DOI: 10.14256/JCE.1179.2014

Građevinar 4/2015

Primljen / Received: 25.11.2014.
Ispravljen / Corrected: 19.1.2015.
Prihvaćen / Accepted: 6.2.2015.
Dostupno online / Available online: 10.5.2015.

Multicriteria assessment of unfinished construction projects

Authors:

Marius Lazauskas, MCE
Vilnius Gediminas Technical University, Lithuania
Faculty of Civil Engineering
marius.lazauskas@gmail.com

Vladislavas Kutut, PhD. CE
Vilnius Gediminas Technical University, Lithuania
Faculty of Civil Engineering
vladislavas.kutut@vgtu.lt

Prof. Edmundas Kazimieras Zavadskas, PhD. CE
Vilnius Gediminas Technical University, Lithuania
Faculty of Civil Engineering
edmundas.zavadskas@vgtu.lt

Original scientific paper

Marius Lazauskas, Vladislavas Kutut, Edmundas Kazimieras Zavadskas

Multicriteria assessment of unfinished construction projects

Possible ways for assessing completion of unfinished residential buildings to achieve appropriate construction project objectives are presented in the paper. The developed model enables an efficient assessment of unfinished projects in Vilnius, the capital of Lithuania. Unfinished building solutions, expressed through indicators, were selected and used to formulate a multicriteria task to be solved by combinations of methods AHP+ARAS, MOORA and MULTIMOORA. A computational model was created and adjusted for a simple and efficient assessment of the adequacy of investment projects in many areas of construction.

Key words:
unfinished buildings, AHP, ARAS, MOORA, MULTIMOORA, construction projects

Izvorni znanstveni rad

Marius Lazauskas, Vladislavas Kutut, Edmundas Kazimieras Zavadskas

Višekriterijsko ocjenjivanje nedovršenih građevinskih projekata

U ovom radu su prikazani mogući načini ocjene obnove nedovršenih stambenih zgrada kako bi se uspješno postigli ciljevi građevinskog projekta. Razvijeni model se pokazao učinkovitim u procjeni nedovršenih projekata u Vilniusu, glavnom gradu Litve. Odabrana su moguća rješenja za nedovršene zgrade te izražena pomoću pokazatelja, koji su potom primijenjeni za višekriterijsko ocjenjivanje koje se rješava kombinacijom metoda AHP+ARAS, MOORA i MULTIMOORA. Napravljen je računalni model prilagođen za učinkovitu i jednostavnu procjenu uspješnosti investicijskih projekata u mnogim područjima graditeljstva.

Ključne riječi:
nedovršene zgrade, AHP, ARAS, MOORA, MULTIMOORA, građevinski projekti

Wissenschaftlicher Originalbeitrag

Marius Lazauskas, Vladislavas Kutut, Edmundas Kazimieras Zavadskas

Mehrkriterielle Bewertung unvollendeter Bauvorhaben

In dieser Arbeit werden mögliche Methoden zur Bewertung der Wiederaufnahme unvollendeter Wohnbauprojekte dargestellt, um die Ziele der Bauvorhaben zu erreichen. Das entwickelte Model hat sich zur Beurteilung unvollendeter Projekte in Vilnius, der Hauptstadt von Litauen, als wirksam erwiesen. Mögliche Lösungen für unvollendete Gebäude sind ausgesucht und mittels Indikatoren dargestellt, die zur mehrkriteriellen Bewertung aufgrund einer Kombination der Methoden AHP+ARAS, MOORA und MULTIMOORA angewandt wurden. Ein Computermodel, das zur wirksamen und einfachen Erfolgsbeurteilung von Investitionsprojekten in vielen Bereichen des Bauwesens geeignet ist, wurde entwickelt.

Schlüsselwörter:
unvollendete Gebäude, AHP, ARAS, MOORA, MULTIMOORA, Bauprojekte

1. Introduction

The subprime financial crisis that began slowly in the first and second quarters of 2007, and that continued to escalate throughout 2008, was due to years of real-estate binging by over-indebted households, enabled by careless Wall Street lending [1-4]. Following the failure of Lehman Brothers in the autumn of 2008, the disruption of financial linkages and the appearance of dysfunctional financial markets, involving both the interbank and debt securities markets, generated widespread concern about possible impacts on the real economy [5].

Many major financial institutions teetered on the edge of collapse, and some failed. Meanwhile, the economy sank into a deep and prolonged recession, and the resulting financial crisis affected many industries [1].

The construction sector is regarded as a factor that significantly influences national economic policies. Construction sector indicators also reflect the general level of national economies. The situation of the construction sector also depends on general economic processes that are conditioned by fluctuations of national and international economic systems. Just like Western economies, Lithuania's construction industry was also affected by this specific period in construction industry. By the end of 2013 and in early 2014, Lithuania's construction industry started to rebound. Lithuania, as many other countries around the world, has dozens of new good-quality construction projects involving buildings and their complexes. Urban development spans old towns, residential areas and suburbs, but the construction industry faces one specific problem, namely that of neglected and unfinished construction projects dropped by construction companies owing to recent situation in construction industry, as well as due to bank policies and changes in the property market. Many construction companies simply went bust during the property crisis.

Problems arising in construction projects are complicated and usually involve massive uncertainties and subjectivities. Compared to many other industries, the construction industry is subject to more risks due to the unique features of construction activities, such as long duration of construction projects, with complicated processes, abominable environment, financial intensity, and dynamic organizational structures [6]. To address the issues brought about by the property crisis, different countries have used different priorities and adopted various approaches for crisis management in the sphere of construction and real estate. It is therefore not surprising that different countries have widely divergent views and interpretations, which are the reflection of their economic, market, legal, institutional, technological, technical, cultural, psychological, and other differences. Furthermore, not all countries understand construction and real estate crisis management in the same way; thus they also adopt differing strategies. The traditional analysis of a crisis in construction and real estate is based on economic, legal/regulatory, institutional, and political aspects. The social, cultural, ethical, psychological, and educational aspects of crisis management tend to receive less attention [7].

Since economic and financial processes (bankruptcies, unemployment, increasing amounts of bad bank loans, decreasing salaries, and dropping real estate prices, and various expectations) have stabilized, and Lithuania's property industry reached a stable level, there is now a need to see what possibilities are available to complete unfinished buildings. The territory in question includes unfinished administrative and residential buildings. A great number of abandoned cultural heritage buildings are located in the old city as well. Every disused building impairs moral purpose of a building to be in use. The aim of this research is to outline possibilities to select an alternative solution for a construction project, and make sure the solution meets the requirements of investors, inhabitants and other stakeholders. Finding solutions for unfinished buildings is of crucial significance for elimination of major negative impacts such as the visual pollution of public areas, danger to nearby residents, and violation of sustainable development principles. *Per contra,* private investors and state institutions shall be provided with the opportunity to get relevant information about potentially favourable urban construction projects. This research contains information about indicators to be used to define alternatives, and to select the data processing methods.. The AHP determines the paramount criteria to gauge the level of influence of the needs of concerned groups. The most efficient alternative was selected with the help of the Additive Ratio Assessment (ARAS), the optimization based on ratio analysis (MOORA), and MOORA plus Full Multiplicative Form method (MULTIMOORA). Then the results produced by the methods were compared.

2. Identifying areas of project implementation and estimating evaluation criteria

The lifespan of buildings is composed of a series of interlocking processes, starting from the initial architectural and structural design, through to actual construction, followed by maintenance and control [8]. Vilnius and its surrounding landscape, its structure and panorama, are in constant transformation driven by continuous construction works and development projects. This change is especially propelled by new contemporary buildings constructed from modern materials [9].

In mid-2013 there were 95 neglected and unused buildings or buildings used for other than their original occupancy in Vilnius, according to the list presented by Vilnius City Municipality. As the national construction industry started to recover, the authorities made it their priority to increase the potential of urban spaces and, at the same time, to avoid expansion to suburbs. Investors also prefer to use urban spaces that are currently vacant by creating attractive construction projects for administrative, public, and residential buildings. Large portions of valuable space are occupied by old, abandoned buildings right in the heart of the city. Furthermore, Vilnius has quite a few decrepit former plants, abandoned residential houses, and unused commercial spaces in residential areas.

The number of unfinished construction projects in any city around the world can be estimated using unsophisticated assessment methods. The situation is no different for the city of Vilnius. Physical visual inspection of the city enabled selection of five major unfinished construction projects, the layout of which is shown in Figure 1. The photograph of the project is presented in Figure 2.

Generally, abandoned alternatives provide information on unfinished construction and opportunity to manage this information for the purposes of public safety. In this case, the authors have selected five major abandoned construction projects in Vilnius, the successful completion of which would provide maximum economic and social added value for the city. Estimated construction values and other statistical data have been evaluated by the authors.

Figure 1. Location of alternatives in Vilnius (*the city centre)

Figure 2. Alternative a_1

Table 1. Factors for the assessment of alternatives

Criterion	Description
x_1	Financial investment needed to buy the building in its current state [mil. EUR]
x_2	Financial investment needed to finish the building [mil. EUR]
x_3	Price per 1 m^2 in the respective district of Vilnius [EUR]
x_4	Rent at market prices per month per 1 m^2 in the respective district of Vilnius [EUR]
x_5	Travel time from the city centre by public transport during rush hour [h]
x_6	Number of flats for rent in the area [number]
x_7	Building's plot ratio [m^2]
x_8	Market value of the land plot [miliona EUR]
x_9	Available parking space for occupants [number]
x_{10}	Number of flats for sale in and around the district [number]

Take any city around the world and you see that its environment interacts with multiple stakeholder groups. Vilnius is no exception. Here the setting of interaction is closely related to governmental agencies, businesses, religious communities, investors, inhabitants, and visiting foreign tourists. The nature and civilisation are intertwined in close interaction, which must be maintained to secure the interests of both parties. To secure interests of multiple stakeholder groups, we need computational methods that make it possible to consider the contribution of each stakeholder group to the decision. To solve this problem, which is an integrated implementation of a construction project, the assessment criteria listed in Table 1 were selected.

To make our analysis, five unfinished construction projects - with only some part of the construction work finished - were selected as unfinished construction project alternatives. The assessment criterion x_1 considers how much the construction company taking over the construction project must invest into it. The amounts invested into the construction site by the previous builder can be assessed in two ways, i.e. that the investment project is on offer by a struggling legal entity or by a bankruptcy administrator in charge of the disposal of the assets of a bankrupt construction market participant, and looking to dispose of the available property for an adequate price. The mental benefits of this criterion can also be assessed in two ways: the lower the investment, the more chances there are to choose proper technology, to ensure high-quality work on the current structures, and to revise spatial and layout solutions; as the required investment grows, it instils an attitude that some completed structures are available and that this would permit rapid completion of the project. In the problem considered in this paper, the rational path based on the sustainable construction approach was selected: the smallest possible investment is sought with an aim to make a reasonable revision of the project's solutions by adopting modern technologies and taking heed of consumer needs.

The assessment criterion x_2 looks at basic estimated construction prices; it is used to determine how much additional investment is needed for this construction project. Construction estimates were made under assumption that all these buildings will be used for residential construction, the goal being to make a finished product with fully equipped interiors, main and individual plumbing fixtures, furniture, and so on - all the necessities that make flats ready for moving in.

The assessment criteria x_3, x_4, x_6 and x_{10} attempt to assess the relationship between the current property market and the planned construction project. The criteria were selected taking into account the situation on the property market in and around the district in question. The criteria seek to assess whether the construction product, once it is finished, will be attractive both in the property sales and rental markets. Obviously, the more attractive the product is to consumers, the sooner the construction project will pay off and deliver gains.

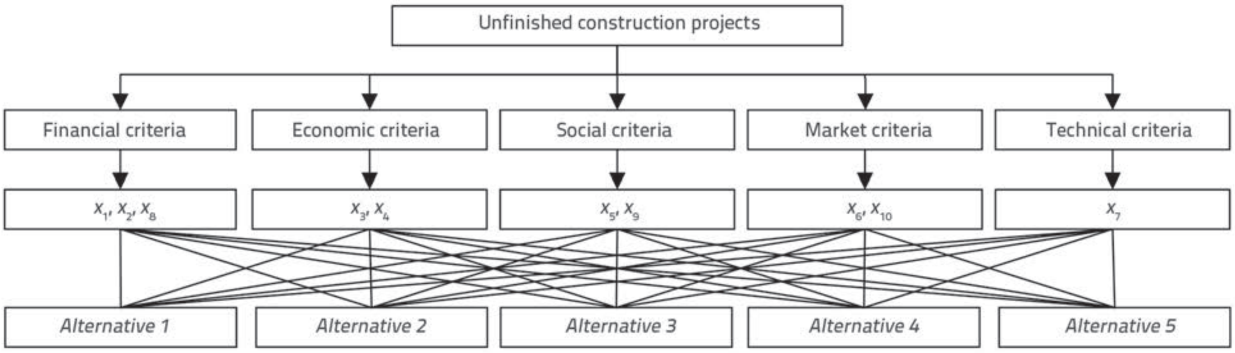

Figure 3. Structural hierarchy research model

The authors of this article made a minor investigation: they took public transport (buses and trolleybuses) to go to the alternatives in questions. The trip time (x_5) was estimated during the hours most relevant to people, i.e. between 7.30 and 8.00 a.m. and between 4.45 and 5.30 p.m. when most people in Lithuania go to or from work or school. The reference points for the trips were the routes between the construction projects and the heart of the Old Town.

The assessment criteria x_7 and x_8 determine the area occupied by the building, and the financial value of the corresponding land plot. In line with the principles of sustainable construction, green areas should dominate in urban landscapes; hence, in this case, the problem is formulated around a notion to have the building's plot ratio and the overall investment into the building's site as small as possible.

Vilnius, just as other densely populated and urbanised city, is faced with the parking problem in zones around residential buildings. Several factors contribute to this problem: abandoned cars left near houses, improving financial standing of inhabitants, growing families, and the need for families to have more than one car. The points scored by the surroundings of a construction object in the criterion x_9 assess future possibilities to park one's car near one's home. This criterion was assessed considering such factors as the building's environment, the area's plot ratio, the occupancy of other buildings, the possibilities to expand, and so on.

3. Determining weights of factors using the Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision making (MCDM) method that assists the decision-maker in solving a complex problem with multiple conflicting and subjective criteria (e.g. location or investment selection, project ranking, etc.) [10]. A popular twin comparison method called AHP, proposed by Saaty [11] and Saaty *et al.* [12], has been widely used for this purpose. Twin comparisons enable us to increase the compatibility of evaluations. The AHP solves problems based on three principles [13]:

1. structural hierarchy (current research model is presented in Figure 3);
2. twin comparison matrix;
3. weighting methodology.

The advantage of the AHP method over other multipurpose decision-making methods is its flexibility, convenience for decision makers, and the possibility to verify compatibilities [14]. The AHP method can assess both qualitative (subjective) and quantitative (objective) attributes of alternatives. The twin comparison methodology reduces partiality and bias in decision making. The AHP method uses relative values and is, hence, a suitable tool to deal with attributes of various dimensions. Traditional multi-criteria decision making methods evaluate all alternatives at a single level, which inadvertently restricts the simultaneous comparison of numerically heterogeneous alternatives [15]. The decision maker can specify preferences about the importance of each performance criteria in form of either natural language or numerical value [6].

In the real world, It is very difficult to extract accurate data pertaining to measurement factors since all human preferences are susceptible to a degree of uncertainty. Decision-makers are also inclined to favour natural language expressions over exact numbers when assessing criteria and alternatives [16].

The AHP method makes it possible to identify the weight (importance) of indicators at one level of hierarchy against a higher level, or the hierarchically non-structured weights of indicators. The essence of the method lies in the matrix of twin comparison [17].

Table 2. Twin comparison matrix of expert opinions

Expert$_i$ (i = 1 to 10)	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
x_1	1	1	3	5	4	5	4	3	4	5
x_2	1	1	3	4	5	4	5	3	4	6
x_3	1/3	1/3	1	2	4	3	3	1	3	2
x_4	1/5	1/4	1/2	1	4	3	4	2	4	1
x_5	1/4	1/5	1/4	1/4	1	2	3	1/4	2	1
x_6	1/5	1/4	1/3	1/3	1/2	1	3	1/8	2	2
x_7	1/4	1/5	1/3	1/4	1/3	1/3	1	1/4	3	2
x_8	1/3	1/3	1	1/2	4	8	4	1	5	4
x_9	1/4	1/4	1/3	1/4	1/2	1/2	1/3	1/5	1	2
x_{10}	1/5	1/6	1/2	1	1	1/2	1/2	1/4	1/2	1

Table 3. The sequence and results of eigenvector ω calculations

Calculation steps	Criteria									
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
Step I	ω''_1	ω''_2	ω''_3	ω''_4	ω''_5	ω''_6	ω''_7	ω''_8	ω''_9	ω''_{10}
Calculated elements aij of all Experts	$\omega_i'' = \prod_{j=1}^{10} a_{ij}$									
Each row multiplication	72.000.00	86,400.00	48.00	9.60	0.0094	0.0042	0.0007	142.22	0.0002	0.0005
Step II	ω'_1	ω'_2	ω'_3	ω'_4	ω'_5	ω'_6	ω'_7	ω'_8	ω'_9	ω'_{10}
n degree root is calculated from each row's calculated ω''_i (n = 10)	$\omega_i' = \sqrt[10]{\omega_i''} = \sqrt[10]{\prod_{j=1}^{10} a_{ij}}$									
10th degree root of all criteria multi-plications a_{ij}	3.060	3.116	1.473	1.254	0.627	0.578	0.483	1.642	0.421	0.470
Step III	ω_1	ω_2	ω_3	ω_4	ω_5	ω_6	ω_7	ω_8	ω_9	ω_{10}
Each element ω'_i is divided by the sum of all elements	$\omega_i = \dfrac{\sqrt[10]{\prod_{j=1}^{10} a_{ij}}}{\sum_{i=1}^{10} \sqrt[10]{\prod_{j=1}^{10} a_{ij}}}$									
Normalized ω_i values (eigenvector) of all criteria elements	0.233	0.237	0.112	0.096	0.048	0.044	0.037	0.125	0.032	0.036

Table 4. Matrix consistency and agreement of expert opinions

Calculation steps	Criteria									
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
Step IV	$\lambda'_{max.1}$	$\lambda'_{max.2}$	$\lambda'_{max.3}$	$\lambda'_{max.4}$	$\lambda'_{max.5}$	$\lambda'_{max.6}$	$\lambda'_{max.7}$	$\lambda'_{max.8}$	$\lambda'_{max.9}$	$\lambda'_{max.10}$
Calculated values of the highest eigenvalues λ_{max} of components	$\lambda'_{max,i} = \dfrac{\sum_{j=1}^{10} a_{ij}\omega_j}{\omega_i};\ \lambda_{max,i} = \dfrac{\sum_{j=1}^{10} \lambda'_{max,i}}{10}$									
The element of the column by the respective weight ω_i and the eigenvalue by each expert	10.846	10.57	10.577	11.974	11.22	11.487	11.759	11.479	11.417	11.487
Step V Matrix consistency	$S_i = \dfrac{S_I}{S_A} = \dfrac{\frac{\lambda_{max,i} - m}{m-1}}{1.49} = \dfrac{\frac{\lambda_{max,i} - 10}{10-1}}{1.49}$									
The values of a random consistency index, matrix order S_A	3	4	5	6	7	8	9	10	11	12
	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48
Consistency	$S_i = 0.096$									
The value is below 0.1, and so the matrix is consistent and experts' estimates are in agreement										

Inhabitants, potential investors, environment protection specialists, architects and construction companies, were all interviewed to determine the attitudes of concerned groups towards the construction project. Five representatives of the concerned groups acting in the interest of investors were interviewed. These assessments were chosen to take a look, as thorough as possible, at the opportunities offered by the current property market to efficiently complete the unfinished construction project under consideration. The representatives of the above groups assessed the factors (Table 2) on the Saaty [18] scale.

Table 2 shows a factor assessment example on a representative sample of inhabitants. In Table 3, the assessments of all representatives are used in calculations by applying the AHP method [17]. The output of these calculations makes it possible to determine the weight of factors, which will then be used to select one alternative.

Once the weight of factors is determined, the consistency of matrixes produced by specialists, and the concordance of their attitudes, can be further assessed. Inverse second-order symmetrical matrices are always consistent. The relationship between the calculated consistency index S_i of a particular matrix, and the average random index value S_A is referred to as the consistency relationship. The value of consistency index S that is smaller than or equal to 0.1 is acceptable, implying that the matrix is consistent [19] (Table 4).

4. Stating problem with MCDM methods

Several MCDM methods are used to solve this problem, namely the ARAS, MOORA, and MULTIMOORA. These three MCDM methods are used to determine whether the choice of a method affects the results. The selection of Multicriteria methods is based on the review of scientific literature presenting well-known methods applicable to solving problems analysed in the paper. It foresees the selection of methods enabling assessment of task data in terms of the opinion of parties concerned on the one hand, and elimination of subjectivity weights on the other.

The first solution method, foreseeing application of the assessment of human opinion factor, is based on the ARAS method. The criteria weights determined by the AHP method are used In data assessments using the ARAS method. The other method, involving application of MOORA and MULTIMOORA computation methods, eliminates the risk of subjectivity due to the omission of criteria weights assessment. These methods afford decision-maker the opportunity to compare results of both methods and make an appropriate decision.

4.1. Problem solving using Additive Ratio Assessment (ARAS) method

Each design product, construction product, or any other related product, can be described by multiple attributes, such as the project timescale, its micro or macro value in regional or national urban contexts, etc. To solve this problem and assess five alternative buildings, several criteria were selected, as shown in Table 1. Each of the five alternative unfinished buildings was assessed using the selected criteria, and the parameters of each criterion (listed in Table 5) were identified.

Table 5. Alternative indicators

Criteria	Alternatives				
	a_1	a_2	a_3	a_4	a_5
x_1	1,611	1,278	0,763	1,343	1,175
x_2	12,843	10,071	5,318	10,645	9,505
x_3	1,606	1,261	1,216	1,332	1,335
x_4	7,70	7,30	5,30	4,90	5,80
x_5	0,63	0,68	0,20	0,78	0,58
x_6	9	7	2	4	8
x_7	1,768	980	1,842	1,008	1,615
x_8	0,686	0,378	0,140	0,460	1,050
x_9	5	9	4	10	8
x_{10}	157	96	114	153	157

Table 6. Changed decision making matrix with criteria weights

Criteria	Criteria weight		Optimum	Alternatives					
				a_0	a_1	a_2	a_3	a_4	a_5
x_1	$\tilde{\omega}_1$	0.233	min.	1/0.763	1/1.611	1/1.278	1/0.763	1/1.343	1/1.175
x_2	$\tilde{\omega}_2$	0.237	min.	1/5.318	1/12.843	1/10.071	1/5.318	1/10.645	1/9.505
x_3	$\tilde{\omega}_3$	0.112	max.	1.606	1.606	1.261	1.216	1.332	1.335
x_4	$\tilde{\omega}_4$	0.096	maks.	7.7	7.7	7.3	5.3	4.9	5.8
x_5	$\tilde{\omega}_5$	0.048	min.	1/0.20	1/0.63	1/0.68	1/0.20	1/0.78	1/0.58
x_6	$\tilde{\omega}_6$	0.044	min.	1/2	1/9	1/7	1/2	1/4	1/8
x_7	$\tilde{\omega}_7$	0.037	min.	1/1.008	1/1.768	1/980	1/1.842	1/1.008	1/1.615
x_8	$\tilde{\omega}_8$	0.125	min.	1/0.140	1/0.686	1/0.378	1/0.140	1/0.460	1/1.050
x_9	$\tilde{\omega}_9$	0.032	max.	10	5	9	4	10	8
x_{10}	$\tilde{\omega}_{10}$	0.036	min.	1/96	1/157	1/96	1/114	1/153	1/157
Value of optimality function i-th alternative	$\tilde{S}_i = \sum_{j=1}^{10}\left(\left(\frac{x_{ij}}{\sum_{j=1}^{10} x_{ij}}\right)\cdot \omega_{\alpha,j}\right)$			0.247	0.12	0.144	0.226	0.133	0.13
Utility level	$K_i = \frac{S_i}{S_0}$			1	0.485	0.585	0.918	0.54	0.526

The five alternatives of unfinished construction projects are defined by different criteria values. It is therefore important to make an integrated assessment and determine which of the alternatives is the closest to the stance of the project developer and the developer's aim to finish and efficiently utilise the project in question. In most real-life situations, concise human judgements are vague and cannot be expressed in exact numerical values. Human thinking and actions deal with ill-structured decision problems in an uncertain environment. Human decision-making should take subjectivity into account [20].

The multiple criteria decision method ARAS is used to solve this problem. The ARAS method is based on the argument that the phenomena of complicated world can be understood by using simple relative comparisons [9]. It describes an alternative under consideration as a sum of the values of normalized and weighted criteria. These criteria describe the optimum alternative, and the level of optimality achieved by the alternatives that are being compared.

The descriptions of alternative factors listed in Table 5, and their weights given in Table 3, are used to solve the problem.

Weights describing factors of different dimensions, listed in Table 5, shall be standardised while solving the Multicriteria problem with the ARAS method. To standardise the dimensions, it is recommended to determine and calculate (if the factor is to be minimised) the maximisation and minimisation directions of the ARAS method. If criteria weights are expressed through the maximisation direction, the following formula is applied:

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \tag{1}$$

If criteria weights are expressed through the minimisation direction, the following calculation is needed:

$$x^*_{ij} = \frac{1}{x_{ij}}; \quad \bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \tag{2}$$

where:

m - number of alternatives

x_{ij} - matrix value *i* of alternative of *j* factor

x^*_{ij} - minimising value of factor a

$\bar{x}_{ij}$ - tandardised value of factor s.

When criteria weights are standardised then all weights, described within the first stage by different measurement dimensions, gain their equivalent values.

Table 7. MOORA method calculations

Calculation steps		a_i \ x_j	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
			Alternative indicator									
Step I	Alternatives	a_1	1.611	12.843	1.606	7.7	0.63	9	1.768	0.686	5	157
		a_2	1.278	10.071	1.261	7.3	0.68	7	980	0.378	9	96
		a_3	0.763	5.318	1.216	5.3	0.2	2	1.842	0.14	4	114
		a_4	1.343	10.645	1.332	4.9	0.78	4	1.008	0.46	10	153
		a_5	1.175	9.505	1.335	5.8	0.58	8	1.615	1.05	8	157
Step II Data normalisation $x_{ij^*} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}}$		a_1	0.57	0.575	0.529	0.547	0.464	0.615	0.001	0.492	0.296	0.006
		a_2	0.452	0.451	0.416	0.518	0.501	0.479	0.0003	0.271	0.532	0.004
		a_3	0.27	0.238	0.401	0.376	0.147	0.137	0.001	0.1	0.237	0.005
		a_4	0.475	0.477	0.439	0.348	0.574	0.273	0.0003	0.33	0.591	0.006
		a_5	0.416	0.426	0.44	0.412	0.427	0.547	0.001	0.752	0.473	0.006
		Way	min.	min.	max.	max.	min.	min.	min.	min.	max.	min.
Step III The ratio system RS		$y_j^* = \sum_{i01}^{i=3} x_{ij^*} - \sum_{i=g+1}^{i=7} x_{ij^*}$ y_2^*= (0.529+0.547+0.296)-(0.570+0.575+0.464+0.615+0.001+0.492+0.006) = -1.351										
		y_2^*= -0.691; y_3^*= -0.116; y_4^*= -0.758; y_5^*= -1.250										
		RS rank:	$a_3 \succ a_2 \succ a_4 \succ a_5 \succ a_1$									
Step IV The reference point (RP)		$\underset{(j)}{Min}\left\{\underset{(i)}{\max}\left\|r_i - x_{ij^*}\right\|\right\}$										
		r1	0.27	0.238	0.529	0.547	0.147	0.137	0.0003	0.1	0.591	0.004
			a_1 = 0.479	a_2 = 0.353	a_3 = 0.355	a_4 = 0.427	a_5 = 0.652					
		RS rank:	$a_3 \succ a_2 \succ a_4 \succ a_5 \succ a_1$									

Taking into account the calculation process, the optimality function $\tilde{S}_i$ (Table 6) has a direct and proportional relationship with the values x_{ij} and weights $\tilde{\varpi}_j$ iof the investigated criteria and their relative influence on the final result. Hence, the greater the value of the optimality function $\tilde{S}_i$, the more effective is the alternative. The alternatives can be ranked by priority based on the value S_i. Consequently, this method is a convenient tool to evaluate and rank alternative decisions [20].

This solution shows that the alternatives can be ranked as follows:

$$a_3 \succ a_2 \succ a_4 \succ a_5 \succ a_1$$

The combined use of AHP and ARAS shows that the most suitable project is the alternative a_3.

4.2. Problem solving using MOORA method

Brauers and Zavadskas [21] proposed the MOORA method. The MOORA method begins with the matrix X where its elements x_{ij} denote the i-th alternative of the j-th objective (i = 1,2,...,m and j = 1,2,...,n). The second stage of the problem solving foresees standardisation of all outcoming data expressed in different units of measurement as non-dimensional values. The MOORA method consists of two parts: the Ratio System and the Reference Point approach [22]. Based on the data given in Table 5, Table 7 shows the MOORA method principles of calculation and the corresponding results.

4.3. Problem solving using MULTIMOORA method

The MULTIMOORA is composed of the MOORA and of the Full Multiplicative Form of Multiple Objectives. Brauers and Zavadskas [23] proposed an update to MOORA by adding the Full Multiplicative Form method, which encompasses both maximization and minimization of a purely multiplicative utility function. Calculations according to the MULTIMOORA method are made based on the data given in Table 5. The overall utility of the i-th alternative can be expressed as a dimensionless number:

$$U_i' = \frac{A_i}{B_i} \tag{3}$$

where:

$A_i = \prod_{j=1}^{g} x_{ij}$, i = 1,2,. . . ,m - denotes the product of objectives of the i-th alternative to be maximized with g = 1,. . . ,n as the number of objectives to be maximized

$B_i = \prod_{j=g+1}^{n} x_{ij}$ - denotes the product of objectives of the i-th alternative to be minimized with n - g as the number of objectives (indicators) to be minimized.

The overall utilities (U_i), obtained by multiplication of different units of measurement, become dimensionless.

$$U_1' = \frac{1606 \times 7{,}7 \times 5}{1{,}611 \times 12{,}843 \times 0{,}63 \times 9 \times 1{,}68 \times 0{,}686 \times 157} = \frac{61831}{22338351} = 0{,}003$$

$U'_2 = 0{,}038$; $U'_3 = 0{,}540$; $U'_4 = 0{,}0021$; $U'_5 = 0{,}004$;

The full multiplicative form solution shows that the alternatives can be ranked as follows:

$$a_3 \succ a_2 \succ a_4 \succ a_5 \succ a_1.$$

4.4. Assessment of end results

An overall analysis of the results (Table 8) produced by three calculation methods ARAS, MOORA, and MULTIMOORA, shows that, taking into account the current situation in the property market, the most efficient choice for private investors would be to invest into and complete the unfinished construction project designated as the alternative a_3.

Table 8. MCDM ranking

Alternatives	ARAS method rank	MULTIMOORA				
		MOORA		Full multiplicative form	Ranking sum	Final rank
		Ratio system	Reference point			
a_1	5	5	4	5	14	5
a_2	2	2	1	2	5	2
a_3	1	1	2	1	4	1
a_4	3	3	3	3	9	3
a_5	4	4	5	4	13	4

This alternative is located in the southern part of Vilnius, at the boundary separating two districts. The alternative is situated in an attractive neighbourhood, i.e. in a part of the city with recently built bypasses and arterial roads leading to the city centre. This part of the city includes both blocks of flats and minor industrial facilities. In addition to traditional trends of blocks of flats dominating the area, residential lofts are also emerging. Taking into account solutions available for this construction project, this alternative is an attractive residential property for middle-income city dwellers. The most unfavourable alternative a_1 is located in a new residential district currently under construction. New problems related to the disposition of newly constructed apartments, and efficient use of implemented projects, could be faced after completion of individual construction projects.

The application of AHP + ARAS and MOORA + MULTIMOORA methods to find the solution and take into account time costs and efforts made, has shown that MOORA and MULTIMOORA methods require less efforts and experience for achieving the result. So far, no other known approach satisfies all the conditions of robustness and includes three or more methods. Thus MULTIMOORA becomes the most robust system for multiple objectives optimization. The MULTIMOORA method includes internal normalization and originally treats all objectives as equally important. In principle, all stakeholders interested in an issue can place a greater emphasis on a certain objective. They can, therefore, either multiply a dimensionless number representing the response to an objective by a significance coefficient, or they can decide beforehand to split an objective into several subobjectives [24].

5. Conclusion

When it comes to making the right decision, it is important, in any life situation, to consider all available information that may prove helpful for achieving the goal. In case of unfinished construction projects, we must also take note of the available information, and rate the success of our intended project as clearly as possible, in order to avoid risky decisions. This paper introduces a computing model for assessing the information and criteria that describe projects. Problems faced within a particular sphere of construction, and related to efficient implementation of projects and efficient implementation of abandoned construction projects, are relevant for the construction market of Lithuania, although the decision-making methods described herein could well be adapted to local circumstances and used for assessment of construction facilities in other countries.

Naturally, we considered only some of the wide array of possible criteria that cover design, construction and maintenance. However, the complete implementation cycle of a construction project should be described by a much greater number of criteria, with an in-depth analysis at each area of the construction process or technology. A project engages various social groups, and their interests have to be restricted, to ensure that the project is successful. Consequently, the most rational solutions can be obtained by applying scientific methods that take into account and evaluate large volumes of information.

Out of numerous MCDM methods available around the world, the complex AHP and ARAS, MOORA and MULTIMOORA methods were applied in the paper to find the solution and determine the most suitable alternative. Expert estimations were weighted using the AHP method. The ARAS, MOORA and MULTIMOORA methods were applied to determine the most suitable alternative.

Calculations based on these methods revealed that, in the current market situation, construction companies should choose the construction project alternative a_3 for their investment project. It is an unfinished block of flats abandoned during the construction crisis. The potential of this alternative lies in the fact that it is a residential building close to the Old Town, next to new high-capacity urban roads, while also being located in a strategically attractive urban area.

REFERENCES

[1] Kang, H. H., Liu, Sh. B.: The impact of the 2008 financial crisis on housing prices in China and Taiwan: A quantile regression analysis, *Economic Modelling,* 42, pp. 356–362, 2014., doi: http://dx.doi.org/10.1016/j.econmod.2014.07.018

[2] Auerbach, A. J., Gale, W. G., Harris, B.H.: Activist Fiscal Policy, *Journal of Economic Perspectives*, 24(4), pp. 141-163, 2010., doi: http://dx.doi.org/10.1257/jep.24.4.141

[3] Hall, R.E.: Why Does the Economy Fall to Pieces after a Financial Crisis?, *Journal of Economic Perspectives*, 24(4), pp. 3–20, 2010., doi: http://dx.doi.org/10.1257/jep.24.4.3

[4] Mishkin, F.S.: Over the Cliff: From the Subprime to the Global Financial Crisis, *Journal of Economic Perspectives,* 25(1), pp. 49-70, 2011., doi: http://dx.doi.org/10.1257/jep.25.1.49

[5] Angelopoulou, E., Balfoussia, H., Gibson, H. D.: Building a financial conditions index for the euro area and selected euro area countries: What does it tell us about the crisis?, *Economic Modelling,* 38, pp. 392–403, 2014., doi: http://dx.doi.org/10.1016/j.econmod.2014.01.013

[6] Taylan, O., Bafail, A. O., Abdulaal, R., Kabli, M. R.: Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies, *Applied Soft Computing,* 17, pp. 105–116, 2014., doi: http://dx.doi.org/10.1016/j.asoc.2014.01.003

[7] Kaklauskas, A., Kelpšienė, L., Zavadskas, E. K., Bardauskienė, D., Kaklauskas, G., Urbonas, M., Sorakas, V.: Crisis management in construction and real estate: Conceptual modeling at the micro-, meso- and macro-levels, *Land Use Policy,* 28, pp. 280–293, 2011., doi: http://dx.doi.org/10.1016/j.asoc.2014.01.003

[8] Kahraman, C., Kaya, T.: A fuzzy multiple atribute utility model for intelligent building assessment, *Journal of Civil Engineering and Management*, 18(6), pp. 811–820, 2012.

[9] Kutut, V., Zavadskas, E. K., Lazauskas, M.: Assessment of priority alternatives for preservation of historic buildings using model based on ARAS and AHP methods, *Archives of Civil and Mechanical Engineering,* 14(2), pp. 287-294, 2014., doi: http://dx.doi.org/10.1016/j.acme.2013.10.007

[10] Ishizaka, A., Labib, A.: Review of the main developments of the analytic hierarchy process, *Expert Systems with Applications*, 38(11), pp. 14336-14345, 2011., doi: http://dx.doi.org/10.1016/j.eswa.2011.04.143

[11] Saaty, T. L.: Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process. 1st edition. RWS Publications, pp. 477 p, 2000.

[12] Saaty, T. L., Vargas, L. G., Dellmann, K.: The allocation of intangible resources: the analytic hierarchy process and linear programming, *Socio-Economic Planning Sciences,* 37(3), pp. 169–184, 2003., doi: http://dx.doi.org/10.1016/S0038-0121(02)00039-3

[13] Aydogan, E. K.: Performance measurement model for Turkish aviation firms using the rough–AHP and TOPSIS methods under fuzzy environment, *Expert Systems With Applications*, 38, pp. 3992–3998, 2011., doi: http://dx.doi.org/10.1016/j.eswa.2010.09.060

[14] Ramanathan, R.: A note on the use of the analytic hierarchy process for environmental impact assessment, *Journal of Environmental Management*, 63, pp. 27–35, 2001., doi: http://dx.doi.org/10.1006/jema.2001.0455

[15] Saaty, T. L., Shang, J. S.: An innovative orders-of-magnitude approach to AHP-based mutli-criteria decision making: Prioritizing divergent intangible humane act, *European Journal of Operational Research*, 214(3), pp. 703-715, 2011., dopi: http://dx.doi.org/10.1016/j.ejor.2011.05.019

[16] Heo, E., Kim, J., Boo, K. J.: Analysis of the assessment factors for renewable energy dissemination program evaluation using fuzzy AHP, *Renewable and Sustainable Energy Reviews*, 14(8), pp. 2214–2220, 2010., doi: http://dx.doi.org/10.1016/j.rser.2010.01.020

[17] Sivilevičius, H.: Modelling the interaction of transport system elements, *Transport*, pp. 26(1), pp. 20–34, 2011.

[18] Saaty, T.L.: *The Analytic Hierarchy Process*, McGraw-Hill, New York, 1980.

[19] Podvezko, V.: Application of the AHP technique, *Journal of Business Economics and Management*, 10(2), pp. 181–189, 2009., doi: http://dx.doi.org/10.3846/1611-1699.2009.10.181-189

[20] Turskis, Z., Lazauskas, M., Zavadskas, E. K.: Fuzzy Multiple Criteria Assessment of Construction Site Alternatives for Non-Hazardous Waste Incineration Plant in Vilnius City, Applying ARAS-F and AHP Methods, *Journal of Environmental Engineering and Landscape Management*, 20(2), pp. 110-120, 2012., doi: http://dx.doi.org/10.3846/16486897.2011.645827

[21] Brauers, W.K.M., Zavadskas, E.K.: The MOORA method and its application to privatization in a transition economy, *Control and Cybernetics,* 35(2), pp. 445–469, 2006.

[22] Brauers, W.K.M., Zavadskas, E.K., Peldschus, F., Turskis, Z.: Multi–objective decision–making for road design, *Transport,* 23(3), pp. 183–193, 2008., doi: http://dx.doi.org/10.3846/1648-4142.2008.23.183-193

[23] Brauers, W.K.M., Zavadskas, E.K.: Project management by MULTIMOORA as an instrument for transition economies, *Technological and Economic Development of Economy,* 16(1), pp. 5–24, 2010. , doi: http://dx.doi.org/10.3846/tede.2010.01

[24] Baležentis, T., Zeng, Sh.: Group multi-criteria decision making based upon interval-valued fuzzy numbers: An extension of the MULTIMOORA method, *Expert Systems with Applications*, 40, pp. 543–550, 2013., doi: http://dx.doi.org/10.1016/j.eswa.2012.07.066