blue nodes represent criteria, while orange nodes represent alternatives. The links between each type of node have also been marked using different colours.

2.3. Application of the AHP method to select the optimal solution

The authors used Super Decisions software to analyse the selection of a telecommunications tower footing reinforcement alternative. To this end, they entered the hierarchical model presented in Fig. 1a into the program. Afterwards, they performed pairwise comparisons of individual criteria relative to the primary goal. The pairwise comparisons appropriate for each decision model were performed by an expert (who designs telecommunications tower footing reinforcement solutions as a part of their professional practice) along with a verification of rating concordance. They were used to calculate weight coefficients for each criterion. The results of this process have been presented in table 1.

Table 1. Criteria weight coefficients

Criterion	Weight
C1 Completion time	0.021
C2 Amount of excavated soil to dispose of	0.034
C3 Amount of necessary machinery	0.063
C4 Cost	0.382
C5 Temporary stabilisation	0.182
C6 Work complicatedness	0.066
C7 Formal and legal requirements	0.252

During the subsequent stage, the authors performed pairwise comparisons between decision alternatives and criteria. Based on the ratings, the authors then calculated local criteria priorities for each alternative. The values of these priorities, as well as those of global priorities, were presented in a standardised form in table 2, alongside a ranking of the alternatives.

Table 2. Local and global priorities, alternative ranking

Alternative	Alternative local priority relative to each criterion							Global priority	Ranking
	C1 Completion time	C2 Amount of excavated soil to dispose of	C3 Amount of necessary machinery	C4 Cost	C5 Temporary stabilisation	C6 Work complicatedness	C7 Formal and legal requirements		
V1 Additional footing pads	0.084	0.231	0.271	0.231	0.194	0.279	0.088	0.191	3
V2 Micropiles	0.705	0.709	0.644	0.060	0.743	0.072	0.669	0.411	1
V3 Reinforced concrete slab	0.211	0.060	0.085	0.709	0.063	0.649	0.243	0.398	2

2.4. Application of the ANP method to select the optimal solution

The decision model analysis presented in Fig. 1b, 1c and 1d was performed using the ANP method using Super Decisions. This required additional pairwise comparisons between criteria and the analysed alternatives (for models presented in Fig. 1b and 1d) and between the criteria themselves (in the case of models presented in Fig. 1c and 1d). The outcome produced local priorities concerning criteria for each alternative as presented in table 3 and local priorities concerning criteria for the criteria themselves, as presented in table 4. Local priorities of each element of the decision model are included in a so-called unweighted supermatrix. In the case of the model that allows feedback between criteria and alternatives, the supermatrix is composed of data featured in tables 1, 2 and 3 (the remaining priorities had zero values). In the case of the model that allows interdependencies between criteria, the supermatrix is composed of data featured in tables 1, 2 and 4. The supermatrix of the last of the analysed models combines data from tables 1, 2, 3 and 4. Table 5 presents standardised global priority values for the analysed alternatives and their corresponding rankings obtained while using each network-based decision model.

Table 3. Local priorities of criteria relative to alternatives

Criterion	Local priority of each criterion relative to each alternative		
	V1 Additional footing pads	V2 Micropiles	V3 Reinforced concrete slab
C1 Completion time	0.050	0.212	0.114
C2 Amount of excavated soil to dispose of	0.199	0.140	0.041
C3 Amount of necessary machinery	0.173	0.062	0.055
C4 Cost	0.342	0.018	0.450
C5 Temporary stabilisation	0.118	0.196	0.025
C6 Work complicatedness	0.098	0.025	0.289
C7 Formal and legal requirements	0.021	0.347	0.026

Table 4. Local priorities of criteria relative to criteria

Criterion	Local priority of each alternative relative to each criterion						
	C1 Completion time	C2 Amount of excavated soil to dispose of	C3 Amount of necessary machinery	C4 Cost	C5 Temporary stabilisation	C6 Work complicatedness	C7 Formal and legal requirements
C1 Completion time	0.000	0.167	0.031	0.048	0.030	0.042	0.042
C2 Amount of excavated soil to dispose of	0.101	0.000	0.146	0.107	0.597	0.041	0.044
C3 Amount of necessary machinery	0.053	0.167	0.000	0.205	0.032	0.208	0.043
C4 Cost	0.114	0.167	0.029	0.000	0.065	0.048	0.124
C5 Temporary stabilisation	0.449	0.167	0.446	0.408	0.000	0.600	0.629
C6 Work complicatedness	0.248	0.167	0.318	0.205	0.174	0.000	0.118
C7 Formal and legal requirements	0.034	0.167	0.029	0.028	0.102	0.062	0.000

Table 5. Global priorities and ranking of alternatives for each network-based decision model

Alternative	Model accounting for feedback between criteria and alternatives		Model accounting for interdependencies between criteria		Model accounting for feedback between criteria and alternatives and interdependencies between criteria	
	Global priority	Ranking	Global priority	Ranking	Global priority	Ranking
V1 Additional footing pads	0.191	3	0.201	3	0.198	3
V2 Micropiles	0.434	1	0.476	1	0.483	1
V3 Reinforced concrete slab	0.375	2	0.323	2	0.319	2

3. Sensitivity analysis

A sensitivity analysis was performed for each of the presented decision models, which investigated the impact of each criterion's weights on the final ranking. In the case of the hierarchical model, it showed that a weight layout that would allow acknowledging variant V1 additional footing pads as an optimal solution did not exist. Depending on criteria significance, the use of either micropiles or the reinforced concrete slab was shown to be the most optimal solution of reinforcing the telecommunications tower's footing.

In the case of network-based models, a lower sensitivity to criterion weight change was observed. This can be observed in Fig. 2, which presents the global priority values for variants depending on the temporary stabilisation criterion weight. Similarly, three possible rankings can be produced by the model that accounts for feedback between criteria and alternatives, yet the change in ranking only takes place for a criterion weight close to either 0 or 1. In the case of the model that accounts for the interdependencies between criteria, it was possible to obtain two rankings (with the micropile reinforcement alternative as optimal in both cases), with the liminal value of the weight criterion being 0.720. The model accounting for both the feedback between criteria and alternatives and the interdependency between criteria indicated the highest output stability, with a clearly defined alternative ranking. The model sensitivity charts that account for changes in the weights of the remaining criteria display a similar characteristic.

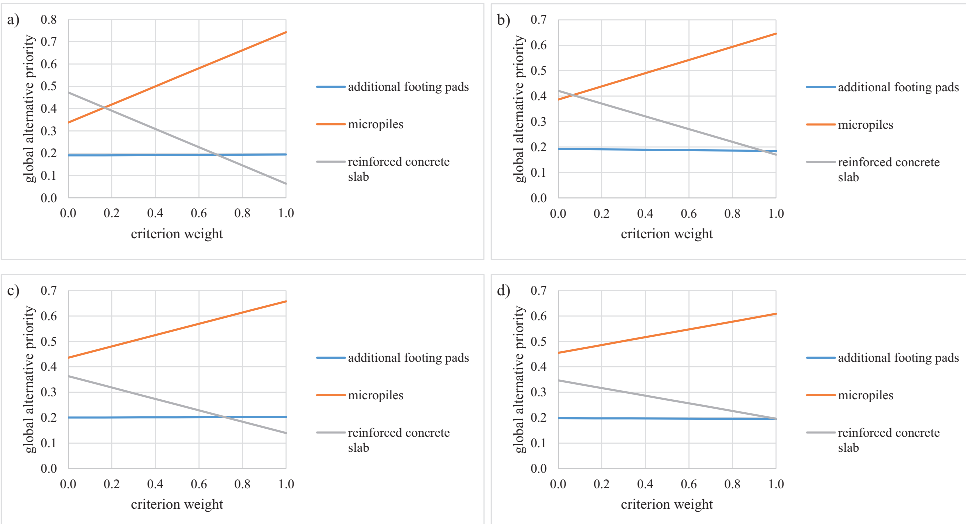

Fig. 2. Global parameter values for alternatives depending on the temporary stabilisation criterion weight for: a) the hierarchical model, b) the model that accounts for feedback between criteria and alternatives, c) the model that accounts for interdependencies between criteria, d) the model that accounts for feedback between criteria and alternatives and the interdependence between criteria

4. Discussion

The decision alternative ranking obtained for each of the network-based decision models is the same as for the hierarchical model. They differ in terms of global priority values for each alternative. Insofar as the difference between the value for micropiles and the reinforced concrete slab was rather small and amounted to 3% in the case of the hierarchical model, it rose to 16% when feedback between criteria and alternatives were accounted for. Accounting for interdependencies between criteria caused the difference to increase to 48%. When accounting for both the feedback between criteria and alternatives and the interdependencies between criteria, the alternative denoting the use of micropiles achieved a global priority that was 51% greater than the priority of building the reinforced concrete slab. The global priority of building additional footing pads changed little in relation to the hierarchical model. Significant changes could also be observed when analysing the standardised global priority values for criteria across each decision model (table 6).

Table 6. Global priorities for criteria by decision model

Criterion	Hierarchical model	Model that accounts for feedback between criteria and alternatives	Model that accounts for criteria interdependencies	Model that accounts for feedback between criteria and alternatives and criteria interdependencies
C1 Completion time	0.021	0.083	0.034	0.074
C2 Amount of excavated soil to dispose of	0.034	0.074	0.108	0.114
C3 Amount of necessary machinery	0.063	0.072	0.082	0.084
C4 Cost	0.382	0.312	0.245	0.224
C5 Temporary stabilisation	0.182	0.149	0.252	0.221
C6 Work complicatedness	0.066	0.102	0.109	0.119
C7 Formal and legal requirements	0.252	0.208	0.169	0.164

Insofar as the clearly preferable criteria for the AHP method were cost and formal and legal requirements, their significance was much lower in the case of network-based models, and the criteria priority values were more balanced (a standard deviation change from 0.125 in the hierarchical model to 0.057 for the model that accounts for feedback between criteria and alternatives and the interdependencies between criteria). Accounting for interdependencies between criteria caused the temporary stabilisation criterion to become one of the most significant criteria alongside cost. Therefore, we can conclude that accounting for feedback between criteria and alternatives and interdependencies between criteria had a very significant impact on the final decision criteria significance classification, and can carry over to the final alternative ranking. Furthermore, due to applying a network-based model, the optimal solution selection became much clearer, with an explicit indication of the most and least favourable alternative. When comparing the global priorities for each criterion as presented in table 6, it can be observed that the criterion of cost, which was the most preferred by the decision-maker when applying hierarchical analysis, lost its significance relative to other criteria after accounting for all dependencies between the model's elements. This is important, as in the real-world construction sector it is often the only aspect used to assess design solutions. The analysis performed by the authors proved that the impact of factors that might appear to be insignificant to a project can actually determine the choice of solutions.

5. Conclusions

Seeing as the ANP method, contrary to the AHP method, does not assume the superiority of individual node types, the goal node is treated the same as other nodes during calculations. When it is linked solely with inbound relations, their impact on the outcome is only superficial. In this case, the results are not dependent on the influences represented by inbound relations in any way. Therefore, the ANP-based analysis of network models required, apart from introducing the dependencies presented in Fig. 1, the introduction of feedback between the goal node and the criteria. This operation ensures that the significance of each criterion is accounted for and is neutral relative to results obtained when analysing hierarchical models.

Despite the fact that the final alternative ranking obtained using different decision models for the set criterion weights was identical, there were clear differences in the global priority values for each alternative. The analysis demonstrated that the use of multi-criteria decision analysis methods in decision-making is justified. The result can be considered unobvious, as the alternative that was considerably less favourable in terms of the cost criterion (assumed to be the most significant in light of the primary goal) turned out to be the best solution. This points to the significance that secondary criteria can have on the final assessment of potential solutions and indicates that ignoring them can be a serious mistake.

The sensitivity analysis indicated that accounting for additional dependencies within the decision model can significantly impact end results. Additional dependencies make the model more stable, which can be considered a predictable effect, as the end result is affected by more variables and therefore the impact of a single criterion weight on the end result is smaller. The analysis points to the high significance of the appropriate assumption of the structure of the decision model and the impact of this structure on the results of multi-criteria analyses. The application of a hierarchical or network-based analysis method cannot be assumed a priori, but must be picked for specific decision problems individually, as depending on their specificity, they can display a smaller or greater number of dependencies between its elements.

References

[1] V. Belton, T. J. Stewart, Multiple Criteria Decision Analysis: An Integrated Approach. Springer, Dordrecht, 2002. https://doi.org/10.1007/978-1-4615-1495-4

[2] M. Dytczak, Wybrane metody rozwiązywania wielokryterialnych problemów decyzyjnych w budownictwie. Politechnika Opolska, Opole, 2010.

[3] M. Fedorczak-Cisak, A. Kowalska-Koczwara, K. Nering, F. Pachla, E. Radziszewska-Zielina, G. Śladowski, T. Tatara, B. Ziarko, Evaluation of the Criteria for Selecting Proposed Variants of Utility Functions in the Adaptation of Historic Regional Architecture. Sustainability. 11(4), 1094, 2019.

https://doi.org/10.3390/su11041094
[4] M. E. Gershon, Model choice in multiobjective decision-making in natural resource systems, University of Arizona, 1981.
[5] A. Kobryń, Wielokryterialne wspomaganie decyzji w gospodarowaniu przestrzenią. Difin, Warszawa, 2014.
[6] M. Książek, Analiza porównawcza wybranych metod wielokryterialnych oceny przedsięwzięć inwestycyjnych. Budownictwo i Inżynieria Środowiska. 2(4), 555–561, 2011.
[7] E. Radziszewska-Zielina, M. Gleń, The application of the Electre I method for the selection of the floor solution variant. Advances and Trends in Engineering Sciences and Technologies - Proceedings of the International Conference on Engineering Sciences and Technologies, ESaT 2015, CRC Press, pp. 359–365, 2016. https://doi.org/10.1201/b19249
[8] T. L. Saaty, The Analytic Hierarchy Process: Planning, priority setting, resource allocation. McGraw-Hill, Nowy Jork, 1980.
[9] T. L. Saaty, Decision Making with Dependence and Feedback: The Analytic Network Process. RWS Publications, Pittsburgh, 1996.
[10] A. Tecle, Choice of multicriterion decision making techniques for watershed management, University of Arizona, 1988.
[11] T. Trzaskalik, Wielokryterialne wspomaganie decyzji. Przegląd metod i zastosowań. Zeszyty Naukowe. Organizacja i Zarządzanie / Politechnika Śląska. 74, 239–263, 2014.

Wpływ struktury modelu decyzyjnego na wybór wariantu wzmocnienia posadowienia wieży telekomunikacyjnej

Słowa kluczowe: MCDA (multi-criteria decision analysis), AHP (Analytical Hierarchy Process), ANP (Analytical Network Process), budownictwo, wzmocnienie fundamentów, wieże telekomunikacyjne

Streszczenie:

W ostatnich latach można zauważyć dynamiczny rozwój metod MCDA (multi-criteria decision analysis), które znalazły powszechne zastosowanie także w budownictwie. Metody te cechuje prostota, a ich istotną zaletą jest łatwe modelowanie nieliniowych zależności w problemach decyzyjnych oraz ich analiza w warunkach niepełnej, niepewnej i trudno mierzalnej informacji. Autorzy niniejszego artykułu przeanalizowali specyfikę dwóch popularnych i uznanych metod wielokryterialnego wspomagania decyzji: metody AHP (Analytic Hierarchy Process) i ANP (Analytic Network Process). Przedmiotem oceny tych dwóch metod jest zagadnienie tzw. strukturyzacji problemu w formie modelu decyzyjnego, która determinuje charakter jego analizy. Ponieważ w praktyce wielu decydentów nie przywiązuje wagi do strukturyzacji problemu, w ramach stosowania w/w metod autorzy swoje rozważania na ten temat oparli na praktycznym przykładzie wyboru wariantu wzmocnienia posadowienia wieży telekomunikacyjnej stanowiącej część Radiowej Stacji Bazowej (RBS) Wierzbięcice w gminie Nysa na terenie Polski. W związku z planowaną modernizacją stacji bazowej i związaną z tym rozbudową infrastruktury antenowej na wieży i zwiększeniem obciążeń zalecono wykonanie wzmocnienia trzonu wieży oraz jej fundamentów. Analizie poddane zostały następujące warianty wzmocnienia fundamentu: V1 dodatkowe stopy fundamentowe, V2 mikropale, V3 płyta żelbetowa. Do oceny wariantów przyjęto siedem kryteriów decyzyjnych: C1 czas wykonania, C2 grunt do wywiezienia, C3 ilość potrzebnego sprzętu, C4 koszt, C5 stabilizacja tymczasowa, C6 stopień skomplikowania robót, C7 wymagania formalno-prawne. Celem przeprowadzonej analizy było ukazanie wpływu struktury modelu decyzyjnego na wybór optymalnego rozwiązania problemu decyzyjnego w świetle przyjętych kryteriów. Analizę przeprowadzono z wykorzystaniem czterech modeli decyzyjnych: modelu hierarchicznego, modelu uwzględniającego sprzężenie zwrotne między kryteriami i wariantami, modelu uwzględniającego współzależność między kryteriami, a także modelu uwzględniającego sprzężenie zwrotne między kryteriami i wariantami oraz współzależność między kryteriami. Otrzymany ranking wariantów decyzyjnych dla każdego z sieciowych modeli decyzyjnych był taki sam, jak dla modelu hierarchicznego i wskazywał jako najlepszy wariant V2 mikropale, zaś jako najgorszy wariant V1

dodatkowe stopy fundamentowe. Różniły się natomiast wartości priorytetów globalnych dla poszczególnych wariantów. O ile w przypadku modelu hierarchicznego różnica pomiędzy wartością dla mikropali i płyty żelbetowej była nieznaczna i wynosiła 3%, tak w przypadku uwzględnienia sprzężenia zwrotnego między kryteriami i wariantami wzrosła do 16%. Natomiast uwzględnienie współzależności między kryteriami spowodowało, że wspomniana różnica zwiększyła się do 48%. Przy uwzględnieniu zarówno sprzężenia zwrotnego między kryteriami i wariantami oraz współzależności między kryteriami, wariant wzmocnienia posadowienia z zastosowaniem mikropali uzyskał priorytet globalny o 51% większy od priorytetu dla wykonania płyty żelbetowej. Priorytet globalny wariantu wykonania dodatkowych stóp fundamentowych zmieniał się nieznacznie w stosunku do zastosowania modelu hierarchicznego. Analizując wartości priorytetów globalnych dla kryteriów decyzyjnych w przypadku poszczególnych modeli również można zauważyć wyraźną zmianę. O ile dla metody AHP zdecydowanie najbardziej preferowanymi kryteriami były koszt i wymagania formalno-prawne, tak w przypadku modeli sieciowych ich znaczenie wyraźnie spadło, a wartości priorytetów kryteriów były bardziej wyrównane. Przeprowadzona analiza udowadnia, że czynniki, które pozornie wydają się być mało istotne dla przedsięwzięcia, w rzeczywistości mogą determinować wybór rozwiązania. Można ocenić, że uwzględnienie sprzężeń zwrotnych pomiędzy kryteriami i wariantami oraz wzajemnych zależności pomiędzy kryteriami miało duży wpływ na ostateczną klasyfikację ważności kryteriów decyzyjnych, a co za tym idzie może przekładać się na otrzymany ranking wariantów. Dodatkowo dzięki zastosowaniu modelu sieciowego wybór optymalnego rozwiązania problemu badawczego stał się bardzo klarowny, z jednoznacznym wskazaniem wariantu najbardziej i najmniej korzystnego. Analiza wrażliwości zakładająca zbadanie wpływu wag poszczególnych kryteriów na ranking końcowy potwierdziła, że uwzględnienie dodatkowych zależności w modelu decyzyjnym może znacząco wpływać na uzyskane wyniki. Dodatkowe zależności czynią model bardziej stabilnym, co można uznać za efekt spodziewany, gdyż na wynik końcowy wpływa więcej zmiennych, zatem udział np. pojedynczej wagi kryterium w końcowym wyniku jest mniejszy. Przeprowadzona analiza wskazuje na duże znaczenie, jakie odgrywa właściwe założenie struktury modelu decyzyjnego i wpływ tej struktury na uzyskane wyniki analiz wielokryterialnych. Stosowanie hierarchicznej lub sieciowej metody analizy nie może być zakładane z góry, lecz każdorazowo dobierane do konkretnego problemu decyzyjnego, który w zależności od specyfiki może charakteryzować się większą lub mniejszą liczbą zależności między poszczególnymi elementami modelu.

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