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CHANGES AND ACHIEVEMENTS IN *CM* RESEARCH AND *CM* EDUCATION AT THE POZNAŃ UNIVERSITY OF TECHNOLOGY

O. Kapliński

Poznań University of Technology

1. Introduction

This paper presents some changes and achievements of the Chair of Construction Engineering and Management at the Poznań University of Technology in the fields of education and research between the 6th (Vilnius '97, May) and the 7th (Aachen '99, September) Lithuanian-German-Polish Colloquiums. The first part of the paper describes a specific character and conditions of university training in Poland. Furthermore, some factors influencing academic curriculum planning are discussed. A review of the research is described in the context of writing PhD dissertations.

2. Factors influencing academic curriculum planning and research

There are many factors influencing education and research. The period after our recent meeting in Vilnius (May, 1997) is characteristic: the same tendency has been strengthened. Political and economic transformation which is still under way in Poland has made a number of possibilities available to the Polish people, and laid the foundations of market economy. Also we have seen crucial influence exerted on the ways and directions in education.

An exceptionally fast accommodation of the Polish society to those changes was caused by a beneficial structure of the education system. Table 1 presents a percentage share in education in the selected areas of studies. It is quite clear that Poland had been prepared

Table 1. Students of the Universities according to branches of study [1]

Selected country	Year	Agriculture	Technical sciences	Juridical and social sciences	Humanities	Exact and natural sciences	Medicine
POLAND	1980	27.3	11.0	25.2	5.4	3.4	10.6
	1985	19.4	7.9	21.3	8.5	4.4	13.5
	1991	17.1	5.6	24.9	9.5	4.5	14.5
	1993/4	18.8	5.4	32.1	10.9	4.3	10.2
CANADA	1980	8.7	2.0	28.2	13.3	5.7	7.2
	1991	10.0	1.1	21.2	5.3	4.5	5.2
GERMAN FR	1980	15.0	3.0	26.7	13.8	11.2	15.1
	1990	19.4	2.5	29.1	12.3	12.9	11.0
USSR	1980	45.6	10.2	7.2	*	*	*
	1990	40.9	10.1	6.6	14.5	(97.9)	
UKRAINE	1980	48.2	9.8	8.[8a]	*	*	6.8
	1991/2	42.1	10.4	7.4[a]	13.7	*	7.0

[a] together with exact and natural sciences

Table 2. A comparison of the ratio of student numbers per 10 000 inhabitants

Country	Year	Ratio	Country	Year	Ratio
Poland	80	166	USA	80	531
	85	122		93	555
	90	142	Canada	92	709!
	93	195	China	80	17
				93	38
Lithuania	80	288	Germany	90	258
	90	243		93	232
	92	205	France	81	212
	93	190		92	172
	94	191		93	362

for the reform, because the structure of education (Law, Economy) was keeping pace with the trends of the best developed countries. In other countries, educating engineers has been driven to extremes.

It does not signify, though, that the number of university graduates is satisfactory. The numbers of students per ten thousand inhabitants constitutes an objective ratio depicting the situation reasonably well. Selected results are presented in Table 2.

For us, comparing those ratios signifies a requirement of making up for the shortcomings presented above. We can see an increase in the number of students, and opening a number of new colleges (mainly privately run). It has also been agreed that international universities can be established in Poland.

One can look at the change in numbers of students in Poland with a dose of optimism (Fig 1).

The number of privately run universities and colleges has increased from 20 (in 1990) to 144 (in 1998/99). These academic institutions provide mostly courses leading to BSc degree, and the most important areas of study are banking, management, and marketing.

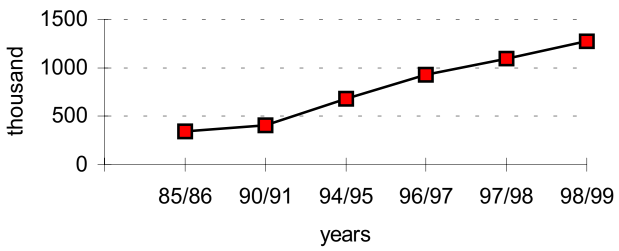

Fig 1. The change in number of students in Poland

In 1986-88, we experienced a deep economic and political crisis. It was reflected by the reluctance among young people to obtain academic qualifications. For example, at the Poznań University of Technology, the number of students was changing according to the following pattern: in 1978 – 8320, in 1986-88 – only 3800-3877 (!), in 1997-98 – 11036-12413, among them 67% studying for MSc degree and 33% for Engineering degree.

At present, we have 2.851 students at the Faculty of Architecture[1], Civil and Environmental Engineering.

Further discussion is illustrated by Fig 2 presenting a number of factors influencing the current situation at Polish universities, and the formation of study programmes. Here is the list of the most popular study courses in Poland:

– Economy,
– Law,
– Management and Marketing.

The most popular faculties at the Poznań University of Technology now:

• Information Technology (Electrical Engineering Faculty),

• Architecture (Architecture, Civil and Environmental Engineering Faculty),

• Management and Marketing (Mechanical Engineering Faculty),

[1] This autumn the branch of study called “Architecture” and the Institute of Architecture and Urban Planning will become a separate faculty.

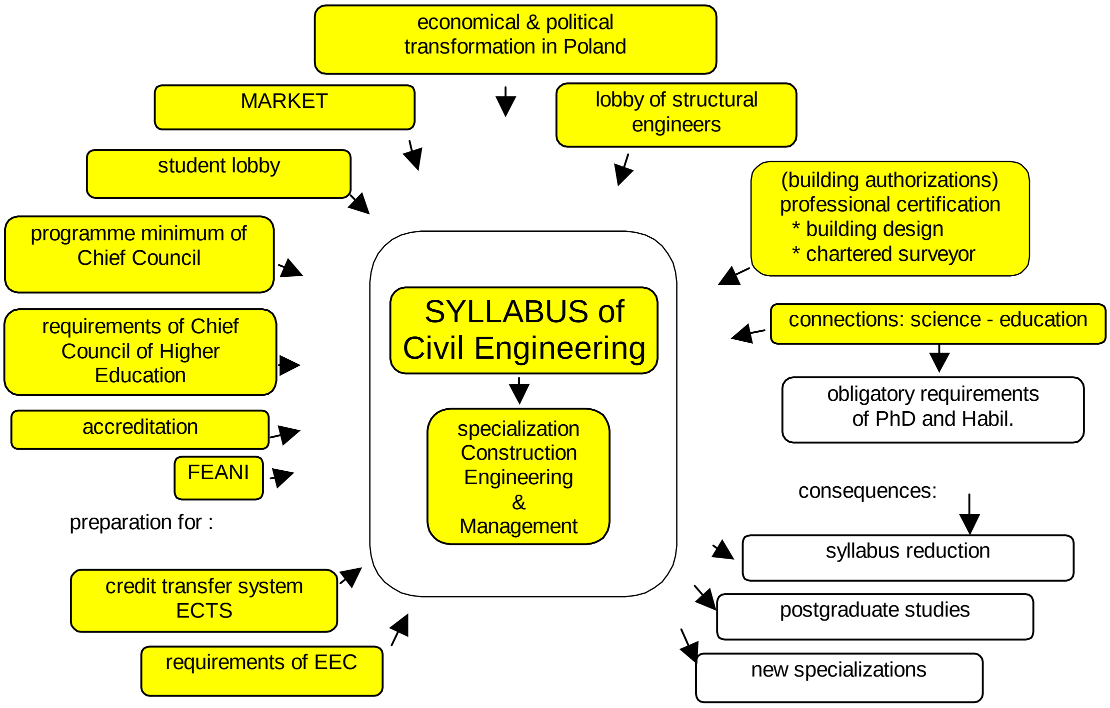

Fig 2. Factors influencing curriculum planning at Poznań University of Technology

- Electronics and Telecommunications (Electrical Engineering Faculty).

The students (and their application forms) exert a certain pressure not only on founding new universities and colleges, but also on the modification of curricula, establishing new courses (for example, MSc courses).

There is a lobby of constructors (to be more precise, construction theory specialists) which often constitutes a voting majority in bodies taking crucial decisions at chairs and faculties. It often exerts a negative influence on the freedom of designing new curricula, especially in management and economics.

Two other factors have to be taken into account when planning curricula:

- the requirements of the Chief Council of Higher Education,
- the Parliamentary Act on Building and Construction Law, including professional qualification certificates.

Two categories of requirements of the Council should be referred to here.

The so-called programme minimum has been laid down. It assumes that the total number of class hours during a study course cannot be less than 2600. The programme minimum includes 1500 hours, and entails three categories of courses:

A – non-technical courses	300 hours
B – basic courses	450 hours
C – technical courses	750 hours

Eleven courses belong to the group of technical courses, including Construction Engineering and Management and Organisation - 75 hours. Further on, universities may form their curricula depending on their specific character, specialisation, and degree profiles. Obviously, while designing detailed curricula, one should make sure that they correspond to the directions of accreditation and the branch of study set out by the European FEANI Association.

Another important condition set out by the Council is the minimum number of autonomous academic teachers and researchers required for establishing a branch of studies. Therefore, for the MSc courses: at least 8 Full Professors or academics with post-doctoral degrees. For the BSc courses: 4 Full Professors or academics with post-doctoral degrees, and six teachers with PhD. It is usually a major limitation for smaller and younger universities.

For Construction Engineering (CE) graduates, acquiring professional certificates is a basic requirement before they can start their independent engineering work. Graduates of the CE Faculty can acquire professional certificates in Buildings Design or in Construction Supervision.

The professional certificates, after the candidates have gone through a period of internship and training, and passed their exams, are granted by local administration authorities. Therefore, the curricula (and specialisations in particular) cannot be randomly created. We had seen a failed attempt of establishing a specialisation called "Computer Mechanics".

In order to understand the mechanisms working behind a typical Polish state-owned university, an additional aspect has to be taken into account. There is a requirement stating that research results should filter into teaching. Therefore, in Poland, obtaining a PhD degree is obligatory. Recently a requirement of obtaining a post-doctoral degree has also been introduced. The idea behind it is that such a university would rank higher, but academics are mostly assessed according to their research results and achievements (for example, a number of publications) and, to a much smaller degree, for their didactic achievements.

The implementation of two major projects is currently under way in Poland. The first is the so-called accreditation of departments and faculties and branches of studies. It is aimed at the assessment of teaching level and classification of faculties and departments according to four categories. It is assumed that the Poznań University of Technology will be placed in one of the top categories. Younger universities, without experienced staff, are going to lose.

The other project is the preparation for implementing European Credit Transfer System, the ECTS. It is particularly important for student exchange, but it is also dictated by the requirements of Polish application for the accession to the European Community.

Due to the fact that curricula at the Poznań University of Technology, at the Faculty of Architecture, Civil and Environment Engineering are developed as blocks of courses constituting basic components of programmes for various specialisations, it is going to be relatively easy to implement the credit transfer system. Examples of some blocks are presented in [1].

It is difficult to discuss education without mentioning money and funding. It might be well worth

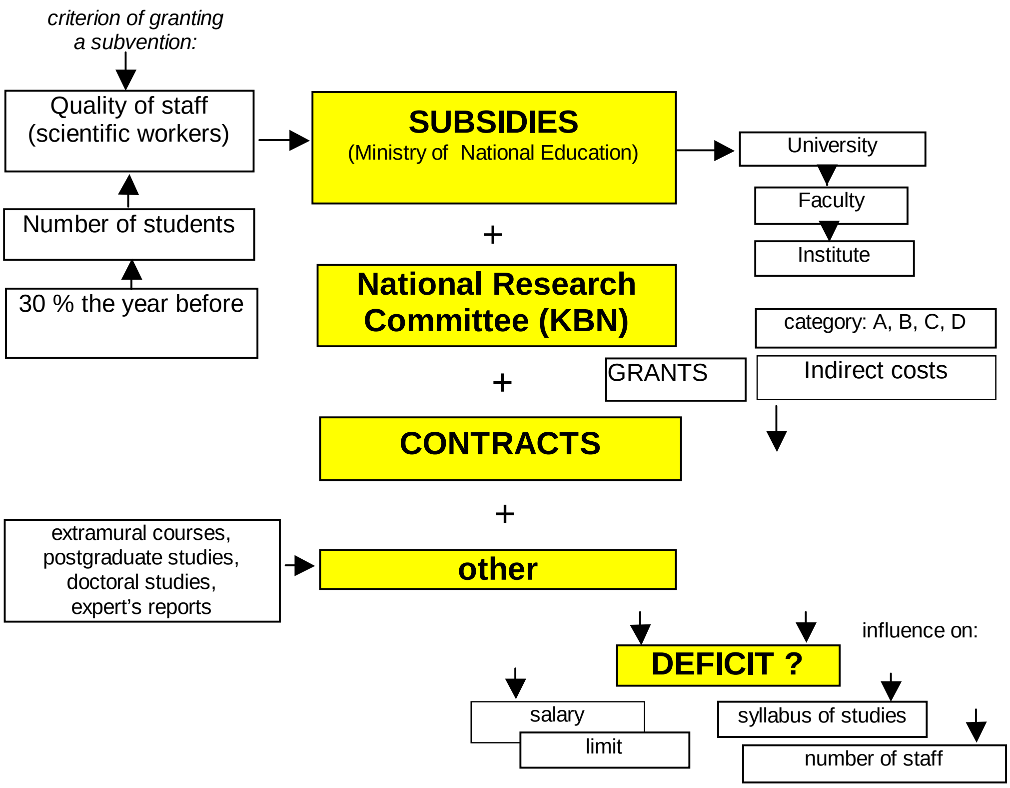

Fig 3. Algorithm of research and education financing at the University

quoting data from two years ago, related to research and implementation spending per capita in various countries: USA – 659 USD, Germany – 459 USD, Poland – 41 USD.

The percentages of the Gross National Product were accordingly 2.72; 2.50; 0.84. It forces the universities to accommodate their academic curricula to the conditions of real life. It does not provide much motivation for implementing difficult reforms.

Governmental Universities in Poland live mainly on the subsidies from the Ministry of Education. Fig 3 presents a way the financial algorithm of the Ministry of Education operates, and the procedures of generating funds by the institutes and chairs of various faculties. This also influences the economic position of faculties, as well as the formation of academic curricula. Namely, a subsidy is envisaged to be a source funding of a branch of study. Consequently, establishing numerous (and new) specialisations is very costly. It is most "beneficial" to teach all seminars and classes within one group of students. It results from the simulations we have made that at the CE faculties (assuming the cost consumption rate to be 2.5) a model structure (in other words, the proportions between various academic activities) is as follows: lectures 1, classes and exercises 0.4, laboratory classes 0.25, project work 0.5.

According to the author, the principles of the Ministry of Education algorithm may stand in a certain contradiction with the system of studying based on credits, in other words, according to the system of taking individual paths in the course of studies.

3. An overview of the situation in Construction Engineering and Management specialisation and post-graduate studies

A course in Construction Engineering (CE) and Management is offered by 19 technical universities in Poland. All those universities work along the lines of a curriculum embracing CE. It can be best seen on the example of a separate specialisation which, depending on a university, has recently been given different names[2]. At the Technical University of Poznań it bears the traditional name of Construction Engineering and Management (CE&M). At some universities this specialisation is also offered as an extramural course (but on the BSc level).

Extramural students in Poznań can only specialise in structural engineering but it is interesting that the graduates inquire about starting a MSc course namely in the field of CE&M!

The CE&M Chair which is an integral part of the Architecture, Civil and Environment Engineering Faculty runs classes, first of all, in CE&M itself.

In the process of adapting to the Ministry of Education algorithm, we have begun some serious reductions in curricula of the study courses.

At the time, the total number of hours of courses (excluding the length of time devoted to research towards MSc dissertation) was 3.900. The new curriculum embraces 3.315 hours. The percentage share of the three groups of subjects is as follows:

- general subjects 15,84%
- foundation subjects 51,88%
- specialist subjects 32,58%

Despite the reduction in the total amount of hours, the number of specialist hours increased from 960 to 1080.

The CM (construction management) problems are also dealt with at our Faculty within the framework of a 3.5 year studies in Engineering, initiated in 1992, within the TEMPUS JEP3757 programme.

The CE&M Chair co-operated with the Wielkopolska Chamber of Construction which, within the framework of the PHARE Fund, ran an extramural Master course in Construction Management during 1997/98.

We also participate in teaching of MSc course for the engineering graduates.

The CE&M staff fully participates in teaching at the postgraduate (two-semester) course in Valuation of Real Estate (established in 1997)[3]. The course is run on a fee basis. It is taught by our staff, as well as by the academic staff from other universities (the University of Agriculture and the School of Economics) and by the Ministry lecturers and experts employed in real life construction companies. At present, the third

[2] For example, at the Warsaw University of Technology: Engineering of Building Processes.

[3] A manager: Prof A. Skarzynski [2].

consecutive recruitment is about to end. The numbers of graduates were as follows: 36, 52 and 54. Such courses are taught in many academic centres throughout the country.

We are offering another course of studies, though touching upon similar problems: Real Estate Management and Trading. It will also be a two-semester course. It is aimed at training prospective real estate managers and real estate agents trading in property. The Parliamentary Act obliges all applicants who want to obtain professional licences in "Real Estate Management" and "Real Estate Trading" to join and graduate such an academic course.[4]

4. Research: problems and scope

Research at the Chair of CE&M is carried out (and subsidised) mainly within the frameworks of grants (statutory – DS and University – BW). The mechanisms and influences of this kind of funding were presented during the last Vilnius Colloquium[5].

Recently, the scope of research has grown, and it is particularly evident in such areas as: macro-organisation, management, law, investment process, problems of restructuring in building and developing companies. The following publications may serve as a good example [3–6].

The following phenomenon is to be observed: those problem areas are the result of a demand from construction practice, nevertheless the Research Councils at the Civil and Construction Engineering Departments do not look at all favourably into the question of presenting PhD dissertations regarding the areas.

Another, quite a new trend in research, closely related to the subject area of the post-graduate courses mentioned above, is the domain of real estate valuation and management. We have already seen the first publications [7–9].

Traditionally, the strongest trend in research is modelling and organisation of construction processes, including the application of computers and artificial intelligence. The survey of all those problems, a synthesis of the research, and guidelines – also for prospective PhD students – have been presented in a monograph publication entitled *"Modelling of construction processes. A managerial approach"* [10].[6]

Dissertations

Two PhD dissertations have recently been presented at the Chair of CE&M. The abstracts and some characteristic elements are given below.

a) ***Methodological aspects of multicriteria decision aid in civil and construction engineering***.[7]

This dissertation is a discussion of some chosen issues and theoretical basis included in the methodological and cognitive part of the research, as well as a presentation of a system of ideas related to the methodology of multicriteria decision aid. A review of multicriteria decision aid methods has been carried out, and the author's own classification of this group of methods has been offered. The examples to date of usage of those methods have also been quoted, relating both to Polish and foreign civil and construction engineering. The concept of multicriteria decision aid has been accepted as a method of solving the selected decision-making problems, as well as the appropriate calculation and computation methods have been selected and duly justified.

Three multicriteria decision problems have been presented and discussed in the research section. The problems pertained to selecting an appropriate order and making a final assessment for a number of options regarding types of floors between storeys multi-layer external main walls in family type housing, and electrostatic flooring in an industrial building. Tests have been performed, related to the assessment of acceptance of multicriteria decision aid as a method for solving the selected problems. A sensitivity range has been defined for the selected methods, and such an analysis for a chosen method has been performed – the ELECTRE III method. A procedure has been proposed to

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[4] This course is organised by Dr D. Pawlicki.

[5] The allocation of funds for the following year depends, among other factors, on the number of publications in the previous year.

[6] Prof O. Kapliński's book was awarded a special award in the Building and Construction Department 1998 competition at the Ministry of Administration and the Interior.

[7] The dissertation was written by Dr T. Thiel [11–12]. It was submitted in 1997. In 1998 the dissertation was granted an award in the Building and Construction Department competition at the Ministry of Administration and the Interior.

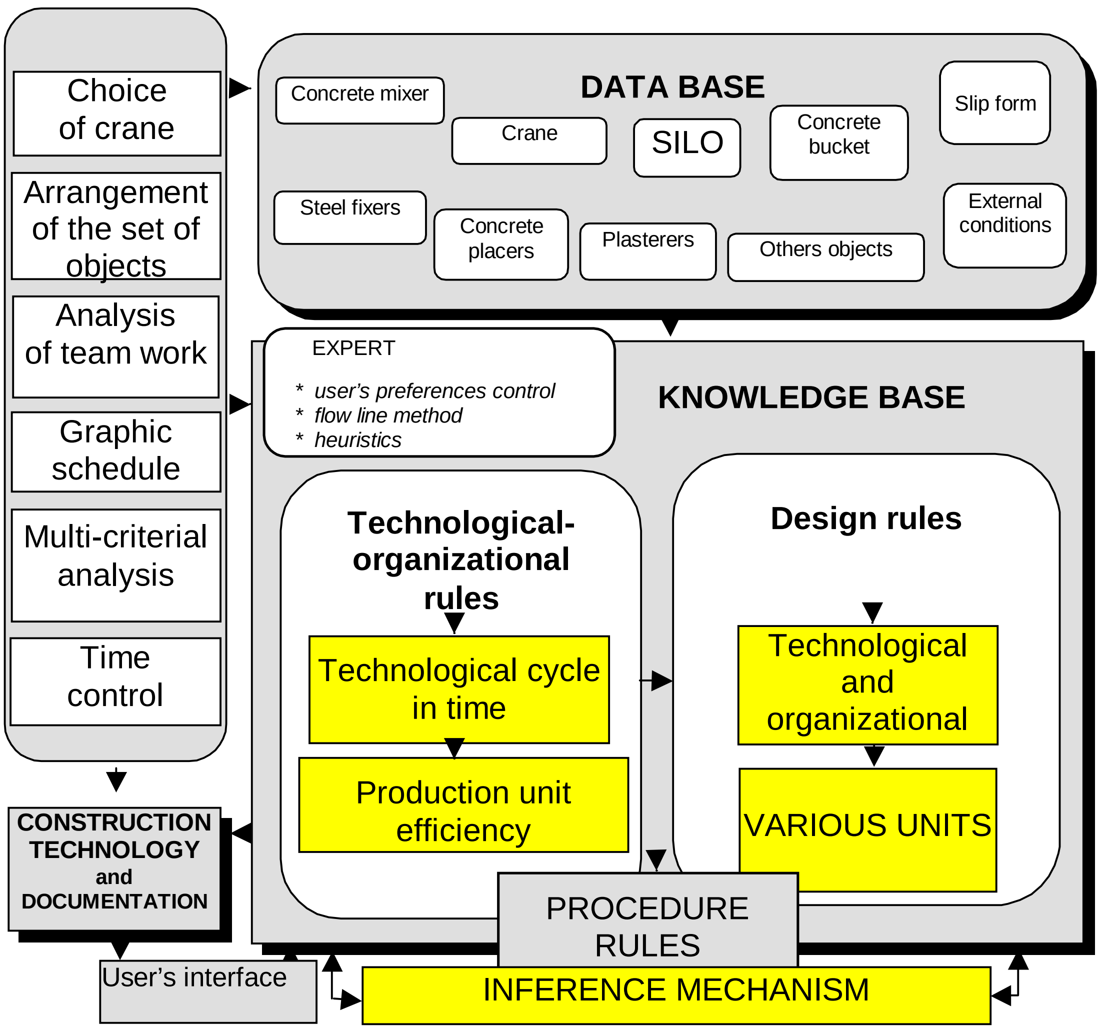

Fig 4. A general architecture of the expert system for construction design of monolithic silos

ensure the appropriate development of the process of assisting decision-making, and this procedure has been used to solve the selected decision-making problems.

b) ***Rule-based knowledge in the system supporting the design for building grain silos erected by the slip method.***[8]

The dissertation presents an expert system controlled by user's references, supporting the design for building grain silos erected by the slip method. The system is used in monolithic technologies (c.f. [13–17]).

The problem consists in such an arrangement of resources that will enable engineers to erect silo walls at a determined rate. The task takes into account the following factors: concrete casting time, external conditions, the dynamic character of the construction process (the structure grows with time). The objects, in this case a slip form, silo batteries, cranes, concrete mixers and teams of workers, form a complex system. The purpose of the expert system is to determine the set of objects that may provide the optimum value with respect to many criteria, and therefore a multicriterial analysis is called upon.

A general architecture of the expert system in question is presented in Fig 4. Within the expert system, we may distinguish the following units: database, knowledge base, inference engine, a user interface. A rule of knowledge representation has been chosen. Due to the specific character of the domain, two kinds of rules are now distinguished: microrules, which describe

[8] The dissertation was written by Dr M. Hajdasz. It was submitted in December 1999. The dissertation has been granted a special nomination by the Department Council.

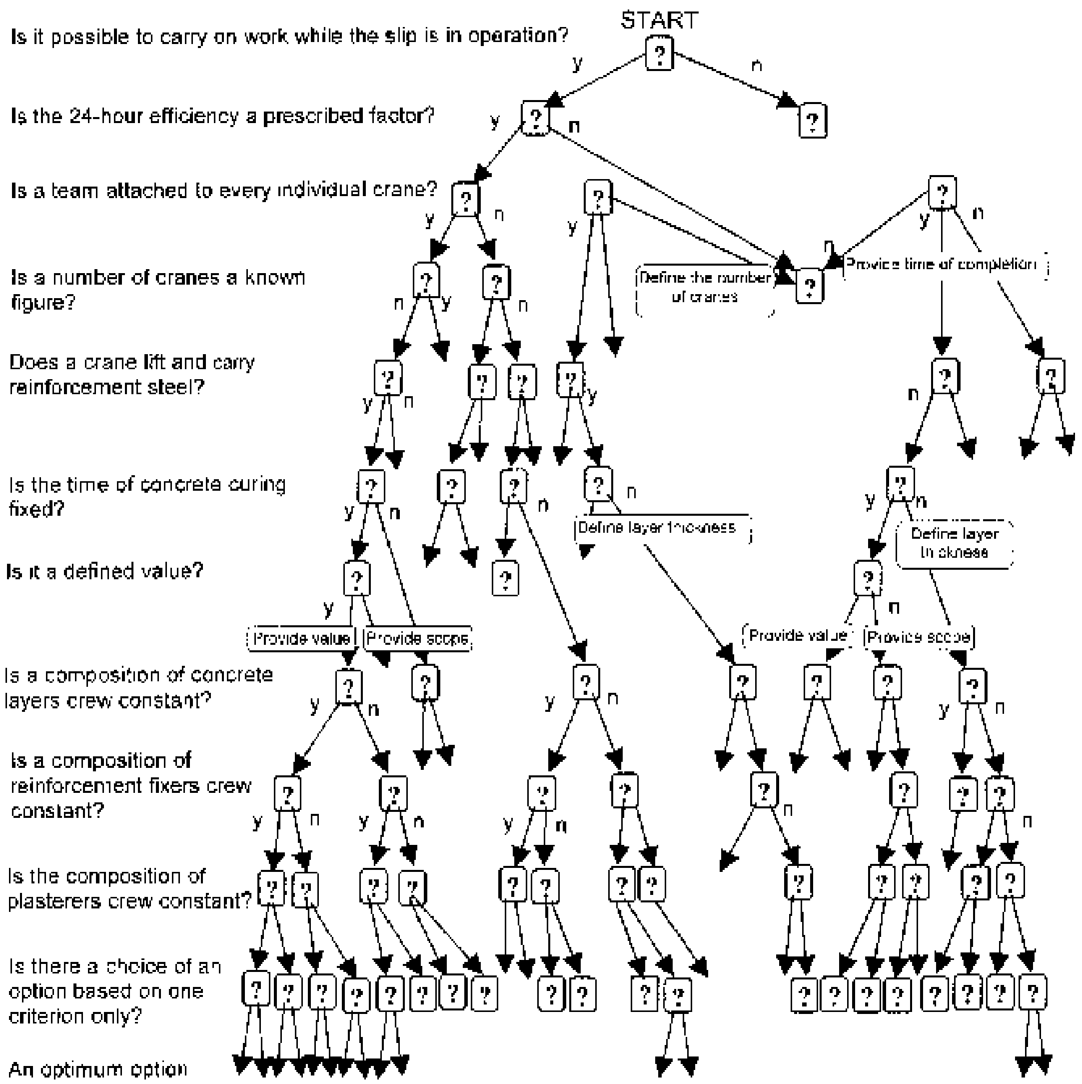

Fig 5. State graph (according to [12])

the technological-organisational processes, and macro-rules that control the design process.

The system is assembled from numerous units. They are integrally involved in the system. Some of these units can be used separately, eg the procedure of accepting a crane, the program analysing the organisation of work teams, the unit arranging the set of objects, the programme preparing graphic schedules, the unit performing the multicriterial analysis.

An interesting unit labelled "*choosing the strategies*" is presented below (according to [15]). The expert's reasoning was followed in the course of designing the system at hand. The structure of the decision tree refers to the experts'heuristicc knowledge, but common design rules are also included. The state graph reflects the logical structure of the computer system and comprises a wide spectrum of problems of various degrees of detail: from the building strategy of the whole construction to such details as the organisation of the activity of workers' teams. There are many strategies at our disposal. A specific strategy is chosen following the user's preferences which are passed to the system in a dialogue session. A special mechanism was designed to search over the state space.

An example of the range of problems receiving attention is shown in Fig 5. Upper levels of the graph deal with so-called principal strategies in the erecting a construction. These strategies are, for example, keeping to the determined time of completion of various stages, maximum efficiency in utilising production resources, work kept within a constant daily rhythm. On next level of the decision tree there are set questions concerning the concrete curing time (and it influences the height of a single concrete layer). Next questions concern the teams of workers (are their number and the way they are organised in time or not?). Finally, on the lowest level, a multicriterial analysis is performed, and the optimum variant is found. The building process dynamics is inherently dealt with by the system. The system looks into objectives, resources, regarding both the technology and organisation of the work.

Other research

Presently, other research goes on looking into the issues of modelling economic phenomena and managing databases, with a strong stress on utilising computer sciences. Two subjects related to this research are discussed below.

The first subject is focused on developing and implementing the knowledge related to multidimensional analysis of information stored in new generation databases, all within the area of construction engineering, utilising some elements of optimisation and artificial intelligence. The research is aimed at arriving at a multidimensional, multimedial consultation system used in the so-called on-going investment and building process. It may be practically applied in managing the maintenance of road networks in urban areas.[9]

The second subject is closely linked with the problems of management in engineering and construction projects. The issue of cash receipts and expenditure, and their interrelations, have been particularly well highlighted. Looking from such a point of view, the way cash receipts and capital expenditure is distributed, has become a vital criterion of correctness of the itinerary (and, in consequently, a true measure of good management in a project and in a company). If we look at the problem from the analytical aspect, it is obvious that the stress is mainly laid on specialist software used in managing businesses and companies (time-tabling and

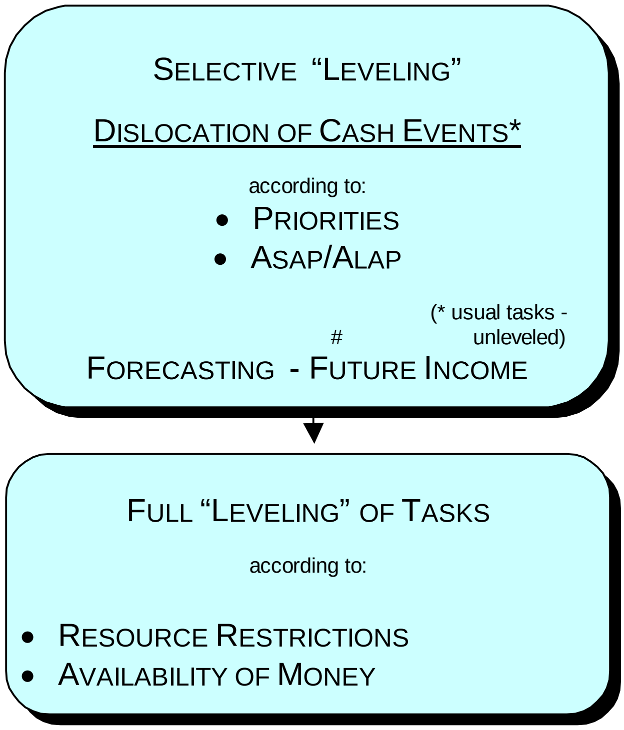

Fig 6. Idea of capital expenditure and receipts analysis in CM

designing itineraries), and a calculation spreadsheet (being the tool which widens the data analysis spectrum). The idea reflecting full analysis of cash receipts and expenses within the computer software is presented in Fig 6. Three main aspects of accounting for funds are pointed at in the research:

– periodical accounting,

– accounting and summing up upon conclusion of construction work,

– accounting in the case of known dates of payments and amounts. This aspect of accounting is a novelty in the research.[10]

It is well worth noting that this type of research has also been transferred into the realm of the MSc degree.

We should note that part of the research work is related to international collaboration, for example with France [21], Ukraine[11], Denmark[12] and first of all with

[9] This research will be concluded with a PhD dissertation to be submitted by A. Fojud (MSc, Civ. Eng.) [18–20]. Recent publications in the subject area are: [9],[10] and [13].

[10] Research in the subject area is carried out by Mr. T. Wiatr (MSc, Civ.Eng.) [22].

[11] Dolotov A. and Sadovskij V. Integrated information support system for design & realization in housing construction // MKIL, No 3, 1997, p. 79-87.

[12] Anderson T. and Gaarlev A. Priorities in construction IT research // MKIL, No 4. 1999, p. 35-45.

our colleagues from Lithuania. We have recently seen one joint publication [23], and a number of publications have come out thanks to our colleagues from Vilnius [7], [9] [14], [24] and [25]. What highlighted the Poznań academic circuit was sending a personal invitation to Prof O. Kapliński to participate in the International Seminar on Construction Management, an event limited by the presence of guests from New Zealand, Canada, the USA, the UK, and Denmark (c.f. [1]).

5. Conclusion and final remarks

Recent economic changes and the fact that a different kind of market, catering for different economic needs has emerged, resulted in a different outlook on the issue of management in technical universities. If, in the past, subjects related to management were tackled in this way or another, they were limited to the organisation of processes on the building site, while company management issues were taught at the Schools of Economics. Nowadays, these questions are coming up at our university, but it is still not possible to write a "pure" PhD thesis on CM (construction management). Such dissertations written here are expected to have a technological bias.

One should express satisfaction of the reinstatement of such courses as Laws of Economy, Construction Laws, Safety and Security Regulations. Following a request of the students, we have recently introduced a course, within the block of optional courses, on capital markets.

According to the author, in the long range, such issues as:

– Robotics (and first of all organisation of construction processes carried out by means of robots),

– Expert Systems (ways of making use of and ways of gathering data for databases and knowledge bases) should be introduced into the academic curricula on the CE.

Obviously, the scope and duration of classes devoted to "traditional" issues, such as feasibility studies, tender procedures, contracts, should be made much wider.

All manners of courses related to property valuation have recently become very popular in Poland. These problems of "Ownership Restructuring and Residential Resources Management" should constitute a new and separate course in the curriculum.

According to the author, the post-graduate course on "Estimation of Real Estate", mentioned above, should be made into a new specialisation called "Real Estate Management". It does not need to be a five-year course but a 3.5 year course crowned with an engineer BSc degree. This is how a specialisation counterpart of such areas of study in the UK as: Estate Management, Quality Surveying, Building Surveying, can be established.

In the context of the above-mentioned suggestions, the previous, traditional specialisation in the CE&M should embrace two profiles of final projects and diplomas:

– Building Rehabilitation,

– Construction Management and Economics.

Making management less centralised and local authorities stronger has resulted, according to the author, in a need of establishing a new professional specialisation. It would be called "Communal Engineering", and such a specialist would be a mayor's assistant, proficient in two areas:

– management (including CM),

– technical skills, such as environment protection, local transport, waste processing, and so on.

Assessing the research carried out directly at the Chair of CE&M, it should be said that widening the spectrum of research, ie adding such issues as economics of building and construction, construction law, organisation and management in the investment process, is something quite positive. There is no doubt that we ought to contribute much more in order to balance this problem area (and render it acceptable) so that it may be equal in weight to the traditional scope of promotion work carried out at academic institutions where Construction and Civil Engineering is taught.

Judging by the assessment to date, the academic standard of PhD dissertations on modelling and implementation of computer sciences presented at the Chair of CE&M is very high.

The form of supporting research by the Committee for Scientific Research (KBN), indeed, deserves praise. Too little research work, though (in spite of its low cost), is directly commissioned by the industrial sector.

Acknowledgements

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STATYBOS VALDYMO MOKSLINIŲ TYRIMŲ IR STUDIJŲ POKYČIAI IR LAIMĖJIMAI POZNANĖS TECHNOLOGIJOS UNIVERSITETE

O. Kapliński

Santrauka

Pateikta statybos valdymo studijų ir mokslinių tyrimų problemų, esamos padėties ir pokyčių tendencijų apžvalga. Aprašytos tipinės programos ir veiksmų grandis (finansavimas, studijų programos ir mokslinis darbas) Lenkijoje. Taip pat pateikti tam tikri statybos technologijos ir valdymo specializacijų aspektai. Naujos tendencijos matomos ir Poznanės technologijos universiteto Statybos technologijos ir valdymo katedros nekilnojamojo turto vertinimo ir valdymo magistrantūros studijose. Doktorantūros studijas galima tęsti studijuojant statybos procesų modeliavimą, kuris yra glaudžiai susijęs su duomenų bazių sudarymu ir tam tikrų dirbtinio intelekto elementų panaudojimu.

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Oleg KAPLIŃSKI. Professor, Dr Habil, Eng. Head of the Chair of Construction Engineering and Management. Poznań University of Technology, 60-965 Poznań, ul. Piotrowo 5, Poland.

Author and co-author of 130 papers, articles and books. Member of Ukrainian Building Academy. Doctor Honoris causa of Vilnius Gediminas Technical University. Member of Civil Engineering Committee of Polish Academy of Science. Research interests: organisation and modelling of construction processes.

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EFFICIENCY INCREASE IN RESEARCH AND STUDIES WHILE APPLYING UP-TO-DATE INFORMATION TECHNOLOGIES

E. K. Zavadskas, A. Kaklauskas

Vilnius Gediminas Technical University

1. Introduction

The Department of Construction Technology and Management at the VGTU has achieved certain results in the fields of research and studies during the period of 1997 to 2000. Six Doctoral students (G. Ambrasas, A. Banaitis, N. Kvederytė, S. Jakučionis, V. Šarka ir V. Malienė) defended their Doctoral dissertations [1–6]. A. Kaklauskas defended a dissertation of Doctor Habilitatis under the guidance of Prof E. K. Zavadskas. Research activities took place at the Department in the following five major fields:

1. Development of a model for a complex analysis of a building life cycle [7–13];
2. Development of methods of multiple criteria analysis [14–24];
3. Development of multiple criteria decision support systems [25–37];
4. Total life analysis, modelling and forecasting construction in Lithuania [38–51];
5. Efficiency increase in of e-commerce systems applying multiple criteria decision support systems [52–56].

The study process also experienced changes. They were related to the implementation of up-to-date information technologies [32, 33, 57] in the process of studies. The following study programmes were available in the Department within the described period:

- Bachelor degree (Construction Management (specializations: Construction Technology and Management, Construction Economics) and Property Management) study programmes.
- Engineer degree (Construction Economics) study programme.
- Master degree (Construction Management (specializations: Construction Technology and Management, Construction Economics) and Property Management) study programmes.

Since 1999 the distance (Internet) Master degree studies "Property Management" have been introduced in the Department, and Master degree studies "Construction Economics" from 2000 as well.

245 students will finish the above programmes at the Department in 2001.

Increasing efficiency of the study process is described from various perspectives in numerous publications by Prof E. K. Zavadskas [58–82].

Further the article contains a brief description of the above-mentioned achievement in research and studies within the period of 1997 to 2000.

2. A model for a complex analysis of a building life cycle

Research into a building life cycle aimed to increase its efficiency being achieved in the world may be classified in different ways:

- the investigations aimed at solving relevant problems of a particular stage of a building life cycle (ie brief, design, construction, maintenance, facilities management, demolition);
- the investigations handling a certain problem through the whole life cycle of a building;
- the investigations aimed to increase overall efficiency of a life cycle of a building;
- the investigations aimed to increase the efficiency of a life cycle of a building or its particular stage by applying recent achievements of IT and the Internet.

The research work carried out by Professors E. K. Zavadskas and A. Kaklauskas refers to the first and the third group listed above. It should be noticed that the researchers from various countries engaged in the analysis of building life cycle and its stages did not consider the research object being analyzed by the authors of the present investigation. The latter may be described as follows: a life cycle of a building, the parties involved in its design and realization as well as micro-, meso- and macroenvironment having a particular impact on it making an integral whole. A complex analysis of the research object formulated was made with the help of new methods multiple criteria project analysis developed for this particular purpose. Today, the authors, in cooperation with the colleagues, are carrying out a research referring to the fourth group of the classification given above.

In order to design and realize a high-quality project, it is necessary to take care of its efficiency from the brief to the end of service life. The entire process must be planned and executed with consideration of goals aspired by the participating the interested parties and micro-, meso- and macrolevel environment.

In order to realize the above purposes an original model of a complex analysis of a building life cycle (see Fig 1) was developed enabling to analyze a building life cycle, the parties involved in the project as well as its micro-, meso- and macroenvironment as one complete entity.

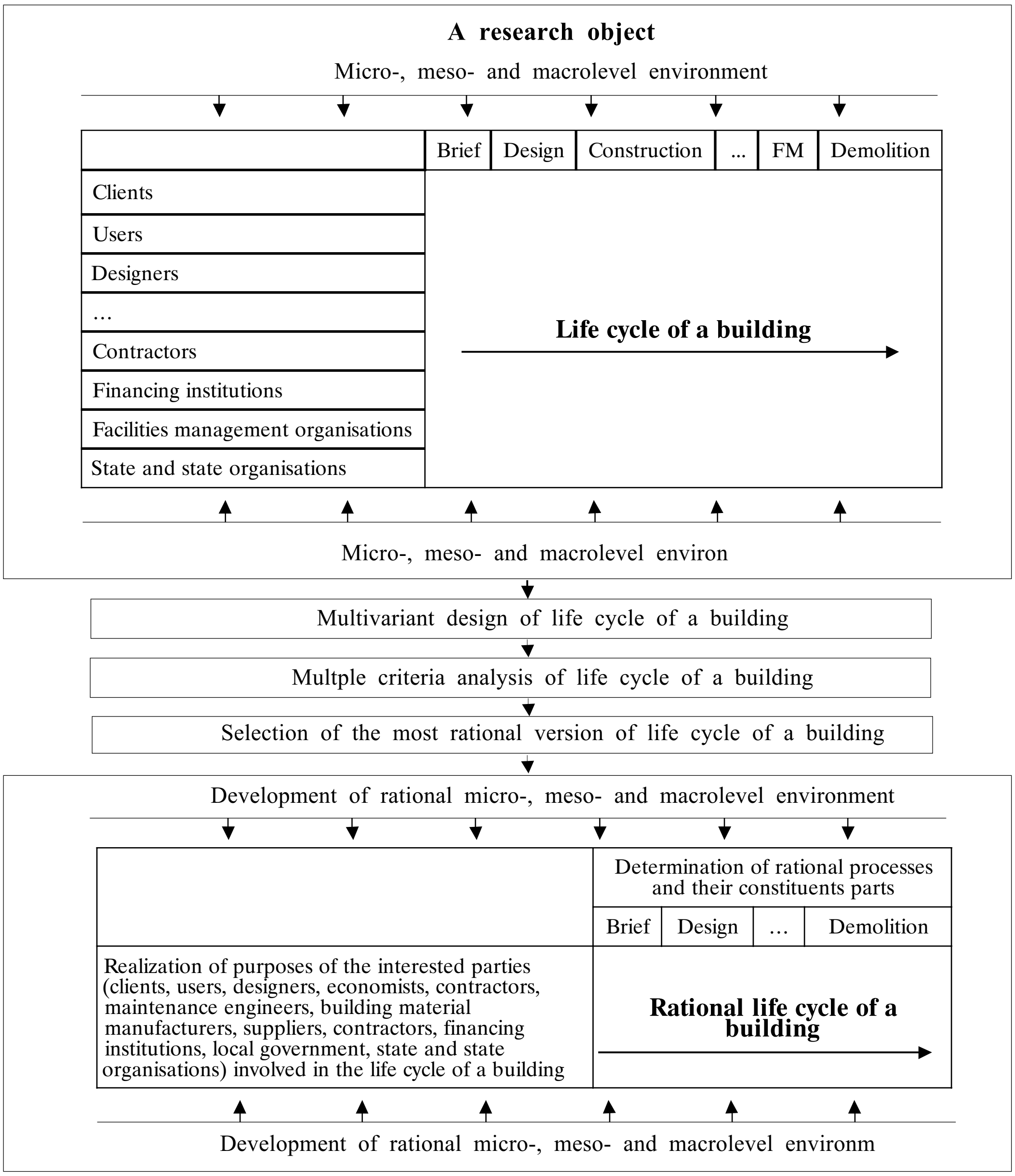

Fig 1. A model for a complex analysis of a building life cycle

A model for a complex analysis of a building life cycle was being developed step by step as follows (see Fig 1):

- A comprehensive quantitative and conceptual description of a research object;
- Multivariant design of life cycle of a building;
- Multple criteria analysis of life cycle of a building;
- Selection of the most rational version of life cycle of a building, development of rational micro-, meso- and macrolevel environment.

A practical realization of a model for a complex analysis of a building life cycle was being developed step by step as follows (see Fig 2):

- A comprehensive quantitative and conceptual description of the life cycle of a building, its stages, the interested parties and environment;
- Development of a complex database based on quantitative and conceptual description of the research object;
- Development of new methods of multiple criteria analysis to carry out multivariant design of a building life cycle, to determine the utility degree of the alternative versions obtained and set the priorities;
- Creation of a multiple criteria decision support systems to be used in computer-aided multivariant design of a building life cycle, determining the utility degree of the alternative versions obtained and setting the priorities;
- Analysis of micro-, meso- and macrolevel environment factors influencing a building life cycle and possibilities to alter them in a desired direction.

The results obtained in the above research may be found in the authors' publications [7–13].

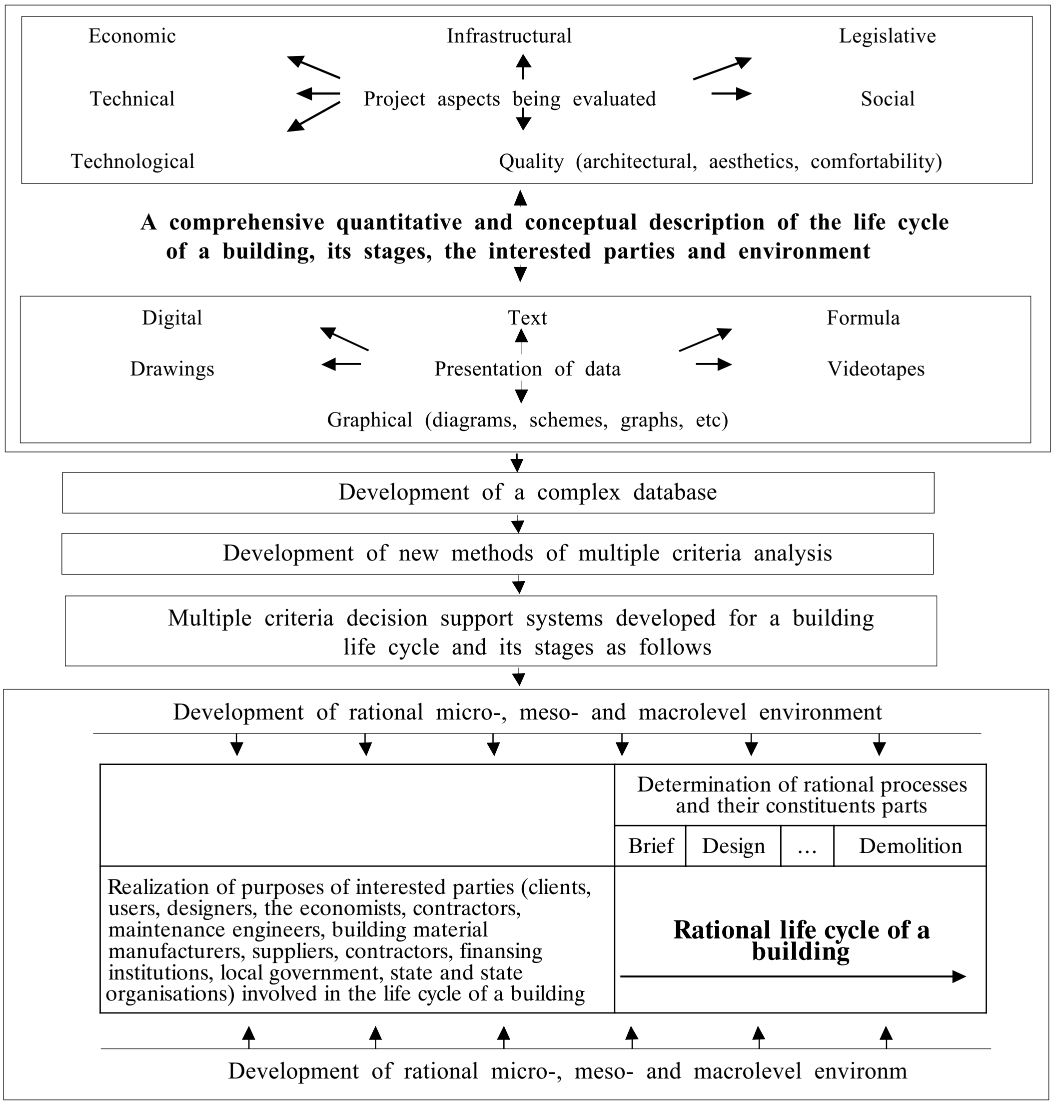

Fig 2. Practical realization of a model for a complex analysis of a building life cycle

3. Proposed methods of multiple criteria analysis

New methods for performing multiple criteria analysis of the research object chosen have been developed by the authors: a method of complex determination of the significances of the criteria taking into account their quantitative and qualitative characteristics; a method of multiple criteria complex proportional evaluation of the projects; a method for defining the utility and market value of an object; a method for multiple criteria multivariant design of a building life cycle; methods of multicriteria decision synthesis.

In order to select the best project, it is necessary, having formed the grouped decision-making matrix, to perform the multiple criteria analysis of the projects. This is done by comparing criteria numerical values and significances and analyzing the conceptual information of the investigated project. The life cycle of an investigated project can be described only on the basis of a criteria system comprising many criteria with different meanings and dimensions. Such variety of criteria makes it difficult to compare the projects directly. One of the major tasks in solving the above problem is to determine the significances of the criteria. It is most commonly done by means of expert methods.

Theoretical and practical aspects of expert methods in construction were dealt with in various research papers by D. Arditi [83], E. A. Chinyio [84], A. Gusakov [85], L. G. Evlanov [86] and others. Having determined the significances of criteria by expert methods, we learn how much one of the criteria is more significant than another one. However, having determined by these methods the significances of quantitative criteria (cost of plot and building, maintenance costs, construction time, etc), we do not find out everything we need. For instance, values of quantitative criteria in this case are not fully evaluated. A new method for complex determination of the significance of the criteria taking into account their quantitative and qualitative characteristics was developed. This method allows to calculate and coordinate the significances of the quantitative and qualitative criteria according to the above characteristics. In this case all the significances of qualitative and quantitative criteria are coordinated exactly at the same time.

V. M. Ozernoy [87] presented a number of multiple criteria decision-making methods to be used in solving discrete alternative problems: weighting methods (MacCrimon), multiattribute utility theory (Keeney and Raiffa), measurable value theory (Dyer and Sarin), analytical hierarchical method (Saaty), weighted-additive evaluation function with partial information (Kirkwood and Sarin), multiattribute method with incomplete information (Weber), pairwise comparison of alternatives with ordinal criteria (Koksalan, Karwan and Zionts), simple multiattribute utility method (Einhorn and McCoach), Electre I, II and III (Roy and Vincke). Each of these methods actually represents a family of methods with similar characteristics. For example, the family of weighting methods contains at least nine different methods [87]. A. Goicoechea [88] analyzed the following multiple criteria decision-making methods: utility function assessment (Keeney), compromise programming (Zeleny), Electre (Roy, Duckstein), surrogate worth trade-off (Haimes), multiobjective Simplex (Yu, Zeleny), method by Zionts, Wallenius, Ariadne (Sage, White), probabilistic trade-off development, Protrade (Goicoechea, Duckstein) goal programming (Lee, Ignizio). The researchers as E. K. Zavadskas, A. Karablikovas, V. Kriukelis, H. Nakas, R. Sakalauskas, J. R. Šimkus [89], G. Geoffrey, P. Goodwin, G. Wright [90] etc also contributed to the solution of these problems. A new method of multiple criteria complex proportional evaluation of the projects enabling the user to obtain a reduced criterion determining complex (overall) efficiency of the project was suggested by the authors. This method assumes direct and proportional dependence of significance and priority of investigated versions on a system of criteria adequately describing the alternatives and on values and significances of the criteria. The system of criteria is determined and the values and initial significances of criteria are calculated by experts. All this information can be corrected by the interested parties (customer, users, etc) taking into consideration their pursued goals and existing capabilities. Hence, the assessment results of alternatives fully reflect the initial data jointly submitted by experts and the interested parties.

In order to find what price will make an object being valuated competitive on the market, a method of determining the utility degree and market value of objects based on the complex analysis of all their benefits and drawbacks was suggested. According to this method, the objects utility degree and the market value of an object being estimated are directly proportional to the system of the criteria adequately describing them and the values and significances of these criteria.

A new method of multiple criteria multivariant design of a building life cycle enabling the user to make computer-aided design of up to 100,000 alternative project versions was developed. Any building life cycle variant obtained in this way is based on quantitative and conceptual information.

The results obtained in the above research may be found in the author's publications [14–24].

4. Multiple criteria decision support systems

Construction is characterised by a rather low productivity and a high fragmentation compared to other branches of industry. Much attention, efforts and time are paid by researchers, engineers and politicians of various countries to eliminate these disadvantages. Various researchers [91–99] developing expert and decision support systems are currently working on these problems at the levels of construction industry, particular organisations and projects.

According to the classification of investigations made in the field of building life cycle, aimed at increasing its efficiency, which was given in Chapter 2, expert and decision support systems used in construction may be divided into four groups.

The analysis of expert and decision support systems used in construction which were developed by researchers from various countries helped the authors to create multiple criteria decision support systems of their own. The systems developed by the authors in cooperation with their colleagues differ from others in the use of new original methods (presented in Chapter 3) and the object of investigation (presented in Chapter 2). Researchers from various countries involved in the analysis of a building life cycle and its components as well as handling the problems of their design did not touch upon the topic making a research object of the authors, ie life cycle of a building, the parties interested in the project and micro-, meso- and macroenvironment factors as an integral whole.

Decision support systems developed by the authors of the present research belong to the first, second and third group of the classification of these systems. Multiple criteria decision support systems developed for a building life cycle and its stages as follows: multiple criteria analysis of a building life cycle and its stages, multivariant design and multiple criteria analysis of refurbishment of residential houses, multiple criteria analysis of construction projects, project total quality analysis, etc

The results obtained in the above research may be found in the author's publications [25–37].

5. Total life analysis, modelling and forecasting construction in Lithuania

The trends of construction industry development were investigated by researchers from various countries in a conceptual form. For example, according to R. C. Harvey [100, 101], past, present and future construction is closely connected with major economic indices of the state, such as total domestic product, state expenditures, consumer expenditures, fixed investment, average earnings, retail prices, disposable income, interest rate, etc To prove this idea R. C. Harvey [100, 101] presents some conceptual material. A. Akintoye [102] analyzed the relationship between cost of construction in the UK in 1974–90 and 23 economic factors (ie rate of pound and unemployment, volume of construction, total domestic product, actual interest rate, income per capita, company's taxes, number of private contractors, etc). The above analysis was made in textual, numerical and graphical forms, yielding diverse results. Researchers from Salford university [103] analyzed (in 1955–94) and predicted (since 1994) the investment in the UK construction, volume of construction, number of workers employed in this branch, as well as investigating the relationships between various factors. R. H. Barnard [104] and P. H. Hillebrandt [105] studied the relationship between the demand for construction products and the economic situation and social and economic policy of the state. G. Briscoe [106] analyzed the relationship between interest rate and state support in dwelling purchasing by the inhabitants, etc and the investment in construction. R. C. Harvey [101] studied the effect of amalgamation of building firms on the increase in construction efficiency. P.H.Hillebrandt [105] described some ways of increasing the export of construction products, while S. Chapman and C. Grandjean [107] considered the ways of harmonizing the activities of construction specialists in the EU, publishing some guidelines in this sphere [108–110]. As it can be observed, researchers from various countries use conceptual and quantitative forms of analysis while studying the effect of certain factors on the efficiency of construction industry. However, the papers mentioned did not deal with a complex approach to construction industry taking into account economic, technical, technological, quality, infrastructural, legislative, social and other factors. The authors of the present investigation was trying to fill this gap by basing his work on all of the above factors.

The life cycle process model of efficient construction industry suggested by this research is based on presumption that the efficiency of construction industry depends on many micro-, meso- and macrolevel variables. The presence of specific macro, meso- and micro-level variable factors right away imposes objective limitations for efficient activities of construction industry. The construction industry, in presence of these objective limitations, tries to perform its functions in their bounds with utmost efficiency. For instance, organisations, depending upon certain micro-, meso- and macrolevel environment, would do their best to look for activities in such fields of construction industry as designing, production of building materials, tools and mechanisms, construction of dwelling houses, thermal refurbishment of buildings, supply, etc, and in geographic locations including the capital, various towns and districts of the country, rural districts, etc as well as working and with the interested parties the goals of which would find maximum satisfaction. Advanced organisations, basing themselves on this assertion, are trying to create for themselves rational environmental and operating conditions in order to achieve the best satisfaction of customers' needs, to win better reputation and to earn more profit. Therefore, basing oneself on main development trends of construction industry in advanced industrial countries, it is possible to issue recommendations on the increase of efficiency of transition construction industry in Lithuania. When rational variable micro-, meso- and macrolevel factors determines for Lithuania have been realized, they should create better and more favourable conditions for efficient realization of construction industry's projects.

The research aim was to produce an analytical model of the rational construction industry in Lithuania by undertaking a complex analysis of micro-, meso- and macroenvironment factors affecting it and to give recommendations on the increase of its competitive ability. The research was performed by studying the expertise of advanced industrial economies and by adapting it for Lithuania, taking into consideration specific history, development level, needs and traditions. Simulation was undertaken to provide insight into creating an effective environment for the construction industry by choosing rational micro-, meso- and macrofactors.

The organisations of construction industry cannot correct or alter the micro-, meso- and macrolevel variables, but they can go into the essence of their effect and take them into consideration when realizing various projects. Organisations, knowing the micro-, meso- and macrolevel factors affecting the projects being realized, can organise their present and future activities more successfully.

Based on the above considerations, it is possible to propose a life cycle process model of an efficient construction industry on the basis of the performed search for a rational variable environment for Lithuania (ie seek to explore ways of harmonising the relationship between Lithuanian construction in transition and its environment). Upon completion of such a model, the interested parties by taking into consideration the existing limitations of micro-, meso- and macrolevel environment and the existing possibilities, will be able to use their resources in a more rational manner.

This research seeks to explore ways of harmonising the relationship between the transitional Lithuanian construction and its environment. The research included the following stages presented in Figure 3.

The results obtained in the above research may be found in the authors'publicationss [38–51, 111–113].

6. Efficiency increase in efficiency of e-commerce systems applying multiple criteria decision support systems

Many systems of electronic commerce are processing and submitting just the economic information for decisions, and applying economic models as well. However, the alternatives under consideration have to be

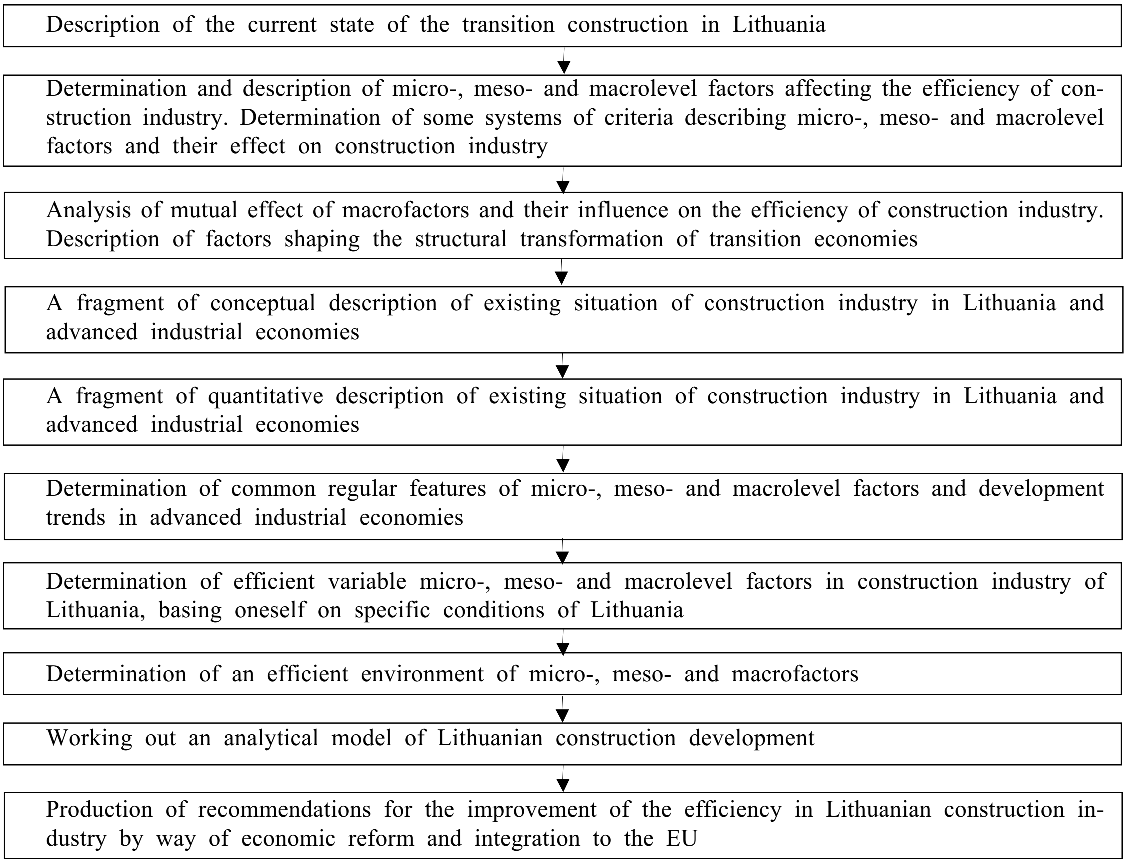

Fig 3. Main stages of working out an analytical model of Lithuanian construction development

evaluate not only in economic position, but taking into account the qualitative, technical and other characteristics, too. For example, the analysis of property is being usually performed taking into account economic, quality (architectural, aesthetic, comfortability), infrastructural, technical, legal, technological, social and other factors. Therefore, the efficiency of e-commerce may be increased applying the multiple criteria decision support systems. This chapter is intended to provide how application of multiple criteria decision support systems developed by the authors could increase the efficiency of e-commerce of construction materials and property. The suggested systems are better compared with other online systems, because the intelligent agents here are comparing a number of alternatives different parameters with each other.

This chapter also includes a short description of the interested parties that could apply suggested systems in their activities and capabilities of systems.

6.1. Efficiency increase in e-commerce construction materials systems

Many e-commerce systems are seeking to find out the most economic decisions, ie most of all they are intended only for economic objectives. However, the alternatives under evaluation have to be regarded not only in economic position, but taking into consideration the qualitative, technical and other characteristics too. For example, the analysis of alternative construction materials is being usually performed taking into account price, discounts given, thermal insulation, sound insulation, harmfulness to human health rate, aesthetic, weight, technical specifications, physical and moral longevity and other factors. Alternative solutions allow for more rational and realistic assessment of economic, technical conditions and traditions and for better satisfaction of architectural, comfort, maintenance and other customer requirements. Their application also enables to cut down project costs.

E-commerce implementation may not be followed by sales. For example, let's look at some of the early Web sites for air ticket sales. They often served only as information providers for those who shop for the lowest discount airfares. Such shoppers leave the site, without any purchase, after collecting the information. In a sense, the similar situation is in Lithuania at the moment. There are various reasons (incompletely arranged legislative base, a comparatively small part of society uses information technologies, and, in order to start e-commerce, considerable initial investments are needed, there is a lack of experience in e-commerce practical activities) predetermining that at the moment it is not useful to apply e-commerce in Lithuania, in a volume being used in the developed countries. For example, electronic procurement systems, which include top-tier features like application programming interfaces to existing legacy systems with the ability to handle different communication among multiple suppliers, can range from $250,000 to $2 million. With such high start-up costs expected and the current limitations of software packages, making a decision on buying versus building is critical. Therefore it is more efficient to apply search and multiple criteria analysis decision support systems in Lithuania. Following the mentioned and other ideas the authors have developed Consumer Multiple Criteria Decision Support (CMCDS) system.

The proposed CMCDS system can be valuable in the following important ways: to help customers assess their needs, to identify suitable offers to fulfil needs, to compare and evaluate offers, to match a particular offering with the customer in an attempt to get the 'best deal' for the customer, to help customers evaluate the usefulness of the product in the after-purchase evaluation stage. In general, the proposed system creates greater convenience and better choices for buyers in the purchase process.

A general purchasing decision-making model for consumers includes five principal stages: demand identification, information search, and evaluation of alternatives, purchase and delivery, and after-purchase evaluation. Efficiency of some above-mentioned stages may be increased applying the CMCDS system for e-commerce of construction materials, which is suggested by the authors. How is such a process viewed in cyberspace?

Now the developed CMCDS system allows performance of the following functions:

1. Search for construction materials. A consumer may perform a search of alternatives from catalogues of different suppliers and producers. It is possible bacause the forms of data submission are standardized in a specific level. Such standardization creates the conditions to use special intelligent agents performing search of the required construction materials in various catalogues, and gathering information about them. One or several regions may limit such search.

2. Finding out alternatives and making comparative tables. Consumers specify requirements and constraints and the system queries the information of a specific construction materials from a number of online vendors and returns a price-list and other characteristics that best meets their desire. The system performs the tedious, time-consuming, and repetitive tasks of searching databases, retrieving and filtering information, and delivering it back to the user. Results of search of a specific construction materials are submitted in tables, which may include direct references to a Web page of a supplier or producer. By submission such a display, the multiple criteria comparisons can become more effectively supported.

3. Alternatives evaluation stage (multiple criteria analysis of alternatives and selection of most efficient ones). While going through the purchasing decision process a customer must examine a large number of alternatives, each of which is surrounded by considerable amount of information (price, discounts given, thermal insulation, sound insulation, harmfulness rate to human health of materials, aesthetic, weight, technical specifications, physical and moral longevity, etc). Following on the gathered information the priority and utility degree (utility degree is directly proportional to the relative effect of the values and significances of the criteria considered on the efficiency of the alternative) of alternatives are being calculated. It helps consumers to decide what product best fits their requirements.

The after-purchase evaluation stage. A consumer evaluates the usefulness of the product in the after-purchase evaluation stage.

6.2. Increase of efficiency of e-commerce property systems

Property decision support (PDS) system home page (http://193.219.145.99) has links to other Web pages:

- Theory Web page (http://193.219.145.99/PROJ2/ TEORIJA/teorija1.htm). It includes the theory suggested by authors following on that the models of model-base have been developed.
- User guide for work with system Web page (http: //193.219.145.99/proj2/help2.pdf). With assistance of this guide it is quite simple to use system in practice.
- Description of system aims and capabilities Web page (http://193.219.145.99/proj2/help1.pdf). This Web page includes a short description of the interested parties that could apply system in their activities and capabilities of system.
- Commercial property Web page (http://193.219.145.99/PROJ2/PARDUOT/ parduot.htm).
- Dwellings Web page (http://193.219.145.99/PROJ2/ NAMAI/namai.htm).
- Farmer's homestead estates Web page (http://193.219.145.99/PROJ2/SODYBOS/sodybos.htm).

These links are presented in underline text. Seeking to explore the link, click the underline place. While further development of PDS system it is provided to expand a database (above Web pages) with other types of property.

Presentation of information in commercial property, dwellings, farmer's homestead estates and other types of property Web pages may be in conceptual (digital, textual, graphical, photographical, video) and quantitative forms. Thus, quantitative information presentation involves criteria systems and subsystems, units of measurement, values and initial significances fully defining the variants provided. Quantitative information of property is submitted in a form of grouped decision-making matrix, where the columns mean n property under valuation, and rows include quantitative information. Conceptual information means a conceptual description of the property, the criteria and ways of determining their values and significances, etc Conceptual information is needed to make more complete and accurate valuation of the property considered. In this way, system enables the decision maker to get various conceptual and quantitative information on property from a database and a model-base allowing him to analyze the above factors and make an efficient solution.

Capabilities to use the PDS system in practice are:

- Property valuation in various aspects (ie determination of market value, value in use, investment value, etc).
- Valuation of factors affecting value of property (for example valuation of property location, property depreciation, etc).
- Determination of the highest and best use of a property.

While further development of PDS system it is provided to expand a database of property, to create possibilities to perform property assignment operations (rent, lease, donation, purchase-sale, etc) and payment, payment control, to receive information about the state of personal account of a customer (checking of availability of the required amount of money in account), to perform information exchange (announcement board, discussions forums, advertising, e-mail box, articles, other information). Since the information on offered property subject on regular changes, therefore the up-to-date information should be searched in Web pages of brokers and other interested in groups. Thus it is envisaged to submit references to Web sites of the interested parties. Moreover, it is foreseen to place information on activities of property appraisers, brokers and other interested parties, various announcements, notices, information of market situation, its changes and future prospects, information bulletins issued, other up-to-date information for users'attentionn.

The results obtained in the above research may be found in the authors' publications [52–56].

7. Property management postgraduate Internet studies

Unprecedented and large-scale transformations of social, economic, legal, political and other spheres are occurring in Lithuania. Lithuania is seeking a rapid integration (harmonisation) with various structures of the EU. At the same time, one of the most intensively developing sectors of Lithuanian economy is the real estate market. The property and construction industry, under the effect of these changes, feel a particular need for property management (PM) specialists, as specialists in a new field, trained according to the highest standards. In 1999, a distance learning programme (via Internet) of "Property management" leading to Master degree was introduced at the Department of Construction Technology and Management. The present programme of distance (Internet) studies is the first of such kind in Lithuania.

The programme of PM distance studies has been developed in the following phases:

- To analyse the needs of the market and learners at national level;
- Alternative curriculum designs prepared and evaluated against market needs. Rational solutions chosen;
- To determine who the learners are likely to be, what is to be learned, where the learning will take place, what equipment and tutorial support will be required;
- To develop appropriate teaching techniques, to set-up and test technical infrastructure;
- To organise the most effective means of delivering learning to satisfy the market needs;
- To develop appropriate teaching techniques;
- To test learning material;
- To revise learning materials subsequent to testing.

Some information on the studies can be found on the VGTU Internet pages (http://www.vtu.lt/dmc01/index1.htm).

After the programme of distance studies has been created all potential users – authorities and organisations were informed about the project and its results by the following means: advertisements in regional and national newspapers, journals; meetings with students, authorities, employees of banks, insurance companies, retail shopping groups, real estate companies, venture capitalists, and other interested parties; sending leaflets to offices of authorities, banks, insurance companies, retail shopping groups, real estate companies, venture capitalists, and other interested parties; publication of the programme materials, use of www, articles in the journals of the professional organisations representing the property management disciplines. This dissemination brings to the attention of a wider audience the issues facing PM professionals in Lithuania.

Students admitted to the studies are being divided into two groups: students who have completed the studies of higher education in this or similar field, and students who have completed the studies of higher education not in this or similar field. The programme for the students of those groups differs at 25%. The students having completed studies of higher education in this or similar field are improving their knowledge further. The students who completed studies of higher education not in this or similar field are trying to fill gaps of unavailable knowledge. Duration of studies is 2 years: three first semesters are intended for studying, and the fourth semester is for final (graduate) thesis. Students have to take five examinations within each semester on average. Duration of a semester covers 16 weeks. The knowledge obtained by a student is being evaluated by an examination. Most of all a student must answer three or four extensive, or ten brief questions within an examination.

The individual modules (property management, economics, valuation, facilities management, real estate investment and finance, law, decision support systems, etc) which make up the distance learning programme are self-contained units of study which can be undertaken by learners at a time, place and pace which suits their needs and those of their employers. It is recognised that the adoption of distance learning can assist learners and their employers by making available specialist knowledge throughout the learner's working life. This enables the concept of lifelong learning to be catered for by the programme.

Undertaking the programme in a distance learning mode of study involves learners in various activities which may initially be unknown to them: induction programme, directed learning, independent study, computing facilities. At the start of the programme, an induction programme is organised which seeks to integrate learners into the distance learning environment and to explain to them the detailed demands. The study material provided for each module seeks to provide learners with guidance on directed learning. After learners' induction into the programme, most of their study is undertaken by them working in their own time and place. It is essential for learners undertaking this programme on a distance learning basis, to have the right computing facilities available to them.

All programme materials are presented as printed programme notes which enhance, where appropriate, to take advantage of modern teaching techniques and delivery mechanisms. In particular, the following media are used in specific modules: electronic format the textbooks, video, computer software, computer learning systems, computer conferencing, computer networks, face-to-face contact. The choice of media is often relatively easy to make because for much of the time, local constraints, questions of accessibility and of cost virtually dictate the media through which learners will have to work. Accessibility is vitally important to any learners who have to use self-instructional materials.

The module writers utilised electronic technologies for preparing their module material. This assisted the programme team to prepare the material in a variety of suitable formats for dissemination. Once in electronic format the material can be made available in paper format, on CD, over the Internet and by file transfer (FTP). This ensures the learners to have the material available in the way which best suits their learning needs. Equipment, such as video-recorders and computers are utilised wherever possible. In addition, face-to-face contact, telephone, fax, surface mail, e-mail are used, too.

The results obtained in the above work may be found in the authors' publications [32, 33, 57].

8. Conclusions

1. An original model of a complex analysis of a building life cycle enabling the user to analyze a building life cycle and its stages, the parties involved in the project as well as its micro-, meso- and macroenvironment as an integral whole is developed. A building life cycle as well as the parties involved in the project and the environment having a certain impact on it are described from various perspectives in numerous publications by the authors in quantitative (a system and subsystems of criteria, units of measure, values and significances) and conceptual (text, formula, graphical (ie schemes, graphs, diagrams and video tapes) forms.

2. The suggested systems and subsystems of criteria relating to a building life cycle and based on economic, technical, technological, qualitative (ie comfortability, architectural, aesthetic, and the like), legislative, social and other factors are described in a number of publications.

3. A new method for a complex determination of the criteria significance taking into account their quantitative and qualitative characteristics was developed. This method allows to calculate and coordinate the significances of the quantitative and qualitative criteria according to the above characteristics.

4. A new method of multiple criteria complex proportional evaluation of the projects enabling the user to obtain a reduced criterion determining complex (overall) efficiency of the project was suggested. This generalized criterion is directly proportional to the relative effect of the values and significances of the criteria considered on the efficiency of the project.

5. In order to find what price will make an object being valuated competitive on the market, a method of determining the utility degree and market value of objects based on the complex analysis of all their benefits and drawbacks was suggested. According to this method, the objects utility degree and the market value of an object being estimated are directly proportional to the criteria system adequately describing them and the values and significances of these criteria.

6. A new method of multiple criteria multivariant design of a building life cycle enabling the user to make computer-aided design of up to 100,000 alternative project versions was developed. Any building life cycle variant obtained in this way is based on quantitative and conceptual information.

7. An original model for a complex analysis of a building life cycle enabling the user to analyze a building life cycle and its stages, the parties involved in the project as well as its micro- and macro- environment as an integral whole is developed.

8. Original multiple criteria decision support systems to be used in construction for a complex analysis of a building life cycle and its stages, the parties involved and micro- and macro- level environment factors were created. These systems were used for multivariant design and multiple criteria analysis of the life

cycles and their stages of one-family houses, agricultural, industrial and in-situ buildings.

9. Formalized presentation of the research shows how changes in the environment and the extent to which the goals pursued by various interested parties are satisfied cause corresponding changes in the value and utility degree of a building life cycle. With this in mind, it is possible to solve the problem of optimization concerning satisfaction of the needs at reasonable expenditures. This requires the analysis of building life cycle versions allowing to find an optimal combination of goals pursued and finances available.

10. In order to increase the efficiency of a building life cycle, a model for analyzing, modelling and predicting the development of Lithuanian construction industry was developed enabling the users to achieve better practical results in designing a more effective life cycle of buildings. Theoretical conclusions of the present work were used in scientific research carried out under PHARE programme as well as in the projects ordered by the Ministry for Construction and Urban Development.

11. Starting from 1999, the distance (Internet) postgraduate studies "Property Management" have taken place in the Department of Construction Technology and Management at the VGTU, and "Construction Economics" studies from 2000 as well.

12. Now the developed e-commerce construction materials system allows performance of the following functions: search of construction materials; finding out of alternatives and making of comparative tables; alternatives evaluation stage (multiple criteria analysis of alternatives and selection of most efficient ones); the after-purchase evaluation stage (a consumer evaluates the usefulness of the product in the after-purchase evaluation stage).

13. The main data obtained in the research were discussed at the scientific conferences and seminars held in Edinburgh, Glasgow (UK), Gavle (Sweden), Paris, Lisbon, Athens, Leipzig, Poznan, Zieliona Gura, Riga, Vilnius, Kaunas, Moscow, Minsk.

14. The theoretical results of the investigation were used in 19 research and budgeted works (1990–1999) performed both in Lithuania and abroad.

15. The data obtained in the research were used in the educational process at Vilnius Gediminas Technical University for:

- Preparing lecture courses on building economy and investment, total quality management, quantitative and qualitative methods of analysis, functional value analysis and contracts at Vilnius Gediminas Technical University for Bachelor and Master degrees as well as for engineers in Civil Engineering, Construction Management and Property Management;
- Compiling the materials for the course of lectures „Multiple criteria analysis of projects" for Doctoral students in construction;
- Developing the Internet module of lectures „Decision support systems in construction".

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MOKSLO IR STUDIJŲ EFEKTYVUMO DIDINIMAS TAIKANT NAUJAUSIAS INFORMACIJOS TECHNOLOGIJAS

E. K. Zavadskas, A. Kaklauskas

S a n t r a u k a

Pristatomi prof. E. K. Zavadsko ir prof. A. Kaklausko 1997–2000 m. laimėjimai moksle ir studijų procese. Šiuo laikotarpiu 6 katedros doktorantai (G. Ambrasas, A. Banaitis, N. Kvederytė, S. Jakučionis, V. Šarka ir V. Malienė [1–6]) apgynė daktaro disertacijas. Prof. E. K. Zavadsko vadovaujamas A. Kaklauskas apgynė habilituoto daktaro disertaciją. Taip pat buvo atlikta daug mokslo tiriamųjų užsakomųjų ir biudžetinių darbų tiek Lietuvoje, tiek užsienyje. Moksliniai tyrimai katedroje buvo atliekami penkiomis pagrindinėmis kryptimis:

1. Sukurtas originalus pastato gyvavimo proceso kompleksinės analizės modelis [7–13]. Šis modelis leidžia kompleksiškai analizuoti pastato gyvavimo procesą, jo sudėtines dalis, suinteresuotas grupes ir išorinę aplinką kaip visumą.

2. Buvo sukurti nauji daugiakriterinės analizės metodai [14–24]: kompleksinis kriterijų reikšmingumo nustatymo, atsižvelgiant į jų kokybines ir kiekybines charakteristikas; projektų daugiakriterinio kompleksinio proporcingo įvertinimo; daugiakriterinis objektų naudingumo laipsnio ir rinkos vertės nustatymo; pastato gyvavimo proceso daugiakriterinio variantinio projektavimo; daugiakriterinių sprendimų sintezės metodai.

3. Sukurtos originalios daugiakriterinės sprendimų paramos sistemos [25–37] statyboje, sudarančios sąlygas kompleksiškai analizuoti pastato gyvavimo procesą, jo sudėtines dalis, jame dalyvaujančias suinteresuotas grupes ir šį projektą veikiančią išorinę mikro-, meso- ir makrolygmens aplinką. Su šiomis sistemomis buvo atliktas vienbučių gyvenamųjų namų, žemės ūkio gamybinių, pramoninių, monolitinių gyvenamųjų bei kitų pastatų gyvavimo proceso ir jo sudėtinių dalių variantinis projektavimas, daugiakriterinis įvertinimas ir naudingumo laipsnio nustatymas.

4. Siekiant padidinti pastatų gyvavimo proceso efektyvumą, buvo sukurtas Lietuvos statybos šakos analizės, modeliavimo ir prognozės modelis [38–51], kurį įdiegus praktikoje būtų sudarytos sąlygos racionaliau įgyvendinti pastatų gyvavimo procesus. Šio darbo teoriniai rezultatai buvo pritaikyti atliekant mokslinius tyrimus pagal PHARE programą bei vykdant Statybos ir urbanistikos ministerijos užsakymus. Taikydamos šį modelį statybos šakos organizacijos ir kitos suinteresuotos grupės, atsižvelgdamos į esamus mikro- ir makrolyg-

mens aplinkos apribojimus bei galimybes, galės racionaliau panaudoti savo išteklius.

5. Kuriamos elektroninės komercijos sistemos [52–56].

Studijų procese taip pat vyko permainos. Jos buvo susijusios su naujausių informacijos technologijų diegimu į mokymo procesą. Jau aprašomuoju laikotarpiu Statybos technologijos ir vadybos katedroje buvo nemaža studijų programų: pagrindinės studijų programos (statybos valdymas (pakraipos: statybos technologija ir vadyba; statybos ekonomika ir verslas) ir nekilnojamojo turto vadyba); specialiųjų profesinių studijų programa (statybos ekonomika ir verslas); magistrantūros studijų programos (statybos valdymas (specializacijos: statybos technologija ir vadyba; statybos ekonomika ir verslas) ir nekilnojamojo turto vertinimas ir vadyba). Nuo 1999 m. katedroje vyksta nuotolinės (internetinės) magistrantūros „Nekilnojamojo turto vertinimas ir vadyba“, o nuo 2000 „Statybos ekonomikos ir verslas“ studijos [32, 33, 57]. Numatoma, kad minėtas programas katedroje 2001 m. baigs 245 studentai. Taip pat prof. E. K. Zavadskas parašė daug straipsnių ir knygų studijų efektyvumo didinimo klausimais [58–82].

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Edmundas Kazimieras ZAVADSKAS. Doctor Habil, Professor. Rector of Vilnius Gediminas Technical University. Member of Lithuanian Academy of Sciences. Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-2040 Vilnius, Lithuania. E-mail: Rector@adm.vtu.lt

In 1973 PhD (building structures). Professor at the Dept of Building Technology and Management. In 1987 Dr Habil (building technology and management). Research visits to Moscow Civil Engineering Institute, Leipzig and Aachen Technical Universities. He maintains close academic links with the universities of Aalborg (Denmark), Salford and Glamorgan (Great Britain), Poznan University of Technology (Poland), Leipzig Higher School of Technology, Economics and Culture (Germany) and Aachen Technical University (Germany). Member of international organisations. Member of steering and programme committees of many international conferences. Member of editorial boards of some research journals. Author of monographs in Lithuanian, English, German and Russian. Research interests: building technology and management, decision-making theory, automation in design, expert systems.

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Artūras KAKLAUSKAS. Doctor Habil, Professor. Dept of Building Technology and Management. Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-2040 Vilnius, Lithuania. E-mail: property@st.vtu.lt

A graduate of Vilnius Civil Engineering Institute (since 1990 Vilnius Technical University) (1984, civil engineer). PhD (1990). Research visits to Aalborg University (Denmark, 1991), University of Glamorgan (UK, 1993/1995). Author and co-author of 4 monographs and more than 50 papers. Research interests: multiple criteria decision-making, expert systems, total quality management, computer-aided design.

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METHODS FOR RISK MANAGEMENT IN CONCRETING AT LOW TEMPERATURES

J. Pasławski

Poznań University of Technology

1. Introduction

The notion of risk seems obviously associated with business activity. Although reduction of risk is enhanced by such elements as a reduced task complexity, on the one hand, knowledge of any possible event liable to occur during the task execution, having complete information, all the necessary means required for the task, execution and the necessary experience to fulfil the task, on the other, such situation would be exceptional in business practice. Therefore, the notion of risk must not be underestimated in business.

The construction industry is a specific kind of business as regards its exposure to risk [1]. One of the basic elements of risk involved in the construction industry is the influence of climate and weather, which for obvious reasons affect the process of concreting at low temperatures. Being highly variable, weather conditions are liable to cause serious problems in the process of concreting, such as demolition of a structure or element having a poor quality. Therefore, it seems advisable to investigate the problem for identifying the sources of risk and defining acceptable strategies of risk management.

The notions of risk and uncertainty will be defined in the first place, since these key terms are variously interpreted by authors. Discussion of methods of how to proceed in conditions of risk and uncertainty as well as the applicable strategies of risk management will follow.

2. Risk and uncertainty

Since the notions of risk and uncertainty are variously explained due, first of all, to an approach based on probability and mathematical statistics and, second, to their informal interpretation, these notions need to be clearly defined.

In most references [2–4], Knight is indicated as the first author to have formalized the notion of uncertainty. When examining phenomena connected with economic competition, Knight noted problems arising out of our inaccurate knowledge of the future. In his classification, three categories of probability are involved [5]:

- a priori probability – entirely known and invariable mathematical probability;
- statistical probability – experimentally determined occurrence of events;
- estimated probability – one that is not based on any values, whether mathematical or experimental.

The a priori probability is defined by logical reasoning and based on the knowledge of possible events and their identity, ie the chance of their happening. Therefore, empirical research to determine the chance of a certain event out of a definite set of events happening is not required in the case of the a priori probability. This kind of probability is obviously more typical of gambling rather than running a business.

The second category of probability in the Knight classification, the statistical probability, involves the necessity to find empirically the frequency of certain possible random events happening. It is not possible to indicate any set of events with the same probability. Unlike the a priori probability, the statistical probability provides just empirical generalization within a given group of events, without providing much information on a specific single event.

Although the statistical probability tends to occur more frequently in business practice than does the a priori probability, the type of probability that is typically encountered in business is one that has no measurable basis for classification of events [3]; it is referred to as 'estimated probability'. Association of a given estimated probability with an element of a given set results from one's knowledge and experience. According to Samecki [3], all three categories of probability have one characteristic in common: there is a finite set of alternatives and determination of probability results from one's objective knowledge in all three cases. The difference is that probability distribution is objectively expressed in a numerical form in the two former cases, while in the third case, it is based on a subjective opinion of a person in his or her probabilistic reasoning.

As regards the question of differentiating between risk and uncertainty, having examined the works of Knight and Shackle, Samecki [3] finds that risk requires the possibility of definition according to one of the three groups of probability indicated by Knight, each of them is based on objective knowledge. Probability, the essence of risk, assumes knowledge which, in turn, excludes uncertainty. The latter is the case whenever probabilistic reasoning is inapplicable. Under the circumstances, anticipation of a result may just be an act of creative imagination while the consequences of the decision taken can not be accurately indicated. According to the above definition, unexpectedness, a feature inherent in such decision, is the key element.

On the other hand, in Perrouty and d'Harteville's [5] interpretation of the Knight theory, the type two of risk is most frequently encountered while according to Knight, risk is connected with the type one (a priori) probability, while uncertainty is with the type three (estimated) probability. A notable difference between the two opinions is the approach to the estimated probability: some authors (eg Samecki [3], Popławski [2]) perceive it as a definable value while others (eg Perrouty and d'Harteville [5]) do to the contrary.

According to Nogalski and Rybicki [4], problems with determining a univocal approach in the nomenclature of risk and uncertainty may be interpreted as proof of their complex nature and the necessity of the realization that actions taken in conditions of risk are not dependable ones. Furthermore, they emphasize an important difference in various approaches to the issue of risk: it may be perceived either as a hazard alone (possibility of loss) or also positively (possibility of either loss or gain). A similar approach is presented by Popławski [2] who refers to profit as a specific form of remuneration to a businessman for his taking initiative, risk and making the right decision. In the present paper, risk is referred to as a hazard of incurring a loss that results from taking a certain decision.

3. Methods to proceed in conditions of risk and uncertainty

In terms of the conditions the works are carried out, for instance, in comparison with industrial processes (which are typical in the latter), the construction industry is a specific kind of business. Consequently, management in the construction industry requires special attention due to the diversity and complexity of situations that may possibly occur. As a rule, any of the following three basic groups of situations may occur [6]:

- Determined conditions,
- Random conditions,
- Indeterminacy conditions.

In business practice, determined conditions occur extremely rarely. They may only be assumed when the influence of random conditions is insignificant.

Construction processes are usually carried out at random conditions. Some of the typical random conditions are: project completion time, weather conditions, equipment failure frequency, etc. A diversity of management methods are applicable when acting under random conditions. As regards weather conditions, avoidance (or holding up the execution of construction works in adverse weather conditions) is a typical strategy. The influence of equipment failure frequency may be reduced by improving the quality of daily maintenance, providing a sufficient stock of machine parts, etc. Another option is to establish a reserve of equipment in any one of the two possible variants: the cold (or unloaded) reserve or the hot (or loaded) reserve. Improved supplies will result in keeping sufficient stock. It should be emphasized that, in management at random conditions, appropriate factors have to be minimized in the first place, followed by finding the most suitable strategy of management in the given situation. Indeterminacy conditions are ones that do not have the deterministic nature, while the extent of influence of random conditions is hard to assess due to the limited set (or even lack) of statistic data. Management at such conditions may be based on theory of games. In the construction industry, the so-called ‘games with nature’ are especially useful (‘nature’ in this case is understood as the various conditions affecting the consequences of decisions taken; nature is perceived as a passive player, one not interested in winning the game at all). Solutions to the games with nature are based on the following decision-making criteria [6]:

a) Wald criterion, also called the mini-max criterion, assumes the most cautious strategy of the decision maker; the choice of such strategy positively means avoiding risk;
b) Hurwicz criterion, in which the decision-maker’s pessimistic view of the anticipated natural conditions may be taken into account as the pessimism factor į (ranging from 0 to 1);
c) Bayes-Laplace criterion, which involves a degree of probability rather than complete uncertainty of the occurrence of natural conditions;
d) Hodge-Lehmann criterion, based on the three criteria mentioned above, where: for $\alpha=1$ it is identical with the Wald criterion, and for $\alpha=0$ it is identical with the Bayes-Laplace criterion.

The choice of management methods should be based on the character of the specific situation in decision-making. Generally, there is a choice of applicable strategies of risk management [7]:

- impassive strategy – avoiding risk by failure to take actions burdened with risk;
- conservative strategy – taking risk cautiously, that is, acting up to certain level of risk only (for instance, holding up the implementation of a new process technology because of the risk inherent in it);
- expansive strategy – typical of taking risk in acting to win higher profits than usual.

The above strategies of risk management are connected with detailed strategies resulting from examining a specific situation in decision-making, taking into account the level of risk and the potential consequences of events (see Table).

Strategies of risk management [7, 8]

Level of risk	Potential consequences		
	Negligible	Medium	Significant
Low	Ignoring	Retention	Reduction
Medium	Retention	Transfer	Reduction
High	Retention	Reduction	Avoidance

Transfer of risk means the transfer to another object of the consequences of a situation burdened with risk (activities of insurance institutions are a typical example). Retention of risk means that risk is retained in an organization. Two variants are applicable to cover losses connected with risk retention:

- active retention – which means that a special fund (financial reserve) is established to cover losses;
- passive retention – which means that potential losses are covered from means other than such special fund.

The retention strategy may be applied provided that the following three conditions are satisfied [7]:

– the consequences and amount of potential loss are easily anticipated,
– the amount of a single loss is relatively low,
– the probability of loss accumulation to a significant amount is insignificant.

Risk reduction is made possible by implementing special safety devices, eg in the area of raw materials quality control or technological process control [9–11].

4. Strategy risk management in concreting at low temperatures

In the light of the above considerations on various strategies of risk management, as regards the process of concreting at low temperatures, the potential risk factors inherent in such process should be taken into account. This analysis is focused on technological risk which seems the key factor in this case. The risk involved in concreting at low temperatures is characterized by the following typical elements:

– fluctuations in the prices of raw materials,
– accuracy with which various components are added to a concrete mix,
– failure frequency of equipment and facilities for making the concrete mix,
– variability of weather conditions during the transport and application of the concrete mix,
– requirement to provide transport of different duration and at various weather conditions,
– failure frequency of equipment and facilities for transporting the concrete mix from the plant to the construction site,
– fluctuations in the parameters of the process technology to apply the concrete mix,

– failure frequency of equipment and facilities for transporting the concrete mix within the construction site,
– failure frequency of equipment and facilities for consolidation of the concrete mix,
– suitability of the methods used for concrete curing,
– failure frequency of heating equipment,
– variability of weather conditions during the concrete curing, etc.

The above elements of risk may be classified in four basic categories, connected with the applicable strategy of risk management. The following basic strategies were used with regard to the above-mentioned potential elements of technological risk in the advisory system for concreting at low temperatures, named COLCON (after COLd CONcreting):

a) ignoring strategy – applicable to failure of equipment and facilities for concrete mix production, transport and application;
b) retention strategy – applicable to fluctuations in the prices of raw materials, accuracy of their addition to the concrete mix, variability of process parameters, and the requirement to provide transportation of different duration and at various weather conditions;
c) reduction strategy – applicable to the variability of weather conditions;
d) avoidance strategy – applicable under unusually bad weather conditions.

Such strategies were implemented in practice as follows:

1) failure to take action to modify the risk related to the situation in decision-making (for item a);

2) establishing a strength reserve to enable compensation of fluctuations in the prices of raw materials and their levels in the concrete mix, having to transport the concrete mix for periods of different duration at various weather conditions, and the variability of the process technology parameters (for item b);

3) establishing a cold reserve in the form of guards and hot air blowing facilities to heat the concrete in the case of a pessimistic scenario for weather conditions;

4) holding up the construction work in the case of unusually bad weather conditions (temperature of air below –5° C or potential drop of temperature to below –15° C the first night after the concrete mix application).

The aim of risk management in concreting, as discussed above, was to carry out the process while minimizing the influence of risk.

4. Conclusions

The approach to risk management, as discussed in the present paper, has emerged as an element of the COLCON advisory system, developed in order to aid decision-making in traffic engineering (construction of engineering structures). It seems that decision-making in situations burdened with difficulties such as adverse weather conditions should be based on an analysis of the costs of holding up construction works (penalties for delays) versus the costs of going on with the construction works (which involve the risk of insufficient quality of work or unjustified high costs).

Obviously, there is also the question of providing the means to carry out the two basic strategies of risk management in the system (apart from the ignoring and the avoiding strategies), namely the following:

- Retention strategy – in the form of the strength reserve;
- Reduction strategy – by establishing a cold reserve (guards and hot air blowing equipment).

Although theoretically independent in the conditions the concreting works are carried out, such strategies have a similar function in minimizing the effect of risk, and the mutual relations between those strategies should be decisive for their contributions in the risk management system.

The validity of the accepted strategy has been shown in the construction works on the execution of the POZNAŃ BY-PASS A2 project in winter 1999/2000 – continued practically without any stoppages and with assured good quality of work.

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BETONAVIMO ŽEMOJE TEMPERATŪROJE RIZIKOS VALDYMO METODAI

J. Pasławski

Santrauka

Pirmiausia pateikiami rizikos valdymo teoriniai pagrindai. Antrojoje studijos dalyje analizuojamas sprendimų, susijusių su betonavimu žemoje temperatūroje, priėmimas. Pateikti tam tikri COLCON patariamosios sistemos sprendimams priimti betonuojant žemoje temperatūroje elementai.

Pateiktas rizikos ir neapibrėžtumo – pagrindinių punktų, kurie įvairiais požiūriais yra analizuojami nurodytoje literatūroje, apibrėžimas. Siūlomi metodai ir jų taikymo, atsižvelgiant į riziką ir neapibrėžtumo sąlygas, galimybės. Tuo pagrįstos suformuluotos rizikos valdymo betonuojant žemoje temperatūroje strategijos. Daug dėmesio skiriama bendrai kompensuojančiajai dviejų pagrindinių strategijų: rizikos išvengimo ir jos mažinimo, charakteristikai. Kaip pagrindinis elementas priimant sprendimus, susijusius su rizikos valdymu pasirenkant bendrą strategiją, išskirta išlaidų analizė.

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Jerzy PASŁAWSKI. PhD, Associate Professor. Institute of Building Structures. Poznań University of Technology, PL 61–699 Poznań, ul. Piotrowo 5, Poland.
E-mail: jerzy.paslawski@put.poznan.pl

Doctor (1994). Supervisor of laboratory for concrete quality for BY-PASS POZNAN A2 project – new highway near Poznań. Research interests: computer-aided systems for concrete technology decisions, numerical simulation of concrete.

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APPLICATION OF MULTICRITERIA DECISION-AID METHODOLOGY IN BUILDING PRODUCTION ENGINEERING

T. Thiel

Poznań University of Technology

1. Introduction

In building production engineering, embracing building investments management and building maintenance, building company management, building processes control, and building materials engineering [1]:

- decision problems occur where various alternatives are assessed, taking into consideration a specific number of criteria;
- specific complications occur while those problems are solved;
- there is a need for accepting such calculation procedures, which would allow incorporating the decision-maker's preferences to a maximum extent;
- instances of inaccuracy, imprecision, and vagueness must be taken into account while analysing the decision problems.

The decision-makers feel the need for applying procedures allowing an extensive comparison and reliable assessment of the accepted alternatives.

Satisfying those needs is much easier thanks to the methodology and methods of multicriteria decision-aid (MCDA).

The article presents a situation whereby the decision-maker is confronted with a problem of multicriteria assessment and final ranking of the compared alternatives of solutions concerning the chosen structures and designs of a road surface feasible under specific Polish conditions.

Poland has recently begun the implementation of the Motorway Construction Programme. For years we have been hearing debates, whether the road surface of Polish motorways should be asphalt (yielding, partially rigid) or concrete (rigid) [2, 3]. In principle, it is impossible to give one good answer as to which road surface type is best. The choice of the construction type for a specific length of a motorway depends on a number of factors, such as the intensity of traffic, weather and climate, feasibility of using local building materials and so on.

2. A short characteristic of the MCDA methodology and methods of multicriteria analysis

Within the area of the MCDA methodology, a number of basic notions can be identified, such as:

- aiding decisions,
- participants of the decision process,
- types of problem statements of multicriteria decision-aiding,
- modelling preferences,
- aggregation of preferences.

All notions have been defined in [4].

Aiding decisions helps designing, building, and strengthening a conviction, but is not a means for pointing at the optimum character of a decision, or a way of dictating which decision should be taken.

The MCDA methodology clearly identifies the participants of the decision-aiding process, and defines their roles and share in this process. Most often, it is the decision-maker and the analyst who are participants in this process. The decision-maker's role is crucial here: he defines the targets, gives estimates on possibility and results, expresses preferences and makes attempts to adjust the process of surfacing the decision to best suit those preferences. The analyst, by nature external to the problem to be solved and to the decision process, handles the decision-aiding process. His role is, among other things, to present a model and use it in arriving at elements constituting the answer, to explain the consequences of that or other behaviour or moves to the decision-maker and, perhaps, to recommend an action or a series of actions, or even a specific methodology to the decision-maker.

Another important issue in the decision-aiding is situating the multicriteria decision problem in relation to one of the four basic problems statements of aiding decisions which facilitate the description of decisions as targets to be aimed at. The following problem areas have been named: aiding multicriteria choice, sorting, ordering, and description.

Other important elements constituting the decision-aiding process are: modelling preferences and formulation of a global model of preferences (preference aggregation).

Modelling preferences in decision-aiding extensively uses the possibility of occurrence of different decision related preferential situations. Therefore, the systems of relational preferences and relational structures of preferences that are their counterparts (much richer than those in the classic decision theory) and are more varied. A system based on binary outranking relation is the most typical example of a relational system of preferences, placing itself within the framework of the discussed methodology.

The MCDA methodology gave way to introducing new models of aggregating, for example, a procedure of aggregating preferences based on the binary outranking relation, a procedure of aggregating preferences based on the local dialogue type assessment.

Within the framework of methodology under discussion, two basic groups of methods can be identified. The division stems from the mode of aggregation: global aggregation is reflected by multicriteria analysis methods, whereas local aggregation is reflected by dialogue methods, sometimes called interactive. The same groups of methods can be identified from the point of view of the character of a set of alternatives.

Methods of multicriteria analysis are used in solving multicriteria decision problems when the set of alternatives is known and well defined at the very beginning of the decision process (the set of alternatives is discrete). The criteria are also directly defined. Additional characteristic notions, typical for methods of multicriteria analysis, are as follows:

– a potential alternative,
– a coherent family of criteria,
– criteria discriminating thresholds,
– a concept (a model) of pseudo-criterion,
– incomparability of alternatives.

All notions have been defined in [4].

3. The choice problem of an appropriate calculation methods, classified as one of multicriteria analysis methods

The selection of an appropriate calculation method, classified as one of the multicriteria analysis methods, can be based on the procedure of multicriteria decision-aiding process, proposed in [5]. The procedure in question facilitates the proper collaboration between the analyst and the decision-maker in the process of multicriteria decision-aiding, and helps overcome difficulties which may come up at the stage of the problem description, as well as select the right method and use it in solving the problem. The procedure has been developed for the type of context in which the process of aiding decisions is targeted at arriving at the final order of all alternatives under comparison (accepting the rank - problem statement of multicriteria aiding). The accepted rank - problem statement of multicriteria aiding is most often used in solving decision problems containing a well defined initial set of alternatives (the amount of alternatives is known). The majority of methods using different items of information on the preferences of a decision-maker have been initiated within this problems statements. Therefore, the selection of the right method in decision-aiding is complicated, the more so that, simultaneously, what needs to be accounted for, is the suggestions and possible recommendations of the analyst, the decision-maker's requirements, and the possibilities of describing his preferences. The procedure, which is proposed, consists of the following stages:

– first stage (I): initial briefing,
– second stage (II): description of the decision-aiding problem,
– third stage (III): selection of the method of multicriteria decision-aiding to solve the analysed problem,
– fourth stage (IV): using the method applied in solving the decision problem.

The most important stage is stage III, focusing on the selection of an appropriate calculation method. It is this stage that is largely decisive about the right solution of the problem, about arriving at the solution in the shortest possible time, and about the trust that the decision-maker places in the analyst, as well as about the acceptance of the final result by the decision-

-maker. The basis of selection of the most appropriate method is constituted by the decision scheme, designed with that purpose in mind, and by the rapport, based on that scheme, between the analyst and the decision-maker [5]. The analyst, at that stage, must help the decision-maker find the right manner of modelling and defining preferences. Furthermore, the selected method should meet certain expectations of the decision-maker related, for example, to the form of the final results, or to other factors which may come up during the rapport between the analyst and the decision-maker.

4. An example of solving multicriteria decision problem

The decision problem being solved refers to the multicriteria assessment and final ranking of the selected alternatives of possible road surface structures and designs which can be practically implemented in the course of construction of a particular section of a motorway under Polish conditions.

4.1. Description of the decision problem

Types of road surface construction

Four alternatives of the designed road surface structures have been used in the analysis. Alternative I and II use asphalt concrete in the top layer (the flexible and semi-rigid construction), and alternatives III and IV - use a cement concrete construction (the rigid construction).

The following is a description of layers in the road surface alternatives:

Alternative I – a flexible construction:

- 0/20 asphaltic concrete abrasive layer, 5 cm thick,
- 0/25 asphaltic concrete binding layer, 9 cm thick,
- 0/31,5 asphaltic concrete base, 12 cm thick,
- 0/31,5 mechanically stabilised crushed aggregate bed, 37 cm thick (laid and condensed in two layers),
- technological layer (working platform), cement stabilised soil, R_m = 2,5 MPa 10 cm thick.

Alternative II – a semi-rigid construction with an anti-crack layer:

- 0/20 asphaltic concrete abrasive layer, 5 cm thick,
- 0/25 asphaltic concrete binding layer, 8 cm thick,
- 0/31,5 asphaltic concrete base 5, 12 cm thick,
- 0/31,5 mechanically stabilised crushed aggregate anti-crack layer, 12 cm thick,
- R_m = 5,0 MPa cement stabilised aggregate bed, 18 cm thick,
- technological layer (working platform), cement stabilised soil, R_m = 2,5 MPa 10 cm thick.

Alternative III – a rigid construction:

- B40 cement concrete slab, 24 cm thick,
- lean concrete layer, 15 cm thick,
- R_m = 2,5 MPa cement stabilised aggregate bed, 15 cm thick,
- technological layer (working platform), cement stabilised soil, R_m = 2,5 MPa 10 cm thick.

Alternative IV – rigid construction, continuous reinforcement:

- B40 concrete slab, continuously reinforced, (reinforcement percentage: μ = 0,67%), 20 cm thick,
- lean concrete layer, 15 cm thick,
- R_m = 5,0 MPa cement stabilised aggregate bed, 15 cm thick,
- technological layer (working platform), cement stabilised soil, R_m = 2,5 MPa 10 cm thick.

Determination of a coherent family of criteria

The assumed alternatives have certain characteristic attributes which, within the scope of the analysed problem, play directly the role of evaluation criteria. The following criteria have been taken into consideration:

- the cost of building 1 m^2 of a given type of road surface in PLN, criterion 1 – crit. 1,
- the cost of work involved in maintaining 1 m^2 of motorway surface in good technical condition over 20 years of service (the cost depends on the amount and kind of maintenance work carried out in this period of time) in PLN, criterion 2 – crit. 2,
- inconvenience for drivers and traffic delays in the phase of actual usage of the motorway related to periodical maintenance work and repair to the motorway surface, criterion 3 – crit. 3,
- calculated durability of the road surface construction expressed in years, criterion 4 – crit. 4,
- feasibility of using local material in the period of building the motorway, criterion 5 – crit. 5,

- road surface resistance to cracks and permanent deformations, criterion 6 – crit. 6,
- the time of building of 1 m² of a given type of motorway surface [machine-hour], criterion 7 – crit. 7,
- environmental impact when the motorway is under construction, criterion 8 – crit. 8,
- traffic noise [dB] (values assumed for a dry surface), criterion 9 – crit. 9.

A description of the motorway surface types, including all the assumed criteria, has been presented in Table 1.

There is an interesting aspect of the problem which has been analysed, namely – within the framework of the alternatives in question – accounting at the same time for the criteria related to the phase of actual building of the motorway surface, and the criteria related to the phase of service of the surface.

Due to the character of the criteria themselves, it is possible to make an evaluation of the road surface alternatives basing on some quantitative or qualitative scales assumed for those criteria.

Table 1. Data describing the types of compared road surfaces on the motorway

Criteria	Alternative I	Alternative II	Alternative III	Alternative IV
Criterion 1 (construction costs)	130 PLN/m^2	110 PLN/m^2	160 PLN/m^2	160 PLN/m^2
Criterion 2 (cost of maintenance work)	replacing the abrasive layer every 5 years (3×10 = 30 PLN/m^2)	replacing the abrasive layer every 5 years (3×10=30 PLN /m^2)	filling in the cracks every 5 years (3×13 = 39 PLN/m^2) and surface retreating every 8 years (2×6 = 12 PLN/m^2)	filling in the longitudinal cracks every 5 years (50%×3×13 = 19,5 PLN/m^2) and surface retreating every 8 years (2×6 = 12 PLN/m^2)
Criterion 3 (traffic delays caused by maintenance work)	temporary closure of 1 lane (3 times in 20 years)	temporary closure of 1 lane (3 times in 20 years)	temporary closure of 1 lane (3 times in 20 years) and temporary closure of 1 lane (2 times in 20 years)	temporary closure of 1 lane (3 times in 20 years) and temporary closure of 1 lane (2 times in 20 years)
Criterion 4 (calculated durability of road surface)	20 years	20 years	30 years	30 years
Criterion 5 (feasibility of using local building materials)	0 cm / 63 cm=0 (0%)	18 cm / 55 cm=0,33 (33%)	15 cm / 54 cm=0,28 (28%)	15 cm / 50 cm=0,30 (30%)
Criterion 6 (surface resistance to cracking and permanent deformation)	average resistance to permanent deformation, considerable resistance to cracking	average resistance to permanent deformation, considerable resistance to cracking	considerable resistance to permanent deformation, average resistance to cracking	considerable resistance to permanent deformation, considerable resistance to cracking
Criterion 7 (the time of building 100 m^2 of the road surface)	12,7 machine-hour	9,1 machine-hour	17,0 machine-hour	15,4 machine-hour
Criterion 8 (environmental impact during the actual building of the motorway surface)	occurrence of 3 harmful factors: dust, aromatic compounds filtering through to the air at high temperatures, soil and ground water pollution	occurrence of 3 harmful factors: dust, aromatic compounds filtering through to the air at high temperatures, soil and ground water pollution	occurrence of 1 harmful factor: dust	occurrence of 1 harmful factor: dust
Criterion 9 (traffic noise; mean values for dry surface)	77 dB(A)	77 dB(A)	82 dB(A)	82 dB(A)

Table 2. Evaluation table – an overview of alternatives of the motorway surface structur

Criteria / Type of road surface	crit. 1 [PLN/m²]	crit. 2 [PLN/m²]	crit. 3 [points]	crit. 4 [years]	crit. 5 [-]	crit. 6 [points]	crit. 7 [m-h]	crit. 8 [points]	crit. 9 [dB]
Alternative I	130	30	3	20	1	3	12,7	4	77
Alternative II	110	30	3	20	0,67	5	9,1	4	77
Alternative III	160	51	8	30	0,72	3	17,0	2	82
Alternative IV	160	31,5	5	30	0,70	1	15,4	2	82

The qualitative scales (discrete values) should be properly designed, on the assumption that the separated states may be equivalent to certain integers.

The grades in the assumed scales (both quantitative and qualitative) constitute a total order reflecting the character of preferences (where the preferences grow with the increase in value), we call the scale an increasing scale – a „profit" type criterion. And where, on the other hand, preferences diminish alongside with the increase of value, we call the scale decreasing one – a „cost" type criterion. It has been assumed that the criteria are monotonous, non-decreasing functions. A function, as defined for the qualitative scales, is a more arbitrary concept.

Regarding the criteria: the cost of building 1 m² of road surface expressed in PLN – crit. 1, the cost of work involved in maintaining 1 m² of motorway surface in good technical condition expressed in PLN – crit. 2, the calculated durability of the road surface construction expressed in years – crit. 4, feasibility of using local material in the motorway building period – a quantity without denomination – crit. 5, the time of building 1 m² of the road surface, expressed by the machine/hour rate (calculated on the basis of the Catalogue of Work Loads KNR 2-31 [6]) – crit. 7, traffic noise [dB] (values for a dry surface have been taken directly from [3]) – crit. 9, the evaluation of alternatives is made on the basis of quantitative scales (the scale of money, of time and of volume – a coefficient of the percentage share of local building materials with regard to the total amount of building materials in the total vertical cross-section of the layers of road surface, the noise level). This is why the values have been taken directly from Table 1 and transferred to the evaluation table (Table 2), with the only exception being criterion 5, whose values quoted in Table 2 were calculated by the formula of: $1 - U_{mm}$ (a quantity without denomination), where U_{mm} signifies a % share of local building material used in the motorway construction.

A basis for evaluation of the remaining criteria shall be the properly defined qualitative scales, which are described in [7].

Designing an evaluation table

Basing on the assumed solutions regarding the structure of the motorway surface (selected alternatives), and the criteria (all criteria have been taken into account), an evaluation table has been compiled (Table 2) which includes the values available for the criteria in the compared alternatives. The values for the qualitative criteria have been arrived at on the basis of Table 1, and on the data in [7]. The following criteria: crit. 1, crit. 2, crit. 3, crit. 5, crit. 6, crit. 7, crit. 8 and crit. 9 are the „cost" type criteria, whereas criterion 4 (crit. 4) is a „profit" type criterion. The evaluation table represents the conclusion of the problem and is a starting point for further analysis related to the full spectrum evaluation of the compared alternatives of the motorway surface structure, accounting for the criteria which have been originally assumed.

4.2. Selection of the most appropriate multicriteria decision-aid method

Justification of the feasibility of using the MCDA methodology in solving the analysed problem

It was only possible to describe the problem, the way it was done in paragraph 4.1, due to a close cooperation between the analyst and a decision-maker. They both are crucial players in the decision-aid process. Pointing at their individual roles is part of the MCDA methodology. What should be stressed is that a decision-maker was a technology specialist representing a prospective investor. There is a set of potential alternatives within the problem [4]. Each alternative is described by means of values associated with individual criteria. The assumed family of criteria is coherent [4]. From the mathematical standpoint, the problem is poorly defined. Only on the basis of: additional information about the preferences of the decision-maker, assuming a manner of modelling the said preferences, and application of a calculation procedure which enables one to carry out a thorough comparison and a final evaluation of all the alternatives, it is possible to solve the problem. It has been assumed that a target of the comparative analysis in question shall be arriving at the final ordering of the alternatives, from the most to the least favourite. The data used to define the values of the criteria for the alternatives are not absolutely accurate, and this fact is significant in modelling the decision-maker's preferences. The values of a number of criteria are not exactly precise, and this is a result of lack of precision and arbitrariness of the assumed qualitative scales that describe the criteria. That is why, during the comparison of any two alternatives, the decision-maker may want to refrain from expressing an opinion regarding preferences solely on the basis of the fact that, regarding certain alternatives, the values for a criterion may be different (preference) or equal (equality). The decision-maker may, on the other hand, want to stress that the compared alternatives are not equal, and neither of the alternatives is preferred (a situation of weak preference). In such circumstances, a concept of a pseudo-criterion may be used [4]. It facilitates modelling the following situations: equality, weak preference, and ordinary preference by means of introducing indifference and preference thresholds.

All the issues discussed above are characteristic of the methodology of multicriteria decision-aid. The fact that those issues were present in the problem in question, influenced the decision to assume the methodology and to select an appropriate calculation and computation methods which also constitute a part of multicriteria analysis.

Selecting an appropriate calculation method

Using the procedure proposed in [5], and basing on the dialogue with the decision-maker (which in itself is part of the procedure), the ELECTRE III method was chosen. This method:

- accounts for the lack of precision and accuracy of the values describing the criteria;
- gives a decision-maker a degree of freedom in submitting information on preferences regarding individual criteria in the form of indifference and preference thresholds, using the pseudo-criterion model and the veto threshold, as well as information regarding relative significance of individual criteria;
- allows the presentation of the final result in the form of an outranking final graph, defining the outranking levels and placing the compared versions on specific levels.

Description of the selected MCDA method

The ELECTRE III method is based on the binary outranking relation [8]. In this method, the basic set of data consists of the following: a finite set of alternatives, a family of criteria, and information submitted by the decision-maker. This information constitutes indifference thresholds, preference thresholds, and veto thresholds for individual criteria (the thresholds may be constant or take the form of a linear function [8]), as well as the relative significance of the defined criteria. The veto threshold facilitates accounting for the situation of the so-called strong opposition regarding a given criterion. The result of going above the threshold is that, while the first of the compared alternatives is better than the other from the point of view of many criteria, it is impossible to assume a hypothesis that the first option outranks the second. The outranking relation in the ELECTRE III method is built on the basis of the so-called concordance and discordance tests. The values of outranking relations, arrived at as a result of a computation procedure, inform the user about the degree of credibility of occurrence of those relations for all pairs of compared alternatives. The final result, in this method, is an outranking graph which stems from a cross between two preliminary total orders built by means of the so-called distillation procedure [8]. Basing on the interpretation of the final result, the decision-maker may accept the form of the outranking graph, or modify the initial information about preferences.

4.3. Using ELECTRE III in solving the problem

Input data assumed for the calculation constitutes the basic values displayed in Table 2 (the evaluation table). All compared alternatives and criteria have been accounted for during the computation. The information about the decision-maker's preferences – the provided threshold values (threshold functions) and the values of relative significance of criteria have been compared in Table 3.

The decision-maker's experience was a basis for evaluating the alternatives at hand, and it was implemented by providing the information about the decision-maker's preferences, obligatory in the chosen computation method.

It has been assumed that the threshold values shall be constant for all criteria. Regarding the criteria described by qualitative scales, it has been assumed that the indifference threshold shall be zero (the decision stems from the arbitrariness of the assumed grades on the scale). The values of relative significance of the criteria indicate that what is most important for the decision-maker: the cost of building 1 m² of motorway surface, the calculated durability of the motorway surface, and surface resistance to cracking and permanent deformations.

The computation has been made, basing on the input data (Table 2), and on the information about preferences of the decision-maker (Table 3), using the „ELECTRE III" software.

4.4. The analysis of the final ranking

An outranking final graph was a basis for comparison of the debated alternatives of chosen types of construction of the motorway surface. The graph presented in Fig 1 constitutes a final ordering tool in the ELECTRE III method. The first (top) outranking level in the graph is taken by the semi-rigid tape of road surface, with roadway surfaces made from asphaltic concrete (Alternative II). This alternative outranks all other alternatives. The second outranking level in the graph is occupied by the rigid construction, with continuous reinforcement (Alternative IV), outranked by the first level solution, and outranks the remaining two alternatives. The last (bottom) second outranking level in the graph is occupied by the cement concrete construction (Alternative III), outranked by the remaining alternatives. The semi-rigid alternative was so highly rated because it is inexpensive to build, and economical to maintain in good technical condition, while the percentage of usage local building material at the time of actual construction of the motorway is high, and the

Table 3. Information about decision-maker's preferences required by the ELECTRE III method

Criterion / Information about decision-maker's preferences	indifference threshold	preference threshold	veto threshold	relative significance of a criterion
the cost of building 1 m^2 of the road surface [PLN/m^2]	5	15	60	10
the cost of maintenance within 20 years of usage of the road surface [PLN/m^2]	5	10	30	6
assessment of traffic delays during the time of usage due to periodical repair work done to the motorway surface [points]	0	1	–	4
the calculated durability of the road surface construction [years]	5	10	20	8
the feasibility of using local materials in the phase of motorway construction (no denomination)	0,05	0,15	0,60	3
surface resistance to cracking and permanent deformation [points]	0	1	7	7
the time of building 1 m^2 of the road surface [m-h]	1	2	10	3
environmental impact in the phase of building the motorway surface [points]	0	1	–	4
traffic noise [dB]	1	3	9	5

traffic delays at the stage of service of the motorway related to maintenance are the shortest, and it is the quickest to build. On the other hand, the low score given to the cement slab surface resulted mainly from the high cost of building such a motorway surface, high maintenance costs, long traffic delays while the motorway is in use, it would take the longest to build, and the traffic on such a motorway would be extremely noisy.

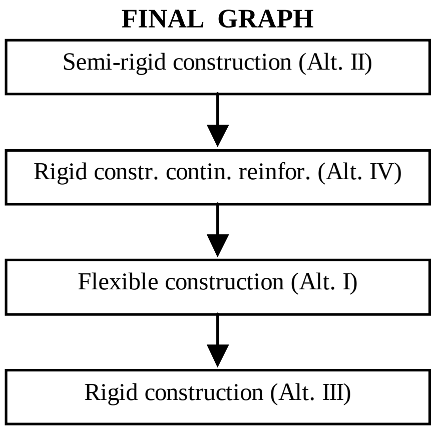

Fig 1. The final ordering of the compared solutions of motorway surface in ELECTRE III method – an outranking graph

Basing on the evaluation table, the credibility matrix, the outranking graph, and information about the decision-maker's preferences, the best solution has been selected, namely the semi-rigid asphaltic concrete construction, as well as the second best, namely the reinforced concrete road surface alternative, and the satisfactory alternative, namely asphaltic concrete flexible road surface alternative and, finally, the worst alternative has been named, ie the cement concrete surface.

4.5. Sensitivity analysis of the final result

Sensitivity analysis is understood to be the influence of the change of values quoted with regard to parameters which include the information about the decision-maker's preferences on the form of the final result (various methods use different parameters reflecting the decision-maker's preferences). It is quite useful in interpreting the results, which have been arrived at, in the course of modifying the values of the appropriate parameters reflecting the decision-maker's preferences, and in estimating the influence of the modifications on the final result.

Within the framework of the analysed problem, the analyst suggested a sensitivity analysis of the final outranking graph that had been arrived at. The decision-maker has quoted some changes in values, which he accepted, with relation to the chosen parameters reflecting his preferences (minimum and maximum values for a specific parameter). In the course of the sensitivity analysis, the decision-maker was not interested in taking into consideration simultaneously the influence of changes in values of relative significance for a single criterion, or for a number of criteria and the changes in threshold values, ie the indifference thresholds (q), preference thresholds (p), and veto preference thresholds (v) for a single criterion or for a number of criteria. What follows is the result of the sensitivity analysis performed depending on the range of changes of the selected parameters reflecting the decision-maker's preferences (the arrangement of the initially assumed preliminary values for all parameters is illustrated in Table 3). Only selected examples of those changes have been presented for individual ranges of change, and the final ranking form.

1. The influence of the change in value of the relative significance introduced only for individual criteria in the initially assumed arrangement of values which had been accepted by the decision-maker – see Table 3 (values of threshold functions: the q, p, and v thresholds remain unchanged – compare Table 3):
   - changes of values of relative significance for the criterion of feasibility of utilising local materials (crit. 5), reducing the significance from 3 to 2 or, regarding crit. 6, the increase in significance from 7 to 8 influenced the form of the final graph of outranking. The same form of final ordering arrived at in that way in all cases has been presented in Fig 2.

2. The influence of changes in values of relative significance introduced simultaneously for a larger number of criteria in the initially assumed and accepted arrangement of values of the relative significance of criteria – see Table 3 (values of threshold functions: the q, p, and v thresholds remain unchanged – compare Table 3):

– changes in values of relative significance introduced for a number of criteria simultaneously, for example, for criterion 1 decreasing the significance from 10 to 9, for criterion 2 increasing the significance from 6 to 7, and for criterion 3 increasing the significance from 4 to 5. Those changes have not influenced the form of the final graph of outranking. The form of the final ranking, arrived at in this case, has been presented in Fig 2.

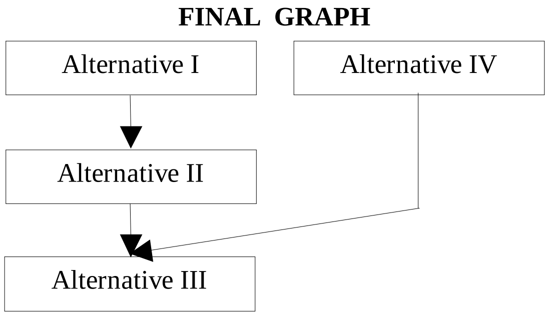

Fig 2. The form of the outranking graph, part of ELECTRE III method, derived from sensitivity analysis within ranges 1 and 2 of changes in values of chosen parameters regarding information on the decision-maker's preferences

3. The influence of changes in threshold functions (for q, p, and v thresholds), introduced for a single criterion only, in the arrangement of values of threshold functions, defined separately for each criterion, initially assumed and accepted by the decision-maker, see Table 3 (the values of the relative significance for all criteria remain unchanged – compare Table 3):

– changes in values of threshold functions – for criterion 1 increasing the value for threshold q from 5 to 8, for threshold p from 15 to 18, for threshold v from 60 to 80, have resulted in the form of the final graph of outranking, as presented in Fig 3.

4. The influence of changes in threshold functions (for q, p, and v thresholds), introduced for a number of criteria simultaneously, in the arrangement of values of threshold functions, defined separately for each criterion, initially assumed and accepted by the decision-maker, see Table 3 (the values of the relative significance for all criteria remain unchanged – compare Table 3):

– changes in threshold (for q, p, and v thresholds) introduced for a number of criteria simultaneously, for example, for criterion 1 increasing the value for threshold q from 5 to 8, for threshold p from 15 to 18, and for threshold v from 60 to 80, for criterion 2, reducing the value for threshold q from 5 to 3, for threshold p from 10 to 6, and for threshold v from 20 to 18, whereas there was only one change for criterion 5, namely increasing the value of threshold p from 0.15 to 0.20, for criterion 6 increasing the value of threshold q from 0 to 1, for threshold p from 1 to 2 (with threshold v remaining unchanged), for criterion 7, increasing the value of threshold q from 1 to 15, for threshold p from 2 to 2.5, and reducing the value of threshold v from 10 to 9, for criterion 9, reducing the value of threshold q from 1 to 0, for threshold p, reducing the value from 3 to 2, and for threshold v, from 9 to 8, resulted in the form of the final graph of outranking, as presented in Fig 3.

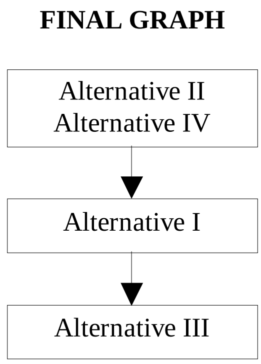

Fig 3. The form of the outranking graph, part of ELECTRE III method, derived from a sensitivity analysis within ranges 3 and 4 of changes in values of chosen parameters regarding information on the decision-maker's preferences

After performing sensitivity analysis the decision-maker relates to obtained results.

Regarding the case of introducing the change of value of the relative significance only for individual criteria and in case of change in values of the relative significance of criteria introduced simultaneously for a larger number of criteria, in the initially assumed and accepted arrangement of values of relative significance of the criteria (see Table 3) which influenced the form of the final graph of outranking (see Fig 2), the decision-maker, basing on the analysis of the evaluation table and the table containing information on his preferences, did not accept this particular form of the final result. As to cases of introducing changes in values of threshold functions, both for a single criterion and for a number of criteria at the same time (in the arrangement of values of threshold functions defined separately for each criterion, initially assumed and accepted by the decision-maker – see Table 3) (compare the ranges 3 and 4 of changes in the sensitivity analysis) which influenced the final form of the graph of outranking (the graph which has been arrived at is presented in Fig 3), the decision-maker, having taken into consideration the values from the evaluation table and the table containing information about his preferences, has finally accepted the form of the final result. He agreed with the fact that, in both cases, the alternatives of solutions of the design and structure of semi-rigid road surface with an anti-crack layer, and a rigid surface with continuous reinforcement may be considered as the best and equal. Nonetheless, the choice of either of those will always be a compromise. If alternative II of the road surface were accepted, economic criteria would support the choice (crit. 1 and crit. 3), ie the criteria of time and of noise pollution. On the other hand, if alternative IV of the road surface were accepted, such a choice would be supported by the practical usage criteria (related to the usage of the motorway), ie the criterion of calculated durability and road surface resistance to cracking and permanent deformation, and the natural environment related criterion, valid during the construction stage of the selected section of the motorway.

Basing on the sensitivity analysis, it is possible to formulate a following conclusion: the decision-maker is able to accept also a different form of the final ranking. It is, nonetheless, possible when the influence of the introduced changes on the final result can be justified, and when the form of this result changes only slightly, compared to the final ranking accepted by the decision-maker before the sensitivity analysis has been performed (see Figs 1 and 3)

The sensitivity analysis of the final result has shown that it is very important for the decision-maker to make sure that his conviction is strong as to the values provided by him for particular parameters which include information about his preferences (see Table 3) and, consequently, that the final result form is credible.

Within the framework of the method accepted, the decision-maker has made a judgement that the interpretation of the final result, the coherence of the result with his preferences, the easy availability of identifying information which may influence the final result, and the way of modifying this information fully reflected his expectations. The decision-maker was not interested in defining the "distances" between alternatives within the final ranking.

This was the end of the procedure of incorporating ELECTRE III and using this method for solving of the analysed decision problem, and the whole the decision-aiding process.

5. Final conclusions

1. Decision-makers tend to fully accept incorporating multicriteria analysis methodology into the process of solving decision problems, notwithstanding the fact that such methods are not fully formalised from the mathematical point of view. Nevertheless, they make room for a variety of information regarding the decision-makers' preferences.

2. Thanks to the ELECTRE III method of multicriteria decision-aid it was possible to make a full spectrum assessment of the assumed alternatives of motorway surface layers, simultaneously taking into consideration certain technological, economical, and practical usage aspects of the problem, and to point at the alternatives which may be regarded as the best.

3. The practical usage result is in keeping with the preferences of the decision-maker. The form of the final result – an outranking graph – and intermediate results is comprehensible and clear for the decision-maker.

4. The solution of the analysed problem is a basis for the statement that the methods of multicriteria decision-aid should be widely applied in the phase of investment planning and construction projects in the building production industry, as well in the phase of initial design (feasibility study).

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DAUGIATIKSLIŲ SPRENDIMŲ METODŲ TAIKYMAS PROJEKTUOJANT STATINIUS

T. Thiel

Santrauka

Glaustai pateikiamos pagrindinės daugiatikslės sprendimų teorijos taikymo problemos ir klausimai, susiję su tam tikrais daugiakriterinės analizės metodais. Aptarta sprendimų priėmimo, vadovaujantis nagrinėjamų sprendimų (kelio dangos projektiniai pasiūlymai) alternatyvų eiliškumu (nuo geriausios iki blogiausios), problema. Analizei pasirinktos sprendimų alternatyvos gali būti pritaikytos, atsižvelgiant į Lenkijos ypatybes. Skaičiavimams buvo pasirinktas daugiakriterinės analizės metodas ELECTRE III, kurį taikant galima nustatyti alternatyvų eiliškumą. Lyginamų alternatyvų galutinė prioritetiškumo eilė nustatoma, atsižvelgiant į jautrumo analizės rezultatus, pasirinkto skaičiavimo metodo rezultatus ir sprendėjo nuomonę. Siūlomas problemos sprendimo būdas rodo, kad daugiatikslė sprendimų teorija ir daugiakriterinės analizės metodai gali būti taikomi investicijų planavimo ir projektinių pasiūlymų etapais.

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Tomasz THIEL. Doctor, C.E., Assistant Professor. Institute of Structural Engineering. Poznań University of Technology. Piotrowo 5, 60-965 Poznań, Poland.
E-mail: tomasz.thiel@put.poznan.pl

PhD (1997). Research interests: organisation, planning and realisation of building process, construction management, decision-making, decision-aiding and operations research in building production engineering.

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MULTIDIMENSIONAL DATA ANALYSIS IN CONSTRUCTION INDUSTRY

A. Fojud

Poznań University of Technology

1. Introduction

At the end of the century, when it not the access to information necessary in taking decisions which is a prerequisite for success, but the speed of analysing and processing such information, the significance and scope of usage of multidimensional information analysis has increased greatly. Strategic decisions must be taken quickly, firmly and, at the same time, leaving enough room for the presentation of accurate arguments supporting a given choice. Possibilities of analysing and using information stored in data warehouses have now twofold significance, looking from the standpoint of strategic decisions [1, 2]. Firstly, fast multidimensional information analysis facilitates the optimisation of decisions, which are to be taken. It is particularly important in the case of decisions being taken in the context of shortage of budget resources, in the framework of the so-called minimum budget economy. Secondly, fast and efficient data analysis quite efficiently supports arguments highlighting the needs, and helps combat the competition with the arsenal of prospective presentation of multidimensional data.

Another important quality of multidimensional analysis is the possibility of obtaining the answer to „what if...” questions in real time, in the so called „on line” mode. Such a possibility of forecasting change and the influence of decisions to be taken involving the object under scrutiny facilitate fast and efficient assessment of options. In order to fully utilise the possibilities of multidimensional analysis, we need to use information technology in modelling the real world in such a way that the analysed objects or their parts are represented as multidimensional entities with a reflection in a data base. The database itself, as an information warehouse describing the world we are trying to model, must be closely linked to the tools used in multidimensional analysis. The set of tools used in multidimensional analysis, together with the properly designed information warehouse, has been found extremely useful in the design aid systems. A similar arrangement may also be used in building an expert or advisory system, assisted by an appropriate conclusion formulating mechanism which would make the most possibilities presented by the multidimensional analysis performed in real time. Due to the fact that the subject area is vast, the problem under discussion has been narrowed down to the question of designing and maintenance of roads and motorways. Due to the editorial limitations, the subject area will be presented in more detail and discussed in the papers to follow this one shortly. This paper is divided into two parts: the first describes the questions of modelling and multidimensional analysis in view of road design, and the second part touches upon the module structure of building an expert system embracing a mechanism of multidimensional analysis of information. How such a system is built will be shown on the example of a Advisory System used in road network management [3].

2. Modelling and multidimensional analysis in design

During the process of numerical modelling, the first element that undergoes analysis is landform (terrain). Landform is created on the basis if land surveys (geodetic measurements) and mapped as a numerical model of land. The elements constituting a numerical model of the land form are the strings of graphic data, ie sets of interrelated points. Each string has its co-ordinates: x, y, an ordinate, and the point number. Moreover, each string has an individual name. Such strings are three-dimensional information strings, called sub-strings.

Sub-strings help describe the landform (terrain), defining the characteristic contours, and dispersed picket points. Such a representation, though, is not an accurate representation of the terrain. Having at our disposal a model consisting of 3D sub-strings representing, for example, the contours of a road, hard shoulders, ditches, and so on, we can put such a model through a process of multidimensional analysis. If such an analysis is performed using a two-stage interpolation (primary and secondary), what we get in effect is a 36-dimension triangulation model. It is a multidimensional analysis of a simple string model with a resulting transformation leading to a triangulation model.

Thanks to such an analysis we obtain an accurate model of the terrain. Another example of multidimensional analysis and the resulting transformation is the analysis of a triangulation model going from the 36-dimension form to a 2.5 dimension form. In effect, we obtain a layer type model of land surface, which describes it equally accurately, with a simplified notation in the data warehouse pertinent to the model.

String type	No. of dimensions	
Master strings	6	X Y Z Chainage Bearing Radius
Geometry strings	12	X, Y, Z, Chainage, Bearing, Radius, Gradient, M value, Hcode, Vcode, HName, VName
Contours	2	X Y
Sub-strings	3	X Y Z
Survey stations	4	X Y Z Station ID
Sections strings	5	X, Y, Z, Offset, Label of intersecting string

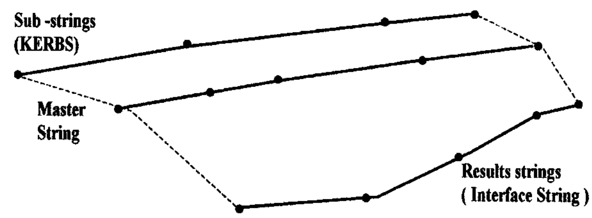

Fig 1. Basic types of strings used in modelling and in multidimensional analysis

Since the route axis is one of the most important elements in the process of designing linear objects, it is defined in a very special way by the multidimensional system. A 6-dimensional string, called a Master String, having referential links with a 12-dimensional geometric string generated automatically when the master string is built defines it. Performing a multidimensional analysis and a geometrical transformation, we can generate the whole body of the road on the basis of the master string.

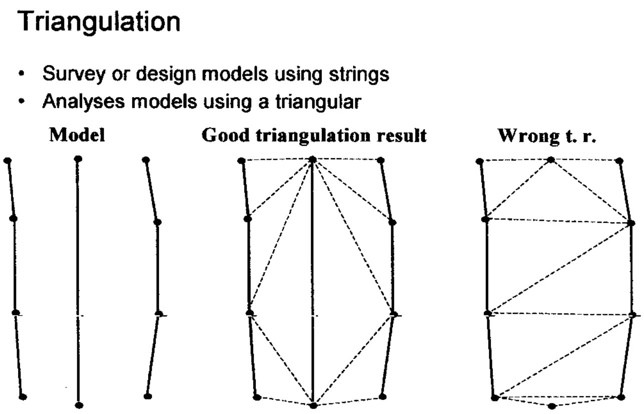

Fig 2. Triangulation – a result of a multidimensional analysis and transformation

Following the analysis of two models, for example, the model of terrain and the model of the designed road body, it is possible to arrive at a string defining the line where those models come across. It is particularly useful in modelling slopes. Such an analysis is performed in a forward and backward option, defining the linking parameters in the two options. In effect, we obtain a 5-dimensional resulting string, called the interface string.

It is possible to use a thorough multidimensional analysis to test a single string model, in order to, for example, arrive at cross or longitudinal sections of the terrain only.

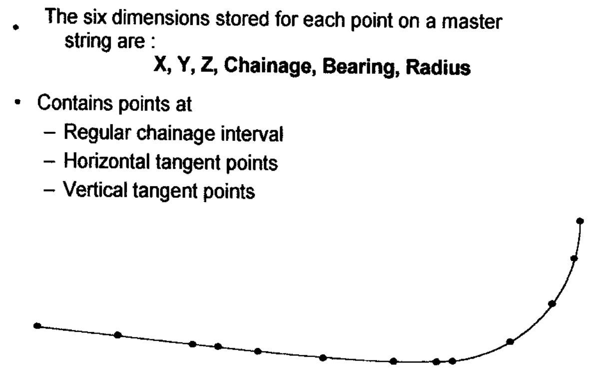

Fig 3. Multidimensional MASTER STRINGS

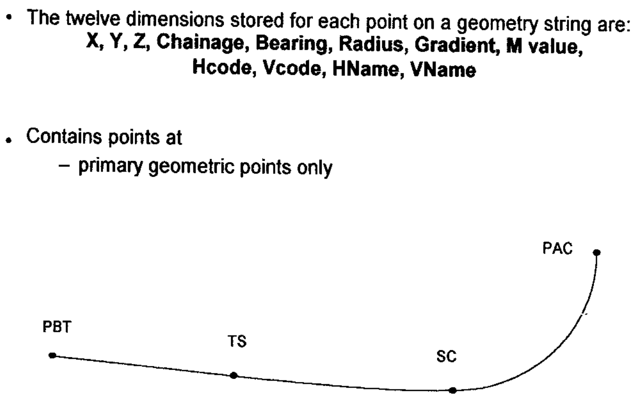

Fig 4. Multidimensional GEOMETRIC STRINGS

Or else, a number of models together arriving at, for example, a designed road body and the terrain, and obtaining the results regarding volume of area of future earth or surface work.

Therefore, a multidimensional model is a good and reliable tool, which can be used in modelling and reviewing design options of different kinds of linear and three-dimensional structures. Summing up, it is possible to adopt the procedure described above to assist and facilitate modelling and multidimensional analysis in design. Using geometric strings, we can give a representation of contours of an existing road, hard shoulder, ditch, pavement, buildings, and so on.

Another element contributing to the information about the modelled fragment of the real world is a string of dispersed points. Such a string may represent a set of point type elements classified into one category, such as: characteristic features land, or trees, lamp-posts, and so on.

This type of string, in contrast to the previous one, does not have obvious geometric links between the points and, therefore, the system analyses it as a set of dispersed points, not accounting for the links between points as contours.

The terrain represented by means of those two types of strings forms the so-called primitive numerical model of the land formation. It is a simplified version of the terrain because the system, during the analysis, may represent an untrue reflection of reality due to, for example, little density of points and contours in the fragment of terrain under scrutiny.

In order to support the person responsible for technical drawings, and try to represent more accurately the numerical model of the terrain, another type of string has been introduced. This string is generated on the basis of the analysis of a primitive model of the terrain.

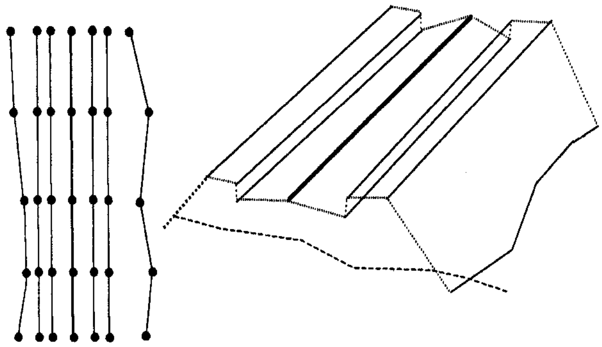

Fig 5. A model of the road body under design together with the terrain model

The string in such a shape has 36 dimensions and represents a model of triangulation of the terrain, ie the representation of the terrain by means of triangular planes of the same inclination.

The basic benefit of the 36-dimensional triangulation string is an accurate representation of the terrain, and its drawback is a huge memory demand. In order to minimise the trouble of having to provide so much information for each individual point on the string, the triangulation string itself is regarded as a transition analysis tool and a basis for generating a string which unequivocally describes a model of the terrain, and has a benefit of being 2,5-dimensional. The reason is that it only has *x*, *y*, *z* co-ordinates, and an ordinate for a heading of each series of points constituting a string.

Another characteristic type of information is a string representing a section of the existing terrain through the modelled body, called an interface. It is a 5-dimensional string, generated automatically as a result of the analysis of the numerical model of the terrain and of the body (Fig 1).

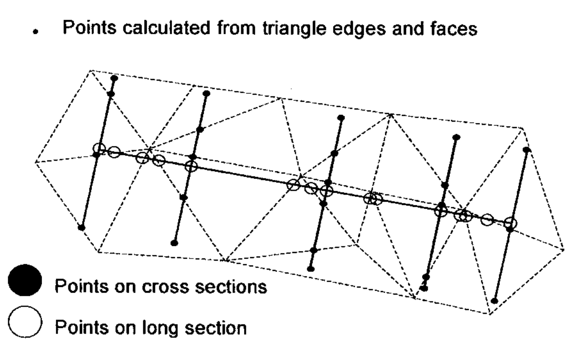

Fig 6. Sections through triangulation

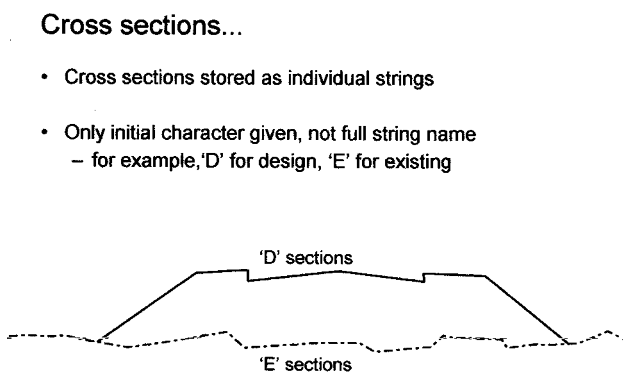

Fig 7. Cross and longitudinal sections resulting from multidimensional analysis of string model

Yet another element occurring in a technical design of a road is the road axis. This element is modelled numerically, often as a 6-dimensional element of the road that, apart from the first four dimensions, namely: point number, *x*, *y*, and *z*, contains information about the azimuth, and about picketage. On the basis of such a string, pending an appropriate analysis, it is possible to generate simple strings and add to the designed body, for example, of a road. Using the elements, so expanded in dimensions, it is possible to make clear designs of various linear objects. A multidimensional character of such a design facilitates fast and accurate analysis of a design and becomes a tool to generate a number of optional solutions. The type of modelling and multidimensional analysis presented in Part I has been used in many new generation CAD systems, and the MX family products based on the MOSS system may serve as a good example of this statement.

3. Multidimensional analysis in property management

Another example of utilising multidimensional data analysis in construction industry is applying it to road maintenance. The awareness of the necessity of planning the development and maintenance of the network of roads, defining strategic targets and methods to reach those targets is a key ability of staff responsible for road network maintenance. Fast development of information technology has resulted in the advisory systems using multidimensional informational analysis in data warehouses becoming the basic tool in property management.

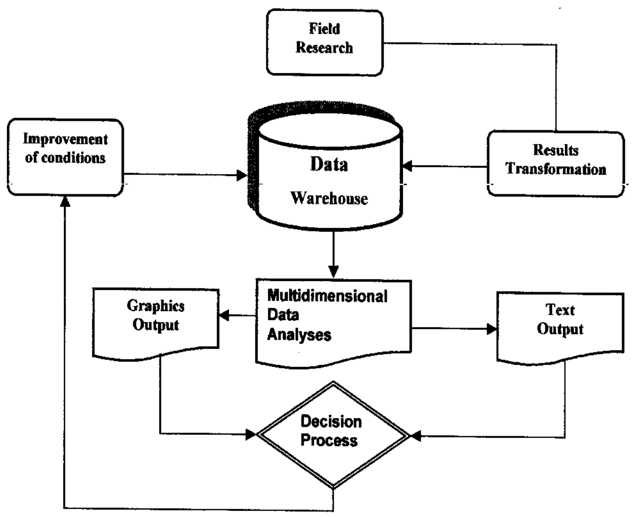

Fig 8. An example of a pattern of an advisory system using a multidimensional analysis module

Proper organisation in data warehouses facilitates fast, multidimensional analysis of information and its prospective presentation. Information is made available and is analysed in accordance with the user's level of accessibility. The authorisation level is a consequence of the role a user of the system plays in the decision-making process, in other words, is a consequence of the user's competence.

The multidimensional character of the advisory system is not only reflected in the way information is analysed, but also in its multidimensional presentation.

In presentation, multidimensional systems use both information displayed as text and graphics. A general pattern of an advisory system, which uses this type of analysis, is shown in Fig 8.

As a result, the advisory system, thanks to the multidimensional analysis of historical information and current data, facilitates the presentation of the real or prospective state of the managed property, depending on the needs of a person taking a decision. The system enables a spatial presentation of information, as illustrated in Fig 9.

A spatial set of information consisting of time, condition, and types of elements facilitates analysis within a given range. The „A" type of spatial perspective presents the result of the analysis, thanks to which we obtain information regarding all objects within a network of streets in a selected time span. Such an analysis may provide an accurate answer to the question of the state of road network over the time that is interesting for the user. Adding other dimensions, such as a set of maintenance decisions, we can obtain simulations illustrating the effect of the decisions which have been taken about the state of managed property.

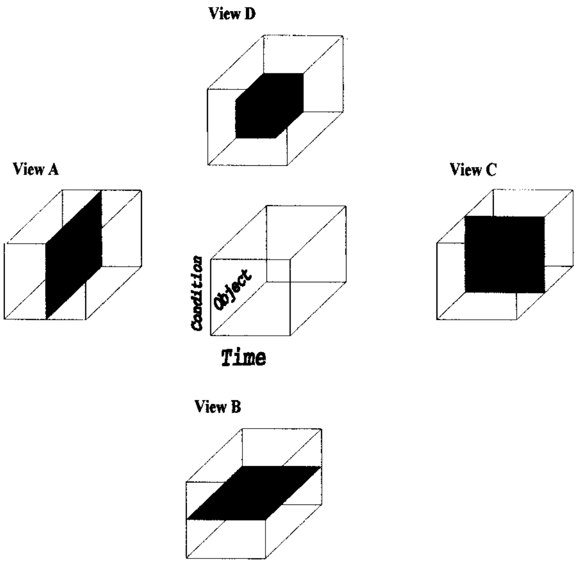

Fig 9. Selected examples illustrating multidimensional features of an advisory system

The „B" perspective presents the result of the analysis which provided an answer to the question as to which elements still remain in the state assumed for them in a chosen time span pointing, for example, at the elements which have not become degraded since the previous year.

The „C" perspective illustrates a possibility of obtaining an answer to the question of the state represented by all the elements categorised as one type. Such an analysis facilitates the verification of the degradation of road surface, for example, from SMA on expressways.

Another interesting example of spatial analysis is the analysis of selected elements which, within the assumed time span, would reach the assumed qualification, for example „poor" – perspective „D". Having a properly designed data warehouse related to the mechanism of multidimensional analysis at our disposal, we could multiply dimensions and categories of the analysis. In effect, we could obtain fast reporting on the existing or forecast state of the network. If we state tasks related to the dimensions we are interested in, and state masks the user is interested in, the multidimensional analysis can provide quite accurate answers to fairly complex problems.

These categories of systems, presented in a sketchy way, have found its way to engineer's everyday practice. Such advisory systems using a multidimensional analysis tool linked with a properly designed data warehouse can be extended by an addition of a multidimensional economic analysis module. The author will present the subject in forthcoming work. The discussed systems facilitate forecasting, and not only with respect to technical condition of the network, but also with respect to the risk related to the decisions which have been taken, and help optimise the distribution of resources necessary to maintain the road network in good technical condition.

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DAUGIAMAČIŲ DUOMENŲ ANALIZĖ STATYBOS VEIKLOJE

A. Fojud

Santrauka

Šiuo metu statyboje vis plačiau diegiamos naujausios technologijos, kartu kiekvienoje pastato ar statinio statybos stadijoje atsiranda vis daugiau projektinių sprendimų. Dėl to kyla įvairių problemų, susijusių su sprendimų priėmimo proceso optimizavimu bei tinkamų argumentų, priimant konkrečius sprendimus inžineriniame darbe, pateikimu. Todėl inžinerinėje praktikoje labai svarbi sisteminė daugiamatės informacijos analizė. Straipsnyje pateikiama daugiamačių duomenų analizės statybos veikloje galimybių studija ir pabrėžiama didėjanti daugiamatės informacijos analizės svarba kasdieniame inžinieriaus darbe, taip pat valdant nuosavybę. Aprašytos projektavimo, pagrįsto daugiamačiais duomenimis, galimybės ir tokių, projektuose naudojamų duomenų, analizė. Antrojoje straipsnio dalyje pateikiama daugiamatės analizės taikymo sprendimų priėmimo sistemose, skirtose žmonėms, priimantiems nuosavybės valdymo sprendimus, naudingumo ir svarbos analizė.

Artur FOJUD. MSc, C. E. /Doctor Candidate/, Assistant in Division of Construction Engineering and Management. Poznań University of Technology. Structural Institute of Engineering, Piotrowo 5, 60-965 Poznań. Poland.
E-mail: Fojud@sol.put.poznan.pl

Research interests: evolutionary programming and genetics algorithms, hybrid advisory systems, databases, scheduling, road management, road design, road conditions and transportation problems.

CAPITAL EXPENDITURE AND RECEIPTS ANALYSIS IN CONSTRUCTION PROJECT MANAGEMENT (DESCRIPTION OF THE MODEL)

T. Wiatr

Poznań University of Technology

1. Problem outline

Traditional project planning in construction industry focuses on the issues of the production process, highlighting elements such as rhythm, continuity, and uniformity. This situation is reflected in an informal and unofficial two-stage management structure of many organisations. It assumes the existence of a higher level of management, specialising in the issues of economy and finance, and a lower (separated) level of management specialising in the issues of technology and production. In this arrangement financial planning is highly general, with little relationship to the complex issues of technology and engineering. Today, in the age of integrated information systems, such an approach to management of project seems truly obsolete.

The approach needs changing by integrating the production planning and the financial planning into one system of management [1]. Looking at it from the theoretical standpoint, the problem can be presented as the question of optimum technological-economic control. The article focuses on the relations between what is spent and received relation to the value of works and project schedule (Fig 1). These relations may be a source of risk, especially in cash flow forecasting [2, 3]. It is very important problem because the extent of risk and uncertainty associated with construction projects is considerable and should not be underestimated [4].

2. Decomposition and systematisation

The project schedule is a basis of the production process in construction industry. The financial schedule (schedule of payments and cash flows) closely related to the schedule of works is a source of integration between the production planning and the financial planning (Fig 1). Cash events (inflows and outflows) reflecting receipts and expenditure are elements of the financial schedule. These events define the discrete character of distribution of the receipts and expenditure. Discrete form of expenditure is in the opposition to actual knowledge [3, 5] because cumulative expenditure are not continuous here (only value of works has a continued form of an S-curve). Proposed name of the model is IVO (Inflow-Value-Outflow) according to these features.

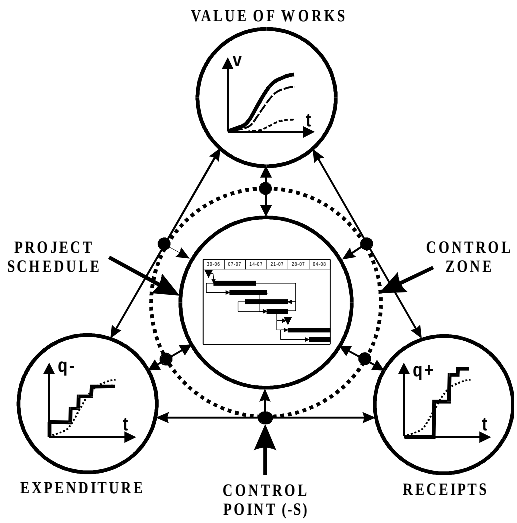

Fig 1. Ideograph of project control (simplified model)

A discrete distribution reflects the project cash flow and it is a basis for financial control. The control embraces four principal quantitative elements: every scheduled receipt should be characterised by quoting the amount received (Q+) and the time when the amount was received (T+). Similarly, every scheduled amount spent should be characterised by quoting the amount spent (Q-) and the time when the amount was spent (T-). Taking the four highlighted parameters into consideration, it has been assumed that each one may be known (answer = 1), or unknown (answer = 0). Basing on the above-defined dichotomy, a systematisation of simple cash flows has been worked out (Fig 2) and described (Table 1).

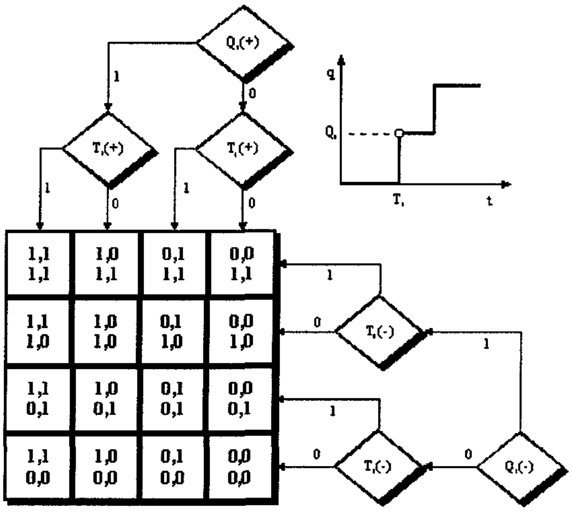

Fig 2. Dichotomic systematisation of simple cash flows

The scope of the classification contains fourteen cases and two extreme cases. The first occurs when the amounts of receipts and expenditure are precisely defined and is, therefore, a deterministic case reflected in the table by four positive answers (1,1/1,1). The other extreme case refers to the situation whereby the dates and amounts of receipts and expenditure are unknown, and it has been reflected in the table by means of four negative answers (0,0/0,0).

3. Interpretation of the model

In practical terms, the dates of some payments (cash events) may be defined rigidly by appropriate law regulations (for example, national terms of taxes – vat and so on) or by contract. In such cases, it must be mandatorily assumed that the date is known (answer = 1). A similar situation occurs in case of amounts which may be fixed at a certain level and, therefore, it should be assumed that the amounts are known (answer = 1).

Description of the simple cash flows (abbreviations: rec. – receipts, exp. – expenditure)

Q-	T-	Q+	T+	Explanation of the simple cash flows
group 1				**all parameters known**
1	1	1	1	known amounts and dates of receipts and expenditure
group 2				**one parameter unknown**
0	1	1	1	known amounts and dates of receipts and expenditure dates, unknown expenditure amounts
1	0	1	1	known amounts and dates of receipts and amounts of expenditure, unknown expenditure dates
1	1	0	1	known dates of receipts and amounts and expenditure dates, unknown amounts of receipts
1	1	1	0	known amounts of receipts and amounts and expenditure dates, unknown dates of receipts
group 3				**two parameters unknown**
0	0	1	1	known amounts and dates of receipts, unknown amounts and expenditure dates
0	1	0	1	known dates of receipts and expenditure, unknown amounts of receipts and expenditure
0	1	1	0	known amounts of rec. and exp. dates, unknown amounts of rec. and exp. dates
1	0	0	1	known dates of rec. and amounts of exp., unknown amounts of rec. and exp. dates
1	0	1	0	known amounts of receipts and expenditure, unknown dates of receipts and expenditure
1	1	0	0	known amounts and expenditure dates, unknown amounts and dates of receipts
group 4				**three parameters unknown**
1	0	0	0	known amounts of expenditure, unknown expenditure dates and amounts and dates of receipts
0	1	0	0	known expenditure dates, unknown amounts and dates of receipts and amounts of expenditure
0	0	1	0	known amounts of rec., unknown amounts of expenditure and dates of receipts and expenditure
0	0	0	1	known dates of receipts, unknown amounts of expenditure and amounts and expenditure dates
group 5				**all parameters unknown**
0	0	0	0	unknown dates and amounts of receipts and expenditure

It results from an evident assumption that all amounts and dates of receipts and expenditure have been defined by a contract and, therefore, in the financial schedule (schedule of all payments) which is part of the contract. This is a basis of a traditional planning practice included in contract regulations (only in solid, detailed agreements). In such a case, the contract becomes a basis for further analyses targeted at the sensitivity analysis of the plan to changes of parameters during the life cycle of project. In this case sensitivity analysis helps finding a searching value in effect of change of a single variable within a project by analysing that effect on the project plan [4] in day-to-day management [6] without probability calculations [7] or with them.

In a wider sense, the simulation may serve the purpose of optimisation of the plan before the contract is signed (like a decision support system in strategic decision-making [6]), like a tool for teaching theoretical concepts [6] or management game. It corresponds with all features of simulation in the branch of construction management [8]. Presented problems are included in general area of the Project Time Management, Project Cost Management and Project Risk Management [9].

4. Simulation and sensitivity analysis

Normally the knowledge of the four above-mentioned parameters (amount spent, date of expenditure, amount received, date of receipt) gives a determinist model. It must be stated that the opposite lack of knowledge of a certain parameter (answer = 0) does not mean that it is completely undefined. In practice, the value of each of the listed parameters may differ within certain limits (in an estimated range) and it defines probability of parameters. In this situation we have probable amounts and dates and a model enabling to calculate the expected risk related to financial schedule.

Moreover, in many cases, a given parameter may be only relatively constant (answer = 1) by way of its dependence on other relatively constant parameters (technical and organisational in particular). The reason is that, in practice, the amounts and dates of receipts and expenditure may be directly dependent on the schedule of works (in many cases). The variability of production parameters effects in delays of partial amounts and partial terms, and all those factors define indirectly the variability of the financial schedule. If many technological and organisational factors come into play, their influence on the distribution of the cash flows may be critical. In this situation we are in need of simulation of work's schedule. In such a case, the risk related to the schedule of works combines (multiplies) with risk of financial schedule according to the probability rules.

If, on top of this, there is some influence of factors which are external to a given project organisation (instability on the construction industry market, inflation etc), the analysis of the variability may be crucial from the point of view of the project success (for example, in lump sum contracts or BOT projects and in developing firms). In these most complex cases value of work may be in a probabilistic form but value of works has a continuous form (cash events are discrete). This case is a combination of discrete-event simulation and continuous simulation.

5. Computers and software

Four cash flow parameters have been discussed above, constituting a basis of a common denominator for individual cases, and presenting them as simple cash flows. Although their number (16 cases) is not big, it must be stated that, in practice, they never occur in pure form. In modelling the complex cases, we must associate (combine) simple cases, using the principle of superposition and (in such a situation) the number of existing parameters in the simulation will grow very fast. Specialist software and a fast computer, with technical characteristics reflecting the complexity of the modelled (simulated) projects, are necessary for analyses - especially in connection with complex risk analysis.

At present there is no single software on the market, which might serve the purpose of carrying out such analyses, and therefore, it is necessary to join together a number of specialist software packages. Good example is the proposition of computer program prepared by Navon [10] but the discussed product is directed only to contracts based on the detailed bills of quantities (BOQ) [10] and this software is not available. Similar specialised systems in Poland are used in practice with the database of cost calculation software. They are too rigid (not flexible) for general research (in all aspects of modelling projects and contracts) because these systems focuse on automatic integration of the cost items with the schedule items [10], [11], not on complex analyses. These systems are very useful for practical cases of particular contracts but less universal in all aspects of the research.

In the practice of all types of building and engineering projects (and in the process of real modelling these projects), the recommended software is the world-famous Primavera Project Planner+Monte Carlo for Primavera. What can be used both for theoretical and practical purposes, is difficult CA SuperProject+Predict, or popular MS Project+@Risk for Project packages.

A possible alternative for special cases is Polish program Planista and modules prepared with adoption of genetic algorithms (GA). Taking into account the analyses of test schedules/model schedules for research purposes the recommended software packages is MS Excel+@Risk in dynamic connection with the latest software listed above (and not listed older Pertmaster Advance) or with the optional usage of the software written individually.

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KAPITALO IŠLAIDŲ IR ĮPLAUKŲ ANALIZĖS VALDANT STATYBOS PROJEKTUS MODELIO APRAŠYMAS

T. Wiatr

Santrauka

Aprašytas bendrasis projektų valdymo modelis piniginių srautų ir gamybos bei finansinių planų priklausomybės požiūriu. Šiame modelyje grynieji pinigai yra diskretaus pobūdžio, bet darbų vertė yra tęstinės S-kreivės formos. Nuomonė, kad išlaidos yra diskretaus pobūdžio, prieštarauja nusistovėjusiai nuomonei. Pagal šią savybę siūlomas ir modelio pavadinimas – IVO (angl. *Inflow-Value-Outflow*). Modelis leidžia analizuoti problemas naudojant specialią programinę įrangą. Modelis gali būti pagrindu jautrumo analizei atlikti, atsižvelgiant į pavienius projektų kintamuosius dydžius. Antra vertus, modelis gali būti modeliavimo ir galimos rizikos vertinimo įrankis. Straipsnyje išryškintas gamybos ir finansų planavimo integravimas į vieną valdymo sistemą. Ši sistema tiesiogiai sukoncentruota į projektą, bet netiesiogiai į statybinę firmą (projektų portfelis).

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Tomasz A. WIATR. MSc. Institute of Structural Engineering. Poznan University of Technology, Piotrowo 5, 60-965 Poznan, Poland. E-mail: tomasz.wiatr@put.poznan.pl

Member of SPMP (Polish Association of Project Management – associate in IPMA). Doctoral student. Research interests: construction project management, computer modelling of projects, making the optimal bar charts and networks, methodical organisation of building sites, planning of formworks and scaffoldings, consulting.

MULTIPLE CRITERIA EVALUATION OF CONSTRUCTION TENDERS IN ACCORDANCE WITH THE LAW ON PUBLIC PROCUREMENT OF THE REPUBLIC OF LITHUANIA

S. Mitkus, T. Dėjus

Vilnius Gediminas Technical University

1. Introduction

In order to select an optimal construction (repairs) tender one should evaluate at least several criteria. The problems of the multiple criteria evaluation of tenders have been examined in literature rather widely [1, 2, 3]. Yet, when organizers of biddings for construction contracts intend to procure construction contracts for funds from the government budget, local self-administration budgets and similar funds such organizers should act in accordance with the Law on Public Procurement of the Republic of Lithuania (hereinafter referred to as the LPP) [4].

The new edition of the PPL came into force on October 1, 1999. Although the concept of the multiple criteria evaluation is used neither in this law nor in the normative by-laws this law provides for the possibility to choose the criterion of the economically efficient tender as a criterion of evaluation of tenders. Item 4 of Article 26 of the LPP has charged the Government of the Republic of Lithuania with the task of approving the methods of determining the evaluation criterion of the economically efficient tender. On December 30, 1999 Government of the Republic of Lithuania approved these methods by Resolution No 1503 [5]. The analysis of the methods approved by this Resolution allows to maintain that these methods will secure the possibility of the multiple criteria evaluation.

This paper is aimed at analysing the possibility of using the multiple criteria evaluation of construction tenders by taking into account the scientific achievements and principles of the LPP.

2. Algorithm of evaluation of construction tenders

When a bidding for construction contract is organized in accordance with the LPP, the algorithm of evaluation of tenders shall be strictly regulated. The procuring organization should provide for all the requirements concerning contractors and their tenders in the procurement documents. In the course of evaluation of received tenders, one should first of all evaluate the formal requirements for tenders that are stipulated by the procurement documents and LPP. Let us assume that the customer has received multitude n of tenders:

$$B = \{B_1, B_2, ..., B_n\}, n \geq 3 . \quad (1)$$

If the number of received tenders is less than two, the bidding shall be regarded as not taken place.

Matrix A (Table 1) of satisfying formal requirements for the tenders received may be formed upon receipt of tenders from contractors.

Table 1. Matrix A of satisfying formal requirements for tenders

B_i \ F_j	F_1	F_2	...	F_m
B_1	a_{11}	a_{12}	...	a_{1m}
B_2	a_{21}	a_{22}	...	a_{2m}
...	...	...	...	...
B_n	a_{n1}	a_{n2}	...	a_{nm}

where F_j – formal requirements for tenders. Some formal requirements are stipulated in the PPL (tenders should be bound, signed, sealed, etc), other requirements are determined by the procuring organization itself (mandatory information, requirements for work, etc).

Elements a_{ij} of the matrix of received tenders are binary, they indicate whether tender B_i satisfies requirement F_j, ie their values may be set to YES or NOT.

The LPP provides for an imperative principle under which the tenders not satisfying the requirements as provided by the law and procurement documents shall be rejected, ie tender B_i shall be rejected if the following condition is satisfied:

$$a_{ij} = \text{"NO" where at least one } j = \overline{1, m} \quad (2)$$

Upon rejection of the tenders that do not satisfy the formal requirements we shall obtain the multitude of tenders that satisfy the formal requirements:

$$C = \{C_1, C_2, ..., C_k\}, 3 \le k \le n. \quad (3)$$

The imperative norm of the LLP (Part 1 of Article 7) requires that the procuring organization should find out whether the contractor is competent, reliable and able to fulfil the conditions of the procured construction contract. Therefore, at a certain stage of the procuring procedure the procuring organization shall be entitled to require that the contractor should submit documents confirming qualification of the latter.

In order to evaluate qualification of contractors one should make up matrix D (Table 2) for evaluation of contractors' qualification.

Table 2. Matrix D for evaluation of contractors' qualification

B_i \ n_j	K_1	K_2	...	K_l
B_1	d_{11}	d_{12}	...	d_{1l}
B_2	d_{21}		...	d_{2l}
...	...	d_{22}	...	...
B_k	d_{k1}	d_{k2}	...	d_{kl}

where K_j – qualification requirements for contractors as provided for in the procurement documents. Elements d_{ij} of the contractors' qualification matrix are binary, they show whether qualification of the contractor who submitted tender B_i satisfies qualification requirement K_j provided for in the qualification documents, ie their values may be set to YES or NO. An imperative principle is stipulated in the LLP which maintains that the tenders submitted by all contractors shall be rejected if they do not meet the requirements specified in the bidding documents, ie a tender shall be rejected, if the following condition is satisfied:

$$d_{ij} = \text{"NO" where at least one } j = \overline{1, l}. \quad (4)$$

A procuring organization may also reject tenders submitted by contractors in the following cases:

1) the contractor who submitted a tender has infringed upon the Competition Law;
2) all contractors have offered prices that are too high and not acceptable for the procuring organization. Tenders may be rejected on these grounds only upon obtaining a permit issued by the Public Procurement Agency;
3) the offered prices are too low and the contractor has failed to substantiate them. The procuring organization may reject a tender on these grounds only in case where the contractor fails to substantiate it upon receiving a request to substantiate the price in writing.

Upon rejection of tenders that fail to meet the requirements, we obtain multitude E of tenders to be evaluated:

$$E = \{E_1, E_2, ..., E_p\}, p \le l. \quad (5)$$

If there are three or more tenders remaining, the received tenders shall be evaluated in accordance with the procedure as provided for in the bidding documents. If there are three or less tenders remaining after rejection of a tender, the bidding is regarded as one that has not taken place, whilst the procurement organization may choose to adopt the following resolutions:

1) to organize negotiated tenders if there are two tenders remaining to be evaluated upon rejection of tenders;
2) to effect a single-source procurement if upon rejection of tenders there is only one tender remaining to be evaluated. If the value of work is in excess of 500 thousand Litas, realization of such a procurement will require consent from the Public Procurement Agency;
3) to announce a new bidding. In this case all tenders shall be rejected, which also requires consent from the Public Procurement Department.

3. Multiple criteria evaluation of tenders

The LPP provides for the possibility of using the criterion of the economically efficient tender during evaluation of tenders. This criterion may be used in the case of procuring a construction contract by open tenders, limited tenders and negotiated tenders if the procuring organization has provided for such kind of tenders in the procurement documentation.

The LPP provides for strict limitations in cases where the procuring organization may evaluate tenders using the evaluation criterion of the economically efficient tender, ie when one may use multiple criteria evaluation of tenders. Economic usefulness of construction tenders may be evaluated only if both of these conditions are present:

1) the construction work is being procured in combination with the project services of the procured object of work. In case when the work is procured under the preliminarily prepared project covering the constructional and technical solutions, economic efficiency cannot be evaluated;
2) determination of limits of technical parameters (functional parameters and operating costs) of the procured object in the procurement documentation does not guarantee the procuring organization a sufficiently good selection of tenders.

In addition to the price, the evaluation of economic efficiency may include evaluations of functional properties and operating costs or one of them. Operating costs may be evaluated in the following cases where there is an opinion that:

1) operating costs of the construction object will amount to not less than 50% of the object's construction price within the usual period of operation, yet, no longer than 10 years;
2) the permissible difference of operating costs in different tenders may exceed 15%.

Functional properties can be evaluated only if both of the following conditions are present:

1) improvement of functional parameters of the erected object is important for the needs of the procuring organization;
2) difference of essential functional parameters in different tenders may exceed 15%.

Analysis of the procedure of determining the economically efficient tender [5] approved by resolution of the Government allows to draw a conclusion that these methods provide the multiple criteria evaluation of tenders in accordance with the MWSD1 criterion [2].

When evaluating tenders in accordance with the criterion of the economically efficient tender, the procuring organization may evaluate the tender's price, functional properties of the procurement object and operating costs of this object. Matrix U of decision-making in accordance with the above procedure is shown in Table 3.

Table 3. Decision-making matrix U

Tenders under evaluation	Price	Functional parameters				Operating costs
		F_1	F_2	...	F_r	
$\boldsymbol{E}_1$	c_1	f_{11}	f_{12}	...	f_{1r}	e_1
$\boldsymbol{E}_2$	c_2	f_{21}	f_{22}	...	f_{2r}	e_2
...	...	...	...	...	...	...
$\boldsymbol{E}_p$	c_p	f_{p1}	f_{p2}	...	f_{pr}	e_p

Functional parameters may include technical characteristics of the procurement object (thermal resistance, stability, durability), aesthetic properties, impact upon the environment, etc. Operating costs are future costs associated with the utilization of the erected object. Only those costs may be added which are selected for evaluation of tenders and specified in the procurement documents. Index duplication should be avoided while determining the functional properties and operating costs to be evaluated. For instance, if the thermal resistance of the enclosure is chosen as a functional parameter, then the heating of the building should not be evaluated as operating costs, and vice versa, because there is a great inter dependence of these parameters.

The methods of normalizing the decision-making matrix, which methods are stipulated in the law and by-laws [4, 5], differ from the methods described in many scientific papers [1, 2, 3]. The greatest peculiarity lies in the fact that a two-level system of coefficients of importance is used (Table 4).

Table 4. System of coefficients of importance

Levels	Coefficient of importance of price	Coefficients of importance of functional parameters				Coefficient of importance of operating costs
		1	2	…	R	
1	X	Y_f				Y_e
2		L_1	L_2	...	L_r	

The procuring organization shall specify the coefficients of importance of the price, functional parameters and operating costs in the procurement documents, which coefficients shall total up to 100:

$$X + Y_f + Y_e = 100, \quad (6)$$

where X, Y_f, Y_e – coefficients of importance of the price, functional parameters and operating costs, respectively.

Four methods of determining coefficients of importance are widely analysed in the literature: ie methods of entropy, index value loss, expert test and the complex method [1, 2, 3]. The peculiarity of all these methods, with exception of the expert test method, lies in the fact that they are determined upon formation of the alternatives to be evaluated and upon determination of coefficient values of these alternatives, which values are to be evaluated. The LPP expressively requires that the coefficients of importance to be evaluated should be already specified in the bidding documents, ie prior to formation of the tender matrix. This requirement does not allow to use many possibilities of the multiple criteria evaluation so that the procuring organizations have to resort to the sole opportunity of determining the coefficients of importance, ie by the expert test method. Procurement is often carried out by commissions created by procuring organizations themselves whereof members are not initiated into the multiple criteria evaluation methods. Therefore, having failed to determine the correct coefficients of importance, they may choose to proclaim the tender, which is not the most suitable, the winner, which fact may be considered a drawback in case of applying this method to public procurement.

By-laws provide further restrictions with regard to coefficients of importance. In case of procuring construction work contracts, the coefficient of importance of price evaluation cannot be less than 70, when the price, functional properties and operating costs are evaluated, and cannot be less than 80, when only functional properties or operating costs are evaluated besides the price.

As we can see, irrespective of the fact that there may be several functional properties to be evaluated, only one coefficient of importance shall be assigned to the multitude of them. Therefore, coefficients of importance L_i of the second level whereof total sum equals to one shall be assigned to each functional parameter.

Taking into account the above-mentioned peculiarities the decision-making matrix shall be normalized in the following way. First of all, normalized values of generalized functional parameters shall be calculated by evaluating their coefficients of importance L_i:

$$f_i^n = \Sigma F_i \ , \tag{7}$$

where F_i – evaluation of the i-th functional parameter, which is calculated in accordance with one of these formulas:

$$F_i = \left(P_i / P_{\max}\right) \cdot L_i \, , \tag{8}$$

$$F_i = \left(P_{\min} / P_i\right) \cdot L_i \, , \tag{9}$$

where P_i – value of the i-th functional parameter; $P_{\min}$, $P_{\max}$ – respectively, the minimum or maximum value of the i-th parameter offered by the contractors. Formula (8) is used when the best values of technical parameters are set to maximum, and formula (9) is used when the best values of technical parameters are set to minimum.

The offered prices shall be normalized in accordance with the following formula:

$$c_i^n = c_{\min} / c_i \, , \tag{10}$$

where $c_{\min}$ and c_i – the offered minimum price and the one of the currently considered tender, respectively.

The offered operating costs shall be normalized in accordance with the following formula:

$$e_i^n = e_{\min} / e_i \, , \tag{11}$$

where $e_{\min}$ and e_i – the offered minimum operating costs and the ones of the currently considered tender, respectively.

Normalized decision-making matrix N (Table 5) obtained upon normalization.

Table 5. Normalized decision-making matrix N

Tenders under evaluation	Normalized value of price	Normalized value of technical parameters	Normalized value of operating costs
$\boldsymbol{B}_1$	c_1^n	f_1^n	e_1^n
$\boldsymbol{B}_2$	c_2^n	f_2^n	e_2^n
...	...	...	...
$\boldsymbol{B}_p$	c_p^n	f_p^n	e_p^n

Upon formation of the normalized decision-making matrix, the economic efficiency of each tender may be calculated in accordance with the formula:

$$S_i = c_i^n \cdot X + f_i^n \cdot Y_f + e_i^n \cdot Y_e \, . \tag{12}$$

A priority queue shall be established in accordance with the obtained values of economic efficiency. The procuring organization should propose the contractor who submitted the economically efficient tender to enter into the contract.

4. Conclusions

1. The Public Procurement Law of the Republic of Lithuania and by-laws stipulate that public procurement procedures shall be applied in cases where construction contracts are procured for the money of public and related funds. The above-mentioned law provides a possibility to choose contractors by taking into account not only the minimum price offered but also in accordance with the criterion of the economically efficient tender. Analysis of the methods of determining

the economically efficient tender approved by the resolution of the Government shows that by now the possibility to choose a contractor by application of the multiple criteria evaluation methods has been legally authorised.

2. Although the possibilities for applying multiple criteria evaluation to construction in general and to selection of the best tender submitted by contractors have been widely studied, yet, the application of multiple criteria evaluation by taking into account the currently effective legal norms, which regulate public procurement procedures, has not been investigated.

3. Analysis of legal norms regulating public procurement procedures shows that the multiple criteria evaluation has been legally approved only in accordance with one modified criterion known in the literature [2] under the name of MWSD1.

4. Research into the possibilities of applying methods of multiple criteria evaluation of construction tenders by taking into account the legal regulation of public procurement procedures would allow the procurement organizations to prepare procurement documentation of better quality, the contractors – to bid for construction contracts with more success, as well as to improve the legal normative base regulating the public procurement procedures.

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STATYBOS RANGOS PASIŪLYMŲ DAUGIATIKSLIS VERTINIMAS, ATSIŽVELGIANT Į LIETUVOS RESPUBLIKOS VIEŠŲJŲ PIRKIMŲ ĮSTATYMO NUOSTATAS

S. Mitkus, T. Dėjus

S a n t r a u k a

Norint tinkamai įvertinti statybos rangos pasiūlymus, būtina įvertinti bent keletą kriterijų. Nors statybos rangos pasiūlymų daugiatikslis vertinimas yra pakankamai plačiai išnagrinėtas literatūroje, toks vertinimas, atsižvelgiant į Lietuvos Respublikos viešųjų pirkimų įstatymą iki šiol moksliškai nenagrinėtas.

Nors nei šiame įstatyme, nei poįstatyminiuose norminiuose aktuose nevartojama daugiatikslio įvertinimo sąvoka, šiuo įstatymu yra įtvirtinta galimybė pasiūlymų vertinimo kriterijumi pasirinkti ekonomiškai naudingiausio pasiūlymo kriterijų. Straipsnyje atlikta teisės aktų analizė rodo, kad vertinant rangovų pasiūlymus pagal ekonomiškai naudingiausio pasiūlymo vertinimo kriterijų yra numatyta daugiatikslio rangovų pasiūlymų vertinimo galimybė.

Atlikta Viešųjų pirkimų įstatymo ir poįstatyminių teisės aktų analizė rodo, kad rangovų pasiūlymų daugiatikslį vertinimą galima suskirstyti į tris stadijas.

Pirmojoje stadijoje yra atmetami pasiūlymai, kurie neatitinka konkurso dokumentų reikalavimų. Antrojoje stadijoje atmetami pasiūlymai tų tiekėjų, kurie neatitinka perkančiosios organizacijos keliamų kvalifikacinių reikalavimų.

Trečiojoje stadijoje atliekamas tinkamų pasiūlymų daugiatikslis vertinimas. Parodoma, kad vertinant rangovų pasiūlymus viešuosiuose pirkimuose gali būti taikomas modifikuotas daugiatikslio vertinimo kriterijus, kuris literatūroje yra žinomas MWSD1 vardu [2]. Pagrindinis jo skirtumas nuo literatūroje aprašyto yra dviejų lygių svorio koeficientų sistema (4 lentelė). Viešųjų pirkimų įstatymas ir poįstatyminiai teisės aktai numato ir daugiau daugiatikslio vertinimo galimybių apribojimų, kurie ir yra analizuojami straipsnyje.

Tolesnis statybos rangos pasiūlymų daugiatikslis vertinimas, atsižvelgiant į Viešųjų pirkimų įstatymą, leistų užsakovams pasirinkti geresnius pasiūlymus, o rangovams – parengti konkurencingesnius.

Sigitas MITKUS. Doctor, Associate Professor. Dept of Construction Technology and Management. Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-2040 Vilnius, Lithuania.

PhD (1991). Research interests: theory of multiple criteria decision-making, marketing, construction law. Author or co-author of more than 20 papers.

Titas DĖJUS. Doctor, Associate Professor. Dept of Construction Technology and Management. Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-2040 Vilnius, Lithuania.

PhD (1991). Research interests: theory of multiple criteria decision-making in practice, occupational safety at building sites, improvement of study process. Author or co-author of more than 25 papers.

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ANALYSIS OF EFFICIENCY OF SINGLE-FAMILY HOUSE LIFE CYCLE

N. Kvederytė

Vilnius Gediminas Technical University

1. Introduction

An efficient single-family house is a final purpose of life cycle. It determines the necessity to evaluate various decisions of life cycle of single-family houses, and possibilities to satisfy objectives and requirements of participants of that process. To design and achieve an efficient process of a single-family house life cycle it is necessary to take care of the building efficiency starting from the determination of needs and objectives and ending to usage of a building. In each stage of the life cycle of a building many interested parties are involved: clients, designers, contractors, manufacturers and suppliers of construction materials and products, users, public and municipal institutions, buildings supervisory and repair organisations, etc. While designing the life cycle of a building and making decisions, it is necessary to take into account the interests of these interested parties. Therefore the life cycle of a single-family house has to be designed and implemented taking into consideration its stages, objectives and opportunities of the interested parties after evaluating the environment of micro- and macro-level, simultaneously influencing the efficiency of a single-family house. A variety of factors describing efficiency of single-family houses poses a question: how to evaluate decisions of the life cycle of a building in many aspects?

Many research works have been reported for solving relevant problems of a particular stage of a building life cycle (ie brief, design, construction, maintenance) [1–3]. Most systems, such as QM-XPS [4], the CABMaS research project developed under the heading of "Cooperative Research" [5], and the tools proposed by G. Aouad [6], Y. E. Kalay [7], G. Coetzee et al. [8], use information technology (IT) to support the different decisions of a building life cycle and managing their associated information.

C. M. Eastman et al. [9, 10] presented a survey of software programs, IT, expert and decision support systems used world-wide for solving problems related to brief, design, construction and maintenance processes. According to D. Veeramani et al. [11], the transition of the construction industry to the computer-integrated era requires the development and acceptance of collaboration technologies for all steps of a construction project from design, through construction process planning, as well as project execution and management. In this context, the growing popularity of the WWW and Internet-based technologies is creating new promising approaches to collaborative design, contractor selection, construction process planning and execution, and project coordination.

This paper proposes a model of complex analysis of a single-family house life cycle and the possibilities of its realization. Its purpose is to provide a structure for development of new capabilities and tools for a more efficient implementation of objectives and needs of the interested parties.

2. Analysis and evaluation of efficiency of life cycle of a single-family house

2.1. Development of a model for a complex analysis of a single-family house life cycle

In order to design and realize an efficient life cycle of a building, it is necessary to take care of the building efficiency from the inception to the end of service life. The entire process must be planned and executed with consideration of its key stages, objectives and opportunities of interested parties involved in the process and the environment of micro- and macro level. For complex solving problems and increasing efficiency, a model of analysis of a building life cycle was developed (see Fig) [12, 13]:

- Analysis of component parts of the building life cycle (stages, participants and the factors of environment influencing the building life cycle).
- Multivariant design of life cycle of a building.
- Multple criteria analysis of life cycle of a building.
- Development of rational micro- and macro-level environment.
- Selection of the efficient variant of life cycle of a building and realization of purposes of the interested parties involved.

The life cycle of a building can be divided into five closely interrelated stages, such as inception, design, construction, in-use and demolition. At the stage of inception the client and designers state major requirements and limitations regarding the building in question. A single-family house is being designed with an account of the client's needs as well as the possibilities of designers, constructors, suppliers, etc. At the design stage of building life cycle, multivariant design and multiple criteria analysis should be carried out taking into account the experience gained in realizing similar projects and seeking to harmonize the activities of the interested parties. The strategy and means of its realization related to building maintenance and facilities management should be defined. They should ensure that maintenance and facilities management problems

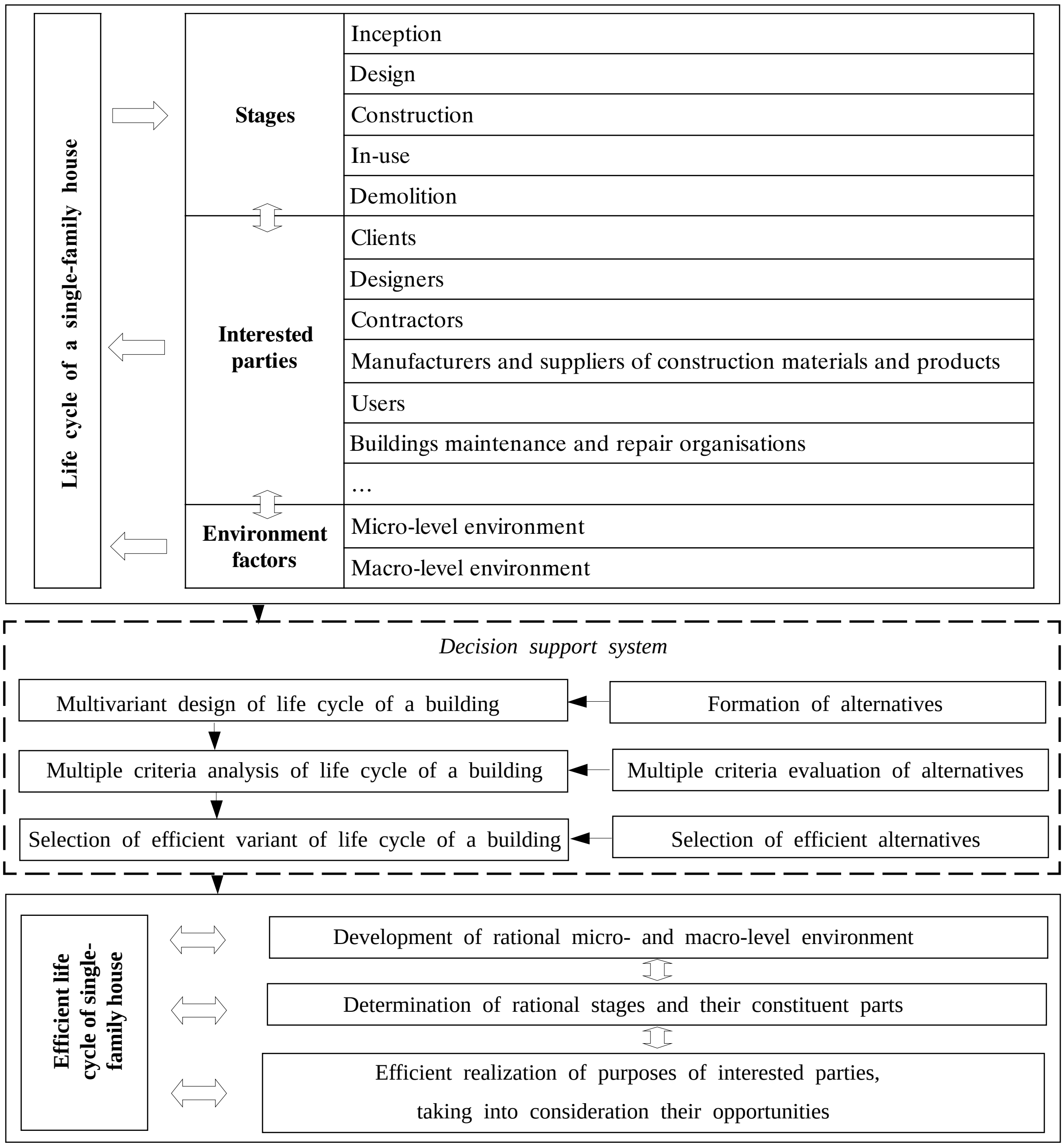

Fig 1. A model for a complex analysis of a single-family house life cycle

are continually dealt with, starting from the inception stage.

A building life cycle may have a lot of alternative versions. These versions are based on alternative inception, design, construction, in-use and demolition processes and their constituent parts. The above solutions and processes may be further considered in detail. For instance, varying its three-dimensional planning, as well as structural and engineering solutions alternative single-family house variants may be developed. Thus, dozens of thousands of alternative versions can be obtained.

Since the rationality of the project aspects often depends on a particular participant, only a complex design of a single-family house life cycle involving close collaboration of major interested parties can lead to good results.

The efficiency of a building life cycle depends on a number of variables, at micro- and macro-levels. The efficiency also depends on the influence of many complex macro-level factors (the government policy, legal and institutional infrastructure, physical infrastructure, financial sector, environment issues, unemployment, interest rate, inflation, innovations, and exchange rate). The efficiency level will, therefore, vary depending on the aggregate effect of these macro-level factors.

The method of multiple criteria multivariant design [14] is applied for making variants of the single-family house life cycle. From the standpoint of long-term prospects, the multivariant design and multiple criteria evaluation of a building life cycle allows the interested parties to make efficient decisions on the ground of quantitative and qualitative variants analysis. Methods of multiple criteria analysis (method of complex determination of the significances of the criteria, method of multiple criteria complex proportional evaluation of the projects, method of defining the utility degree) [14] are applied for complex analysis as well as evaluation of decisions.

Hence, the life cycle efficiency depends to a great extent not only on the selected processes and solutions, the interest level of the parties involved in the project, expressed as the effectiveness of their participation in the process, but also on the micro- and macro-level factors. As Fig shows, the object of investigation is rather complicated; it involves not only a building life cycle and its stages but also the interested parties and micro- and macro-environment factors having impact on the former. For selecting a rational project a new building life cycle complex analysis model was developed. Using this model, the interested parties are able to design alternative variants of a single-family house life cycle (various decisions), to evaluate them and determine the most efficient point: to find an efficient decision for the existing situation. A variety of decisions allows to evaluate more exactly the life cycle in economic, qualitative, legal, technological and other aspects, to agree the interests of the interested parties.

2.2. Realization of a model for a complex analysis of a single-family house life cycle

A practical realization of a model for a complex analysis of life cycle of single-family houses was being developed step by step as follows:

- A comprehensive quantitative and conceptual description of the life cycle of a building, its key stages, interested parties and environment by a set of criteria.
- Development of a complex database based on quantitative and conceptual description of the building life cycle.
- Development of a decision support system of the building life cycle, which would allow to make a complex analysis of such process, to perform a multiple criteria multivariant design and evaluation thereof.

In order to perform a complete study of the building life cycle, a complex evaluation of its economic, technical, qualitative (ie architectural, aesthetic, comfortability), technological, social, legislative, infrastructural and other aspects is needed. The diversity of aspects being assessed should result in the diversity of ways of presenting data needed for decision-making. Therefore, the necessary data may be presented in numerical, textual, graphical (schemes, graphs, charts), formula, videotape and other forms.

In order to assess fully the influence of the constituent parts of a building life cycle affecting the total efficiency of a project, it is necessary to express them through systems of criteria. The alternatives of life cycle of the single-family houses (decisions thereof) are evaluated on the basis of the following criteria groups:

price of a land plot, engineering networks – electric power, water supply, sewerage, etc – telephone, recreational opportunities, roads and access possibilities, dwelling territory, neighbours, district prestige, opportunities of district development, configuration of a land plot, properties of ground, air pollution, etc. Some complex systems of qualitative and quantitative criteria characterising the life cycle are discussed in the author's research [15]. The suggested criteria system allows to evaluate how economic, architectural, technical, technological, comfort and other decisions meet the needs and opportunities of the clients, designers, contractors, users and other participants of this process.

Conceptual and quantitative description of the component parts of a building life cycle provides the information on various aspects of a cycle (ie economical, technical, technological, infrastructural, qualitative, etc). The conceptual description presents textual, graphical, visual information about the projects and the criteria used for their definition, as well as giving the reason for the choice of a particular system of criteria, their values and significances. This part also includes information about the possible ways of multivariant design. The quantitative information is based on the criteria systems and subsystems, units of measurement, values and initial significances as well as the data on the alternative project development.

The life cycle of a building, influencing factors and the interested parties are described in qualitative and conceptual forms. An analysis of component parts of the single-family house life cycle (stages, participants and the environment factors influencing a building life cycle), conceptual and quantitative description of them may be found in [12, 15].

Conceptual and quantitative description of a building life cycle and its stages is used as a basis for developing complex databases containing overall information and allowing to carry out its multivariant design and multiple criteria analysis. Since the efficiency of any project constituent part depends on a particular part of its execution only a complex design of a building life cycle involving close cooperation of all interested parties can yield good results.

Alternative life cycle versions include different cost of a plot and a building, maintenance costs as well as architectural, aesthetic, comfortability characteristics, infrastructure and environment pollution. The interested parties often have their own preferential rating of these criteria, giving also different values to qualitative characteristics. Besides, designing a building life cycle allows the development of plenty of alternative versions of its particular stages. This causes a lot of problems in determining the most efficient project. To overcome these difficulties some complex databases were developed [15]. They contain a complex description of the alternative versions available in conceptual and quantitative forms. These data taken together can describe the object to be considered in detail. The application of complex databases described allows to better satisfy the needs of the parties involved as well as helping to choose an efficient life cycle. The problems solved using a complex database described may be found in some publications of the author [12, 13, 15].

Interacting with the databases the user can get more detailed or integral information on the object considered. Given this opportunity and using the data from complex databases as well as being provided with a decision support system, the user can find an efficient project variant in a comparatively short time. In this way, a project best satisfying the client's needs may be found saving the time for the client and designers.

In order to design a number of alternative life cycle versions as well as to determine the utility degree of the alternatives obtained and to set the priorities, methods of multiple criteria multivariant design and multiple criteria analysis [14, 16] were applied.

It is quite obvious that to develop and analyse thousands of alternative variants based on dozens of criteria having each specific values and significances would be hardly possible without the IT tools. Only development of decision support systems could help solve this problem. Therefore, to achieve the above-mentioned aims an original decision support system "PGP 1.0", its components (ie database, database management system, modelbase, modelbase management system and user's interface) were developed [15]. The system allows to evaluate the single-family houses life cycle in complex, ie to take into account different stages of a cycle, interested parties involved in the process and factors of environment.

3. A decision support system of the single-family houses life cycle

Seeking strategic, economic, technical, social, qualitative and other goals, it is necessary to base on quantitative and qualitative evaluation criteria describing objectives and opportunities, alternative decisions of interested parties, and the existing situation of environment. Seeking to define ground and reach these objectives it is required to apply the methods of multiple criteria design and analysis. Methods of multiple criteria multivariant design and analysis [14, 16] being applied in the developed decision support system, assist to establish in quantitative and qualitative terms an efficient life cycle of single-family houses (decisions thereof) as well as to determine the level of projects utility.

The decision support system for solving problems related to construction activities and the life cycle of a building can be considered a modern and advanced tool. This tool helps the participants of the building life cycle to seek successfully their objectives. While applying the methods of multiple criteria analysis in decision support system it is possible to settle a problem of optimisation of the intended objectives and sources required for their implementation.

Using the information gathered in decision support system database and following the models of model base, the interested parties (including building owners and users, architects, engineers, manufacturers of building materials, contractors, state and its institutions, local governments, etc) of the process of the single-family houses life cycle are able to make efficient decisions. The use of multiple criteria analysis methods in the decision support system makes conditions for implementing objectives of interested parties and satisfying their needs. The solution of sample problems of increasing the efficiency of a building life cycle or its particular stages with the use of the multiple criteria decision support system suggested may be found in the author's research [15].

4. Conclusions and suggestions

1. There is an evaluation model of analysis of the life cycle of the single-family houses developed. The analysis showed that the efficiency of a building life cycle depends on adjustment of stage decisions and interests of parties involved in the process, implementation of objectives and environment influencing the project. Implementation of the developed model of complex analysis would allow the interested parties to meet more efficiently their needs and objectives, to evaluate in detail all expenses relative to implementation of the project and the results obtained.

2. Conceptual and quantitative description of the single-family houses life cycle and different alternatives of its decisions is proposed, which allows to evaluate in detail the life cycle of a building. Following the conceptual and quantitative information, which describes the life cycle of a building, the interested parties (taking into account their priorities and the existing situation) are able to rationalise the decisions made.

3. The proposed methodology allows to evaluate the single-family house life cycle as a whole, ie to take into account different stages of a building life cycle, the interested parties and factors of environment.

4. Methods of multiple criteria multivariant design and analysis being applied in the developed decision support system may be useful for establishing in quantitative and qualitative terms the efficient life cycle of the single-family houses (decisions thereof) as well as to determine the level of utility of projects. The application of the methods of multiple criteria analysis in the decision support system predetermines conditions for implementing objectives of the interested parties (clients, designers, contractors, user, etc) and guarantee a satisfaction of their needs.

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VIENBUČIŲ GYVENAMŲJŲ NAMŲ GYVAVIMO PROCESO EFEKTYVUMO ANALIZĖ

N. Kvederytė

Santrauka

Norint suprojektuoti ir įgyvendinti efektyvų vienbučio gyvenamojo namo gyvavimo procesą, būtina jo racionalumu rūpintis nuo poreikių ir tikslų nustatymo iki pastato naudojimo pabaigos. Kiekvienu pastato gyvavimo proceso etapu dalyvauja įvairios suinteresuotos grupės: užsakovai, projektuotojai, rangovai, statybinių medžiagų bei gaminių gamintojai ir tiekėjai, naudotojai, pastatų priežiūros ir remonto organizacijos ir kt. Projektuojant pastato gyvavimo procesą ir priimant sprendimus, reikia atsižvelgti į šių suinteresuotų grupių interesus. Plėtojant kompleksinį požiūrį, vienbučio gyvenamojo namo gyvavimo proceso efektyvumas priklauso nuo kitų sistemos dalių konkrečiu momentu. Todėl vienbučio gyvenamojo namo gyvavimo procesas turi būti projektuojamas ir įgyvendinamas, atsižvelgiant į jo pagrindinius etapus, dalyvaujančių suinteresuotų grupių tikslus ir galimybes, įvertinant išorinę mikro- ir makrolygmens aplinką, t. y. į visus veiksnius, turinčius įtakos vienbučio gyvenamojo namo gyvavimo proceso efektyvumui.

Straipsnyje pateikiamas vienbučių gyvenamųjų namų gyvavimo proceso efektyvumo kompleksinei analizei sukurtas teorinis modelis, kuriame įvairūs veiksniai ir aplinkybės aprašomi kriterijų rinkiniu. Remdamosi šiuo modeliu suinteresuotos grupės, rengiančios ir realizuojančios projektą, gali projektuoti alternatyvius vienbučio gyvenamojo namo gyvavimo proceso (įvairių sprendimų) variantus, juos įvertinti ir nustatyti racionaliausią: esamai situacijai rasti efektyvų sprendimą. Sprendimų variantiškumas padeda realiau ir racionaliau įvertinti pastato gyvavimo procesą ekonominiais, kokybiniais (architektūriniais, tūriniais, planiniais, estetiniais), teisiniais, techniniais, technologiniais ir kitais aspektais, suderinti suinteresuotų grupių interesus. Pagal pateiktą modelį sukurta ir sprendimų paramos sistema. Ši sistema pastato gyvavimo proceso dalyviams padeda sėkmingai siekti savo tikslų, didinti pastato gyvavimo proceso efektyvumą. Sprendimų paramos sistemoje taikomi pastato gyvavimo proceso daugiakriterinio alternatyviojo projektavimo ir daugiakriterinio įvertinimo metodai leidžia išspręsti siekiamų tikslų ir šiems tikslams įgyvendinti reikalingų išteklių optimizacijos uždavinį: išanalizavus galimus vienbučio gyvenamojo namo gyvavimo proceso variantus nustatomas racionaliausias šio proceso dalyvių (suinteresuotų grupių) siekiamų tikslų ir turimų galimybių derinys.

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Nerija KVEDERYTĖ. Doctor. Dept of Construction Technology and Management. Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-2040 Vilnius, Lithuania. E-mail: nerija.kvederyte@st.vtu.lt

A graduate of Vilnius Gediminas Technical University, civil engineer (1993), MSc (1995). PhD (civil engineering, 2000). Research interests: building life cycle, multiple criteria decision-making, decision support systems.

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MODEL OF RATIONAL HOUSING IN LITHUANIA

A. Banaitis

Vilnius Gediminas Technical University

1. Introduction

Development of housing takes an important place in economic, social and technological activities of a state. At the present moment, among the changes of public, economic, social situation in Lithuania, problems of housing are especially urgent. After the decrease in housing construction and investments in the country, the lack of dwellings has been revealed, problems of homeless people become pressing.

Housing problems are manifold and no complex examinations thereof have been made yet. A lot of variable factors of micro- and macro-level determines the efficiency of housing and trends of its development. Variable factors of macro-level such as a level of economic, social and technological situation of a country, documents regulating construction industry, monetary and fiscal system, inflation, situation on the market, etc, and factors of micro-level such as activities of construction industry companies, financing building organizations, qualification improvement of employees, processes of design, construction and maintenance, etc have a complex influence on the efficiency and development of housing.

The general regularities of these factors affecting the efficiency of housing, trends of their development, mutual dependence are not clear enough. In the present dynamic situation, a question arises how impartially to make prognoses of the future volume of housing. One of possibilities is modelling Lithuanian housing in order to examine the efficient surroundings of housing, ie to determine variable factors of micro- and macro-level that could increase the effectual activities of housing.

The current state of housing and the trends of its development were analyzed from various conceptual and quantitative perspectives by a number of scientists. For instance, P. Balchin [1] studied economic, social and political problems related to dwelling acquisition. M. Ball [2] considered the problems of reducing state expenditures on dwelling, crediting, long-term loans and their various economic, social and political aspects. R. C. Harvey [3] discussed the way the government can affect the housing market through finances, regulating documentation and contracts. In particular, he studied the UK dwelling subsidies, funding and taxes and their effect on demand and offer. J. Hegedus [4] investigated housing strategy in Central and Eastern Europe while P. H. Hillebrandt [5] considered the ways of saving energy in operating buildings. J. Hills [6] summarized the cases when the government may intervene into housing market and the instruments of this intervention. He also dealt with some social problems related to housing. J. Sillince [7] studied some economic, social and political problems of housing. Conceptual and quantitative study of these problems was also performed by A. von Hoffman [8], P. Malpass [9], C. Zimmermann [10] and others.

Researchers from various countries use conceptual and quantitative forms of analysis while studying the effect of certain factors on the housing efficiency. However, the papers mentioned did not deal with a complex approach to housing without taking into account economic, quality, social, technological, infrastructural, legislative and other factors.

The main objective of this research is to present an analytical model of complex analysis of rational housing, following the variable factors of micro- and macro-level surroundings which determine effective selection of housing, to describe these factors comprehensively taking into consideration the gained experience and knowledge in advanced countries and countries of Central and Eastern Europe (CEE), to apply methods of multiple criteria analysis for solving problems of micro- and macro-level of housing, to prepare comparative systems of indices comprehensively describing the housing. Implementation of this purpose allows to reach the complex increase in housing effectiveness.

2. Main stages of working out a model of rational housing in Lithuania

This research seeks to explore ways of harmonizing the relationship between the transition Lithuanian housing and its environment. The research includes the stages presented in Fig 1.

A model in the research is being considered as the system of specific rules in presence of which the housing of Lithuania would apply its potential opportunities. Prospects of future Lithuanian housing and the principal trends of development are linked with analysis of experience and knowledge gathered by advanced and CEE countries, and application thereof having evaluated the specific features of Lithuania. Having used expert methods and analysis of scientific literature, the micro- and macro-level factors are being determined as well as the systems and sub-systems of indices describing them, describing housing in the initial stage. In accordance with the made systems of indices, a situation of housing in Lithuania, CEE and advanced countries is being described conceptually and quantitatively. Following the gathered information, a data-base is made describing variable indices of micro- and macro-level of various countries and their influence on housing. Inviting the information gathered in the database to help, the trends of housing development of advanced, CEE countries, differences of these countries and Lithuania in this field are determined [11].

Having made an analysis of housing differences in Lithuania, CEE and advanced countries on the micro- and macro-level, the tendencies of development of housing of Lithuania are determined.

In order to throw more light on the subject, further follow more detailed description of the some above mentioned stages of analysis.

3. Developing housing indicators

Indicators have been used informally for a very long time, particularly in economics, to evaluate the state of the nation and progress towards national objectives.

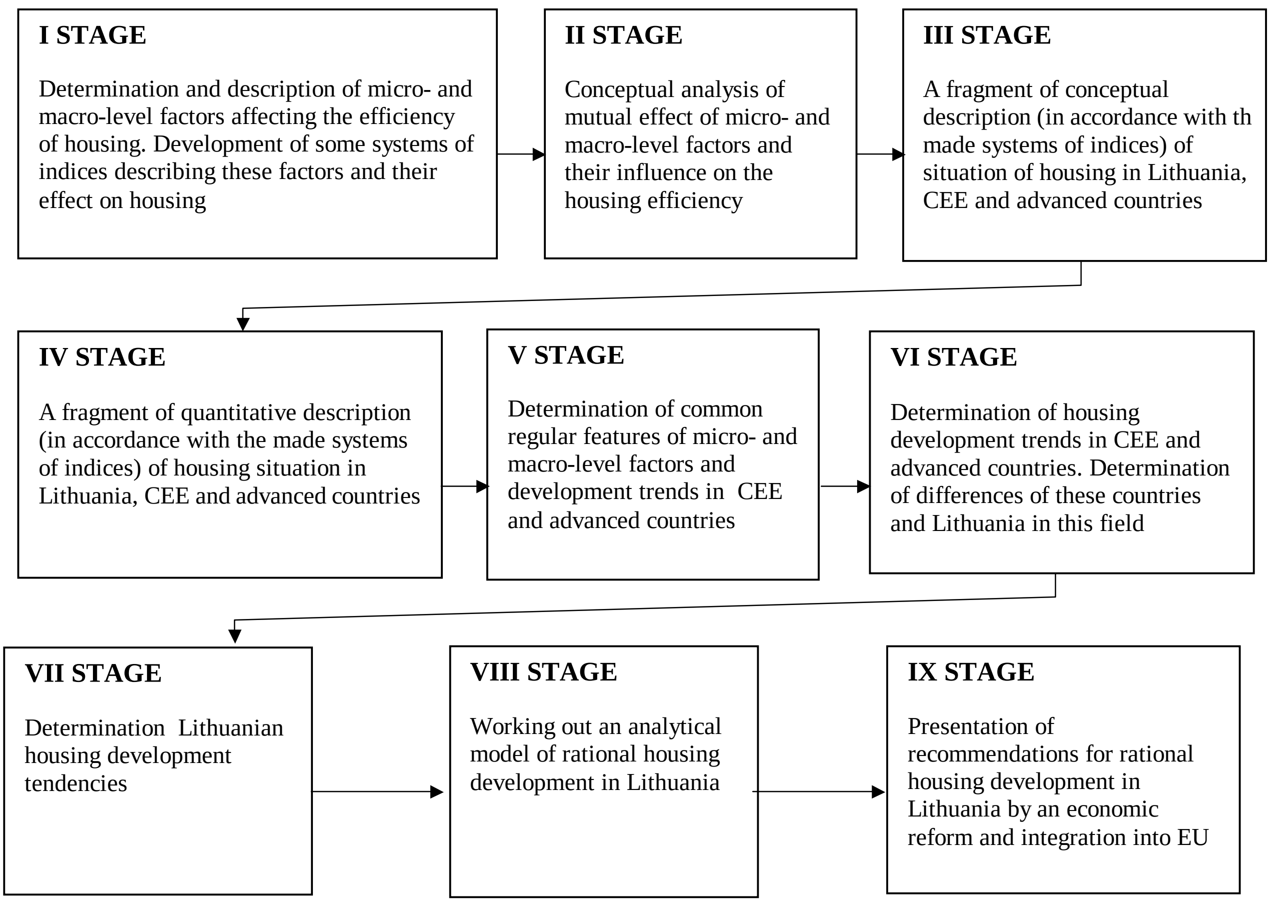

Fig 1. Main stages of working out a model of rational housing

Basically studies on housing indicators have related to particular parts of housing policy, such as housing needs or housing and neighborhood quality rather than to the housing as a whole [12]. Housing Indicators Program was initiated by World Bank and UN Centre for Human Settlement (Habitat) in 1990 and about 150 indicators have been undertaken in several countries. This model is broadly applicable to all policy areas, including housing. However Lithuanian and CEE housing has some unique features that are likely to require special attention.

The performed examinations [11] showed that while solving the problems of housing it is important to create the complex comparative systems of indices describing the housing. Two following systems of indices are suggested in the research:

- Complex system of indices allowing to evaluate the trends of housing policy and activities on a world-scale and allowing to evaluate the housing in countries of different economic development. System of indices allows to determine the problematic fields of housing and contradicting objectives of politics. The system includes indices divided into five groups: *indices describing economics as a whole complex* (GDP per capita; registered unemployment rate; inflation; rate of interest); *indices describing the housing construction, investments and financing* (construction of dwellings per 1000 inhabitants, average useful floor space per dwelling, housing investments as a share of GDP, house price to income ratio, rent to income ratio, housing expenditure, mortgage to credit ratio, long term loans); *indices describing the countries of transitional period* (price liberalization, competition policy, banking reform and interest rate liberalization, governance and restructuring, securities markets and non-bank financial institutions, extensiveness and effectiveness of legal rules on investment); *indices describing the volume, quantity and density of housing* (dwellings per 1000 population, average useful floor space per person, average household size, occupants per dwelling, dwellings with piped water, dwellings with fixed bath/shower, dwellings with flush toilet); *indices describing the housing policy* (dwellings by type of tenure, repair, renovation and energy efficiency, reduction of public expenditure on housing, policy must adequately reflect real situation in country).
- The complex system of housing indices intended to evaluate housing of Lithuania. A system of such group of indices shows potential problems of Lithuanian housing and assists in finding out methods and means to improve the current situation. The system covers indices divided into six groups: *economic* (investment in housing, potential capacities of housing, public investment instruments, private investment instruments, rental policy, systems of housing subsidy); *social* (policies on social housing, social housing affordability and time of waiting); *qualitative, volume and density* (construction of new dwellings, dwellings by period of construction, classification of dwellings according to equipment, renovation, energy efficiency, land supply for housing); *institutional structures* (Seimas / Parliament, central government, counties, local authorities, private sector, owners associations); *legal bases* (law on local authority, law on housing subsidies, law on housing finance and credits, law on construction and maintenance, law on housing acquisition, law on rental housing, law on owners associations, law on restitution of ownership rights to residential houses, harmonization of the legislation and regulation on construction in conformity with those used in EU; *political priorities* (Seimas / Parliament level, governmental level, county level, local authority level).

Following the made systems of housing indices, a comparative analysis of Lithuania, 16 countries of Western Europe, 11 CEE countries and the USA is made, housing of Lithuania evaluated. Following the analysis, the fields of Lithuanian housing has been determined where the current situation is corresponding, partly corresponding and not corresponding to the practice of advanced countries and CEE countries [11].

4. A complex description of housing in conceptual and quantitative languages

An accuracy degree of quantitative description of the housing largely depends on the availability and accuracy of the data as well as on the form of its quantitative presentation. The role of information accuracy is growing with time. The highest accuracy degree of information is reached when it can be expressed in numbers. Therefore, one of the major tasks in creating a model of a rational housing in Lithuania is adequate quantitative presentation of housing activities.

The essence of the process is accurate presentation of system factors in numerical form and indication of their specific measuring units [13].

The efficiency of the housing in a country is largely affected by its economic, political and social situation as well as by such factors as technological development, environment protection, etc. Also various interested parties are involved in housing. Therefore, the variety of measuring units must correspond to the variety of criteria reflecting life cycle process of housing.

Quantitative presentation of various micro- and macro-level factors may be found in literature [14, 15]. Conceptual presentation of housing may also be found in literature [2, 3, 4, 5, 16].

Under some programmes [17, 18, 19], conceptual as well as quantitative description (based on the former) of the present status of Lithuanian and advanced countries housing were made. This formalized presentation is given in Table 1. Any *i* factor of *j* country is given x_{ij} code providing thorough quantitative (system of factors, measuring units, significances, values, as well as a minimizing or maximizing criterion) and conceptual (text, drawings, graphics, etc) information about the alternative being considered.

The magnitude of significance indicates how much in percentage one factor is more significant than the other in a multiple criteria evaluation of housing efficiency. As an example multiple, criteria evaluation of alternative loans from different Lithuanian financial institutions is given in Table 2 [11].

Basing oneself on quantitative description of the current state of housing in advanced countries, CEE and Lithuania it is possible to roughly evaluate the situation in Lithuanian housing in the transition period of its economic development. The conceptual description of the state of housing in advanced countries, CEE and Lithuania is also far from being exhaustive. There-

Table 1. A fragment of quantitative and conceptual description of the present state of housing in compared countries

Quantitative information pertinent to compared countries									
The factors considered	*	Significance	Measuring units	Numerical values of factors of the compared countries					
				a_1	a_2	...	a_j	...	a_n
Quantitative factors	z_1	q_1	m_1	x_{11}	x_{12}	...	x_{1j}	...	x_{1n}
	z_2	q_2	m_2	x_{21}	x_{22}	...	x_{2j}	...	x_{2n}
	...	...	...	...	...	...	...	...	...
	z_i	q_i	m_i	x_{i1}	x_{i2}	...	x_{ij}	...	x_{in}
	...	...	...	...	...	...	...	...	...
	z_t	q_t	m_t	x_{t1}	x_{t2}	...	x_{tj}	...	x_{tn}
Qualitative factors	z_{t+1}	q_{t+1}	m_{t+1}	x_{t+11}	x_{t+12}	...	x_{t+1j}	...	x_{t+1n}
	z_{t+2}	q_{t+2}	m_{t+2}	x_{t+21}	x_{t+22}	...	x_{t+2j}	...	x_{t+2n}
	...	...	...	...	...	...	...	...	...
	z_i	q_i	m_i	x_{i1}	x_{i2}	...	x_{ij}	...	x_{in}
	...	...	...	...	...	...	...	...	...
	z_m	q_m	m_m	x_{m1}	x_{m2}	...	x_{mj}	...	x_{mn}
Conceptual information pertinent to compared countries									
C_f	C_z	C_q	C_m	C_1	C_2	...	C_j	...	C_n

The information provided by code $\mathbf{x}_{ij}$ of *i* factor (evaluation of alternative loans from different financial institutions) *j* country (Lithuania)

The factors considered	Measuring units	*	Significance	Numerical values of factors of the compared loans			
				BalAEF	Vilnius Bank	Agricultural Bank	Hansabank
1. Loan repayment and payment of interest	Lt/month	-	0,8311	1102	1113	1148	1081
2. Hypothecation bond registration fee	Lt	-	0,0028	450	450	450	450
3. A one-off loan administration fee	Lt	-	0,0025	800	400	80	300
4. Life insurance costs	Lt/year	-	0,0115	0	240	240	260
5. Costs of insurance of the real estate to be mortgaged	Lt/year	-	0,0146	184	200	320	230
6. A one-off 30% payment (The mortgage loan covers up to 70% of the value of the housing to be purchased)	Lt	-	0,1371	16000	24 000	24 000	24 000
7. Costs of currency exchange transactions	Lt	-	0,0004	100	0	100	40
8. Maturity of the loan	Years	+	0,2417	10	10	10	10
9. General terms and conditions of the loan	Points	+	0,2477	9,47	7,56	7,34	9,25
10. Notification of the Bank's decision to issue the loan	Weeks	-	0,0020	3	1	2	1

* – The sign (+ (–)) indicates that a greater (less) factor value is better

Table 2. Multiple criteria evaluation of alternative loans from different financial institutions

The factors considered	Measuring units	*	Significance	Numerical values of factors of the compared loans			
				BalAEF	Vilnius Bank	Agricultural Bank	Hansabank
1. Loan repayment and payment of interest	Lt/month	-	0,8311	1102	1113	1148	1081
2. Hypothecation bond registration fee	Lt	-	0,0028	450	450	450	450
3. A one-off loan administration fee	Lt	-	0,0025	800	400	80	300
4. Life insurance costs	Lt/year	-	0,0115	0	240	240	260
5. Costs of insurance of the real estate to be mortgaged	Lt/year	-	0,0146	184	200	320	230
6. A one-off 30% payment (The mortgage loan covers up to 70% of the value of the housing to be purchased)	Lt	-	0,1371	16 000	24 000	24 000	24 000
7. Costs of currency exchange transactions	Lt	-	0,0004	100	0	100	40
8. Maturity of the loan	Years	+	0,2417	10	10	10	10
9. General terms and conditions of the loan	Points	+	0,2477	9,47	7,56	7,34	9,25
10. Notification of the Bank's decision to issue the loan	Weeks	-	0,0020	3	1	2	1
The sums of weighted normalized maximizing indices of the loans S_{+j}				0,0856	0,0763	0,0752	0,0846
The sums of weighted normalized minimizing indices of the loans S_{-j}				0,1606	0,1627	0,1892	0,1658
Significance of the loans Q_j				0,3152	0,3028	0,2700	0,3069
Priority of the loans				**1**	3	4	2
Utility degree of the loans N_j				**100%**	96,06%	85,66%	97,36%

fore, only a combination of two methods can yield a complete picture, demonstrating the actual situation in this field. A quantitative description should be supplemented by detailed conceptual explanation [17, 20]. For more detailed analysis of the housing, with the aim of giving recommendations concerning the possibilities of raising its efficiency, fragmentary description of Lithuanian, advanced industrial countries and CEE housing were made in quantitative and conceptual forms.

The results of this quantitative and conceptual analysis may be widely used for identifying and solving the problems facing Lithuanian housing as far as ways and methods of raising its efficiency are concerned.

5. Conclusions and suggestions

Basing on the research performed it is possible to make the following conclusions and suggestions:

1. The performed examinations showed that it is possible to divide methods and models of construction industry into two groups: quantitative and qualitative ones. Therefore seeking for complex analysis of housing it is necessary to join the qualitative and quantitative evaluations. Only in such a case the complex housing analysis is possible.

2. An analytical complex analysis model of rational Lithuanian housing is developed. The performed examinations showed that the level of effectiveness of housing depends on a specific number of two level – micro- and macro-level variable factors.

3. The performed examinations showed that while solving the problems of housing it is important to create the complex comparative systems of indices describing the housing. Two following systems of indices are suggested in the work:

- Complex system of indices allowing to evaluate the trends of housing policy and activities on a world-scale, and allowing to evaluate the housing in countries of different economic development. A system of indices allows to determine the problematic fields of housing and contradicting objectives of politics. The system includes indices divided into five groups: indices describing economics as a whole complex; indices describing the housing construction, investments and financing; indices describing the countries of transitional period; indices describing the volume, quantity and density of housing; indices describing the housing policy.
- The complex system of housing indices intended to evaluate housing of Lithuania. A system of such group of indices shows the potential problems of Lithuanian housing and assists in finding out methods and means to improve the current situa-

tion. The system covers indices divided into six groups: 1) economic; 2) social; 3) qualitative, volume and density; 4) institutional structures; 5) legal bases; 6) political priorities.

4. The suggested methodology gives an opportunity to solve a lot of objectives of micro- and macro-level analysis of housing.

5. It is seen out of the examinations performed that application of multiple criteria analysis methods allows, on the base of examination of alternative variants, to select the most efficient decisions, to perform the detailed analysis of decisions made, to adjust decisions.

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RACIONALAUS BŪSTO STATYBOS LIETUVOJE MODELIS

A. Banaitis

Santrauka

Būsto statyba užima svarbią vietą ekonominėje, socialinėje ir technologinėje valstybės veikloje.

Būsto statybos problemos yra daugialypės ir nepakankamai kompleksiškai tyrinėtos. Būsto statybos efektyvumą ir plėtros tendencijas lemia daugelis mikro- ir makrolygmens aplinkos kintamųjų veiksnių. Kai yra tokia dinamiška padėtis, kyla klausimas, kaip objektyviai prognozuoti būsto statybos plėtrą. Viena iš galimybių – būsto Lietuvoje modeliavimas siekiant ištirti efektyvią statybos aplinką.

Straipsnyje pateiktas racionalaus būsto statybos Lietuvoje teorinis kompleksinės analizės modelis.

Remiantis įvairių pasaulyje taikomų būsto rodiklių sistemų analize, pasiūlytos kompleksinės būsto statybą apibūdinančios lyginamosios rodiklių sistemos. Rodikliai šiose sistemose traktuojami ne kaip paprasti statistiniai duomenys, bet kaip supaprastinti kompleksinių objektų modeliai. Sudarytos rodiklių sistemos rodo įvairių būsto statyboje dalyvaujančių suinteresuotų grupių interesus.

Straipsnyje pateikta būsto statybos aprašymo koncepcine ir kiekybine forma galimybių analizė.

Straipsnyje siūloma tyrimų metodika leidžia spręsti įvairius būsto statybos mikro- ir makrolygmens analizės uždavinius. Šiems uždaviniams spręsti pritaikyti daugiakriterinės analizės metodai.

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Audrius BANAITIS. Doctor. Dept of Construction Technology and Management. Vilnius Gediminas Technical University (VGTU), Saulėtekio al. 11, LT-2040 Vilnius, Lithuania. E-mail: audrius@operamail.com

Graduated from Vilnius Technical University (since 1996 Vilnius Gediminas Technical University, VGTU), BSc (1994), MSc (1996), PhD (2000). Research interests: building economics and policy, management of construction, multiple criteria complex analysis of construction industry.

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VALUATION OF COMMERCIAL PREMISES BY THE METHOD OF MULTIPLE CRITERIA ANALYSIS

V. Malienė

Vilnius Gediminas Technical University

1. Introduction

A number of problems in the valuation of real property can be eliminated by the methods of multiple criteria analysis, which came into existence only at the second half of the 20th century. Currently, they have become very important in the international practice of the real property valuation. In most cases they are based on market modeling and economic assumptions. Therefore, sometimes they are referred to as separate valuation methods, and classified as modern ones.

This article describes a new method of multiple criteria analysis. This method, based on the market analysis and valuation principle, is in line with the traditional comparative value method, therefore it can be attributed to the group of the indirect comparative value methods. These methods facilitate the universal and more extensive multiple criteria analysis of the property, since they take account of a number of different criteria, ie qualitative, quantitative ones, market conditions [1]. The proposed method can meet the demands and needs of many interested groups since it enables to estimate not only the market value of the property, but also other values, e g investment value, value of use, market value of the current use of the property, etc. This article describes the theoretical model of the method, which was used to estimate the market value of commercial premises.

2. Preparation of the initial data for the multiple criteria analysis

One of the key stages in preparing the initial data is to build a decision-making matrix, which is prepared in the following stages:

- All information about the property to be valued is collected;
- The criteria defining the aims of the multiple criteria analysis are determined;
- Values, significances and units of measurement of criteria of comparable alternatives are defined;
- Criteria, their value and significances make up the grouped decision-making matrix (Table 1).

One of the most important stages in multiple criteria analysis of real property is the determination of the values and significances of the criteria describing the real property objects. Significances of the criteria defining the quality and quantity of the objects to be valued and values of the qualitative criteria for the alternatives are estimated through the application of expert, social, normative, calculation and analogue methods.

When the calculation is performed in accordance with the expert method, the qualitative values of criteria can be expressed in a certain number of points. Criteria can be estimated according to the increasing or decreasing valuation scale.

To estimate the proportional values of the quantitative criteria, the expert valuation is based on comparison. In this case the values of the qualitative criteria are estimated as follows:

- The best suitable value of the criterion x_{best} is selected;
- The value of the best selected criterion is a set equal to the magnitude of one point ($x_{best} = 1$);
- The ratio between the best criterion's value ($x_{best} = 1$) and the rest values (x_i) of the same criterion is estimated and expressed in percentage (p_i);
- The relative values are attributed to the remaining values of the criterion ($x_i = 1 - p_i \div 100$);

Relative values of all the criteria are a set equal to the magnitude of one point.

Table 1. The grouped decision-making matrix of the multiple criteria analysis of the objects to be valued

Quantitative information pertinent to objects									
Criteria under consideration		Significance	Measuring units	Real property objects to be valued					
				1	2	...	j	...	n
Quantitative criteria	z_1	q_1	m_1	x_{11}	x_{12}	...	x_{1j}	...	x_{1n}
	z_2	q_2	m_2	x_{21}	x_{22}	...	x_{2j}	...	x_{2n}
	...	...	...	...	...	...	...	...	...
	z_i	q_i	m_i	x_{i1}	x_{i2}	...	x_{ij}	...	x_{in}
	...	...	...	...	...	...	...	...	...
	z_t	q_t	m_t	$_{t1}$	x_{t2}	...	x_{tj}	...	x_{tn}
Qualitative criteria	z_{t+1}	q_{t+1}	m_{t+1}	x_{t+11}	x_{t+12}	...	x_{t+1j}	...	x_{t+1n}
	z_{t+2}	q_{t+2}	m_{t+2}	x_{t+21}	x_{t+22}	...	x_{t+2j}	...	x_{t+2n}
	...	...	...	...	...	...	...	...	...
	z_i	q_i	m_i	x_{i1}	x_{i2}	...	x_{ij}	...	x_{in}
	...	...	...	...	...	...	...	...	...
	z_m	q_m	m_m	x_{m1}	x_{m2}	...	x_{mj}	...	x_{mn}
Conceptual information pertinent to objects (texts, drawings, graphics, tapes)									
K_f	K_z	K_q	K_m	K_1	K_2	...	K_j	...	K_n

The sign z_i (+(-)) indicates that a greater (less) criterion value corresponds to a higher demand of the interest party.

Initial significance of the criteria is determined in a similar way. The market price of a real property object reflects quality and quantity, supply and demand for the object, therefore, the significance of the market price criterion for the given object is equal to the total sum of significances of all the rest criteria, ie to one point or 100%. The significances of other criteria are determined by the expert method.

The decision-making matrix must be prepared in order to carry out the multiple criteria analysis of real property. The matrix is prepared through the analysis of the quantitative and conceptual information of the objects to be valued, estimation of the criteria values and significances of the objects.

3. The method of multiple criteria analysis in estimating the property value

The value of the property under valuation is determined by means of re-iteration through several repetitive cycles of refinement until the mean deviation k_x of the degree of utility N_j of the property a_x under valuation satisfies the condition $k_{ax} < \pm 1\%$. The initial value of the object under valuation is estimated according to the purchase prices of the comparable objects and is equal to the mean of purchase prices of the comparable objects.

The essence of the method of multiple criteria analysis in estimating real property value is presented in Fig 1. The method is composed of a total of 12 stages, of which two are stages concerned with the preparation of initial data (for formulas, see [2–7]).

4. Estimation of the market value for commercial premises

On the basis of the methods described in this article, valuation of commercial premises was carried out. Two comparable objects were selected for the object under valuation. All of them are located in Vilnius. The object under valuation and the comparable objects contain differences in quality, quantity and market conditions. The description of the object under valuation and the comparable objects is presented further on.

4.1. Description of the property under valuation

The property under valuation (commercial premises) is located in Pylimo Street (Vilnius), 2 km from the city centre, next to the railway and bus stations (1 km). The Pylimo street is one of the city main streets of the and serves as a connection between the city centre and both stations. The premises under valuation are located on the ground floor and in the dwelling house cellar. Currently, those premises are used as a shop. The total area of the premises accounts for 490 m^2 including two salerooms of 115 m^2 each. The area of the auxiliary premises amounts to 160 m^2. There are two separate entrances to the premises – from Pylimo street, and from the end of the building with a car park. The premises on the ground floor are in good condition, rooms have been renovated, the interior decoration is of high quality, the interior of the premises meet modern standards. Premises in the cellar are not used. The four-story building where the premises are located was erected in 1940 and is used as a dwelling house with commercial premises on the ground floor. The construction elements of the building: the foundation is made of stone-concrete, walls made of bricks, plastered, the roof covered with tiles, joist ceilings are made of reinforced concrete; plastic doors. The physical depreciation of the building stands at 57%. Functional and economic depreciations have been estimated by the expert method and make up 37 and 13%, respectively. The premises, like the whole building, are equipped with water supply and sewage systems, electricity, gas, district heating and a telephone line. The alarm system is absent. The land plot is not included into valuation as not belonging to the private ownership. There are no restrictions on holding and possessing the property.

There is a great demand for non-dwelling properties in the part of the Vilnius city where the premises under valuation are located. The building is not far from the city centre, next to the busy street with a heavy traffic flow. In the neighbourhood, there is a lot of companies and other commercial offices. The premises under valuation are marketable due to the location of the building and characteristics of the premises. The premises are suitable for commerce, the door and windows face the main street. The premises are in good repair condition. The cellar contains enough space for warehousing.

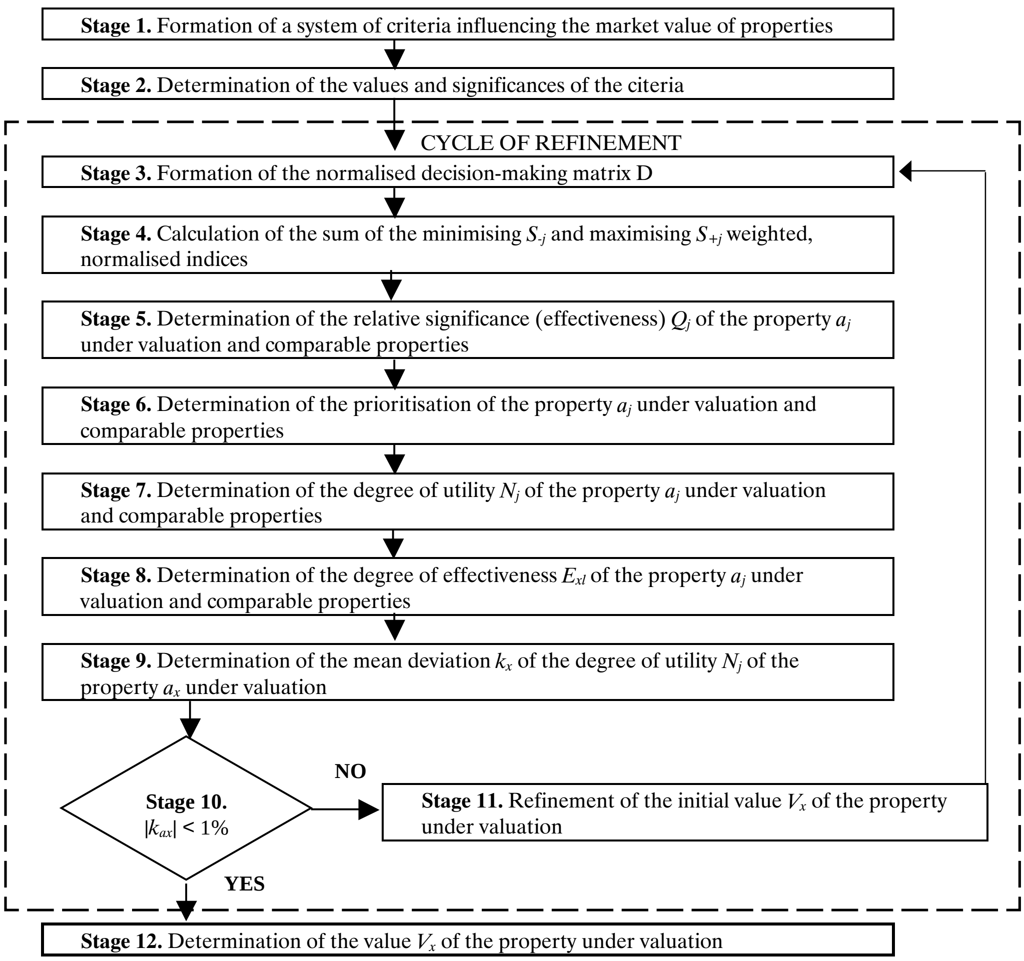

Fig 1. Flow chart of the method of multiple criteria analysis in estimating the real property value

4.2. Description of the first comparable object

The comparable object (commercial premises) is located in Savanoriu Avenue in Vilnius. The premises are located 4 km from the city centre, and 5 km from the railway and bus stations. The comparable object is located in the Naujamiestis district, one of the most prestigious districts of the city, with high prices for the property. New buildings are not frequently built in this part of the city; therefore there is a constant demand for premises. The premises are located on the ground floor and the cellar of the dwelling house with a warehouse in the yard of the building. The total area of the premises accounts for 334 m^2. There is one saleroom with an area of 155 m^2.

The area of the auxiliary premises amounts to 179 m^2. There is a separate entrance to the premises from Savanoriu Avenue. The interior decoration of the premises: the interior is painted, one part of the walls in the saleroom is covered with tiles, the other part is decorated by decorative planks. The premises need to be renovated. The four-story building where the comparable object is located was erected in 1960 and is used as a dwelling house with commercial premises on the ground floor. The construction elements of the building: the foundation is made of concrete, inside walls made of bricks, plastered, partitions made of bricks, the roof covered with metal sheets, joist ceilings are made of reinforced concrete; wooden doors and windows. The physical depreciation of the building stands at 34%. Functional and economic depreciations have been estimated by the expert method and make up 42 and 24%, respectively. There is a warehouse in the yard of the building, which was sold together with the premises. The premises (except the warehouse), like the whole building, are equipped with water supply and sewage systems, electricity, gas, district heating and a telephone line. The alarm system is absent. The land plot was not sold together with the building. There are no restrictions on the use or possession of the property.

The district where this property is located is the conglomeration of many enterprises, offices, and commercial companies. The object is in a busy place next to the basic transport highways with a heavy traffic flow. The premises are marketable due to the location characteristics. The object located on the main street of the district is suitable for commerce and trade with entrance and windows facing the street, and good advertising conditions. There is an auxiliary building in the yard of the building, which is suitable for warehousing purposes. The premises, however, need renovation and modern interior. The selling price for the premises stands at 186 000 Lt.

4.3. Description of the second comparable object

The comparable object (commercial premises) is located ion Goštauto Street, Vilnius, and also belongs to the Naujamiestis district. The location of the premises is especially good, in the city centre, in between the most prestigious districts of Vilnius – Gediminas Avenue and Žverynas. The premises occupy the cellar of the Institute and cover the total area of 308 m^2. There is one saleroom with an area of 216 m^2, and the auxiliary premises with an area of 92 m^2. There are two entrances to the premises – an entrance from the Institute and a separate entrance from the yard. There is a big car park outside the premises. The interior decoration of the premises: the floor is covered with linoleum; walls are covered with paint, plaster, in some places with wallpapers. The main room has recently been renovated – repainted, windows furnished with jalousies. The auxiliary premises have not been repaired. The building, where the object is located, was erected in 1965 and is a four-story building used as an Institute. The construction elements of the building: the foundation made of concrete, outside walls made of bricks, plastered, partitions made of bricks, plaster, joist ceiling made of reinforced concrete, plastered, door is solid-core, double windows. The physical depreciation of the building stands at 29%. Functional and economic depreciations have been estimated by the expert method and make up 52 and 33%, respectively. The premises, like the whole building, are equipped with water supply and sewage systems, electricity, gas, district heating and two telephone lines. There is a local alarm system in the premises. The land plot was not sold together with the building. There are no restrictions on the use or possession of the property.

The site of the object is widely used for commercial activities. Public enterprises, banks, commercial companies, shops are located in this part of the city. The buildings are in a considerably good condition, made of long-lasting building materials, therefore they are being actively repaired, their interior is being renovated, the ground floor premises are being rearranged into administrative and commercial offices. These premises are in the cellar, entrance and show cases are facing the behind of the building. Besides, the premises need to be renovated. Therefore, as commercial premises, they have lower value. The selling price for the premises is 130 000 Lt.

5. Investigation process and summary of the results

With account to qualitative, quantitative and market description of the property under valuation and comparable objects, the grouped decision making matrix was formed (Table 2). The market value of the commercial premises was estimated in 6 cycles of refinement until the mean deviation k_x, of the degree of utility of the property under valuation, calculated in stage 9 of the method, satisfies the condition $|k_{ax}| < 1\%$. Table 3 of this article illustrates the change in the mean deviation of the degree of utility of the property under valuation and the refined value of commercial premises throughout all the six cycles of refinement. In the last (sixth) cycle of refinement the afore mentioned condition was satisfied and the market value of the premises was estimated to be 157 000 Lt (Table 3).

Table 2. Initial data for the multiple criteria analysis of commercial premises. Grouped decision-making matrix

Criteria to be considered		Measurement unit	Significance	The object under valuation	Comparable objects	
					Savanoriu Avenue	Goštauto Street
1. Selling price	-	Thousand Lt	100	X	186	130
Evaluation of the building						
2. Construction design	+	Points	3.5	0.85	0.80	1.00
3. Physical depreciation	-	Per cent	3.0	57	34	29
4. Functional depreciation	-	Per cent	2.5	37	42	52
5. Economic depreciation	-	Per cent	3.5	13	24	33
6. Number of auxiliary buildings	+	Units	4.0	0	1	0
Quantitative assessment of premises						
7. Total area	+	m^2	5.5	490	334	308
8. Number of salerooms	+	Units	1.5	2	1	2
9. Area of salerooms	+	m^2	3.5	230	150	216
Qualitative assessment of premises						
10. Interior	+	Points	4.0	1.00	0.60	0.55
11. Exterior	+	Points	2.5	0.75	0.80	1.00
12. The need for renovation	-	Points	3.5	0.15	0.70	0.50
13. Trading equipment	+	Points	4.5	1.00	0.75	0.00
14. Number of entrances	+	Units	1.0	2	1	2
15. Entrances with respect to the street	+	Points	5.5	1.00	0.95	0.60
16. Position of showcases	+	Points	4.5	0.90	1.00	0.50
17. Advertising possibilities	+	Points	4.0	0.90	1.00	1.00
18. Location with respect to the parts of the world	+	Points	0.5	0.60	0.80	1.00
Assessment of communications						
19. Engineering communications	+	Points	3.5	1.00	1.00	1.00
20. Number of telephone lines	+	Units	1.5	1	1	2
21. Assessment of the alarm systems	+	Points	5.0	0.00	0.00	1.00
22. Assessment of the air conditioning	+	Points	2.0	0.75	1.00	0.25
Estimation of the place						
23. Distance from the city centre	-	km	5.5	2	4	1
24. Public transport	+	Points	5.0	0.80	1.00	0.75
25. Distance from the bus stop	-	km	1.5	100	200	50
26. Car park	+	Points	5.0	0.70	0.50	1.00
Other criteria						
27. Prestige of the locality	+	Points	7.5	0.90	0.80	1.00
28. Assessment of market conditions	+	Points	6.5	0.95	0.95	1.00

Table 3. Estimation of the change in the mean deviation of the degree of utility, the refined value and the market value of the property under valuation

Cycle of refinement	Refined value of the object under valuation V_{xp} (thousand Lt)	The mean deviation of the degree of utility of the property under valuation	Market value of the object under valuation V_x (thousand Lt)
1	156.00	$\lvert 8.83 \rvert > 1$	
2	171.95	$\lvert 3.86 \rvert > 1$	
3	165.31	$\lvert 2.11 \rvert > 1$	
4	161.82	$\lvert 1.14 \rvert > 1$	
5	159.98	$\lvert 1.03 \rvert > 1$	
6	158.33	$\lvert 0.58 \rvert < 1$	
			$158.33\ (1 - 0.58 \div 100) = 157.41$

6. Conclusions

1. The proposed method of multiple criteria analysis for estimating the property value enables to estimate not only the real property market value but other values as well. Application of this method allows to perform a complex analysis of real property, the utility of the given objects and their prioritization in terms of one another and the significance of criteria affecting the real property value and marketability of the given objects.

2. The method of multiple criteria analysis can be applied not only as a separate method for estimating the value but also as composite method in the traditional valuation methods: in the comparative value method – to evaluate specific criteria influencing the market value (eg local infrastructure, location of a property under valuation, etc), in the value replacement method – to evaluate the depreciation of a building under valuation.

3. The method of multiple criteria analysis is based on the market and real property analysis and on the application and evaluation of the qualitative and quantitative criteria and market conditions influencing the real property value. Therefore, this method allows to carry out a complex analysis of the property with not only qualitative and quantitative differences but also different market conditions.

4. The proposed method is flexible and can be made available to all interested parties (market participants: buyers, sellers, investors, valuers and others) seeking to satisfy their needs and different demands. Besides, in evaluating the property for different purposes, the criteria influencing the value differ as well. The number and significances of these criteria can be easily changed when applying these methods.

The system of typical criteria for the estimation of the market value of commercial premises has been built on the basis of the analysis of the property market. This system can be used in the property valuation by different interest groups in Lithuania.

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KOMERCINIŲ PATALPŲ VERTINIMAS DAUGIAKRITERINĖS ANALIZĖS VERTĖS NUSTATYMO METODU

V. Malienė

Santrauka

Daugelį problemų, su kuriomis susiduriama vertinant nekilnojamąjį turtą, galima išspręsti daugiakriterinės analizės metodais. Šie metodai pradėti taikyti tik XX a. antrojoje pusėje. Šiuo metu jie užima labai svarbią vietą pasaulinėje nekilnojamojo turto vertinimo praktikoje. Daugeliu atveju tarptautinėje praktikoje jie yra pagrįsti rinkos modeliavimu ir ekonominiu vertintojų mąstymu, todėl kartais pateikiami kaip atskiri vertinimo metodai ir vadinami šiuolaikiniais.

Šiame straipsnyje siūlomas naujas daugiakriterinės analizės vertės nustatymo metodas. Jis yra pagrįstas rinkos analize bei vertinimo principu ir atitinka klasikinį lyginamosios vertės metodą. Jį galima priskirti netiesioginių lyginamosios vertės metodų grupei. Šie metodai daugiakriterinę nekilnojamojo turto analizę leidžia atlikti plačiau ir universaliau, nes remiasi daugelio skirtingų kriterijų, t. y. kokybinių, kiekybinių bei rinkos konjunktūros įvertinimu. Siūlomas metodas gali patenkinti daugelio suinteresuotų grupių tikslus bei poreikius, nes juo remiantis galima nustatyti ne tik nekilnojamojo turto rinkos vertę, bet ir kitas vertes, pvz., investicinę, naudojimo, esamo naudojimo rinkos vertę ir t. t. Šiame straipsnyje pateiktas metodo teorinis modelis, kuriuo remiantis buvo nustatyta patalpų, skirtų komercijai, rinkos vertė.

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Vida MALIENĖ. Doctor. Dept of Building Technology and Management. Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-2040 Vilnius, Lithuania.
E-mail: Vida.Maliene@st.vtu.lt

A graduate of Vilnius Gediminas Technical University. MSc (1996). Doctor (2000, civil engineering). Research visits to Bonn Friedrich-Wilhelm University (Germany, 1997/1998, 2000), Leipzig Higher School of Technology, Economics and Culture (Germany, 1998). Research interests: real estate valuation and management, land survey.

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A DECISION SUPPORT SYSTEM APPLYING MULTICRITERIA SYNTHESIS METHODS IN CONSTRUCTION

V. Šarka

Vilnius Gediminas Technical University

1. Introduction

The construction industry, compared to other industries, is distinguished by a small productivity of work and large fragmentation. This is a complex system connected by close ties, still being quickly developed, and sensitively reacting to environmental effects. A great number of projects are being constantly implemented there (new construction, building reconstruction and heating renovation, attraction of investment, etc) distinguishing one from another by purposes, volumes and other features.

In investigating any problem connected with certain construction fields: new residential, industrial, commercial, administration building construction, reconstruction or renovation, bridge building, installation of the utility networks, infrastructure creation, the construction materials industry, etc, tremendous problems are encountered. Solution of these problems requires a great deal of time and financial resources. This research enumerates the largest elements describing the construction process. After a deeper investigation, we will see that it is possible to separate each of these processes into several, even quite a few, smaller processes or projects.

Having such a variety of elements participating in the construction process, the necessity araises to reciprocally co-ordinate these activities, to collaborate on various issues, exchange information, and share the experience possessed.

A new decision support system (DSS) using the latest information technology is being developed to implement joint projects. The decision support system is designated to accumulate and process initial data using various mathematical and logical models including multicriteria assessment methods. The DSS then provides the decision-maker with the information necessary to analyse, create, assess, and make a decision concerning alternatives to possible decisions. At last there was a possibility to obtain and store the results obtained.

2. The work aim and research subject

Describing the preconditions set forth after making assertions clarifies the investigation problem connected with the possibility of applying certain multicriteria decision selection methods in the field of construction technology.

The author's purpose was to investigate the current decision support systems and the mathematical models used in them as well as to improve them by introducing several multilevel, multicriteria decision synthesis methods. The proposed methods must correspond to the nature of the problems being resolved and take into consideration the modern view applied to multicriteria decision-making. Based on this, the primary assertion of this research is the following.

Applying corresponding methods according to a procedure assuring a correct course for this process must solve problems of multicriteria decisions by construction technology engineers, with the group of variants known and defined in the decision selection process in the beginning. According to the assertion set forth above in this research, the following aims are being pursued:

- to select those methods, which are the newest and most representative, taking into consideration various viewpoints applied in the multicriteria decision method according to the problems in organising many indexes;
- to investigate once and for all and to apply many indexes for solving a task, three new multilevel, multicriteria decision synthesis methods (for the first time synthesis methods were mentioned in 1991 in the work of Prof E. K. Zavadskas [1], however no final analysis and adaptation were provided);

- to combine 3 new multicriteria decision syntheses, several multicriteria decision-making methods (for separate stage decisions) and expert methods in a newly created decision support system applying multicriteria synthesis methods (DSS_MS) for construction software work;
- to prepare an initial database devoted to DSS_MS for construction.

The subject of the research is multicriteria decision theory and decision support system. Theoretical multicriteria assessment and expert methods are used in pursuing the aforementioned aims.

A thorough description of the scientific research performed and the results obtained is presented in the author's thesis [2].

3. Contents of the research

The primary focus of this research is to clarify the possibilities of using multicriteria decision selection method in an effort to solve the problems of decision-making connected with the construction industry. The development of the multicriteria decision-making methods is presented here. Also, there are briefly presented the connections and problems of the multicriteria decision-making method. The development of the investigation method and the existing single level multicriteria decision-making manner in the construction technology field is investigated. In the first chapter [2], there is a brief review of several decision support systems DSS used abroad and in Lithuania.

In the second chapter [2] are presented the fundamental aspects of the new decision support system created by the author. Here are described the principal two main structural elements of the decision support systems: data (databases and their control system) and the principal elements of the model base structure (the structure of the multicriteria assessment and expert methods used in the system).

Besides the aforementioned assertion, an initial database for the decision support system in construction and structural schemes for decision-making have been created. A thorough description of the proposed database structure (DBS) and the multicriteria decision-making structure scheme are presented by the author [2].

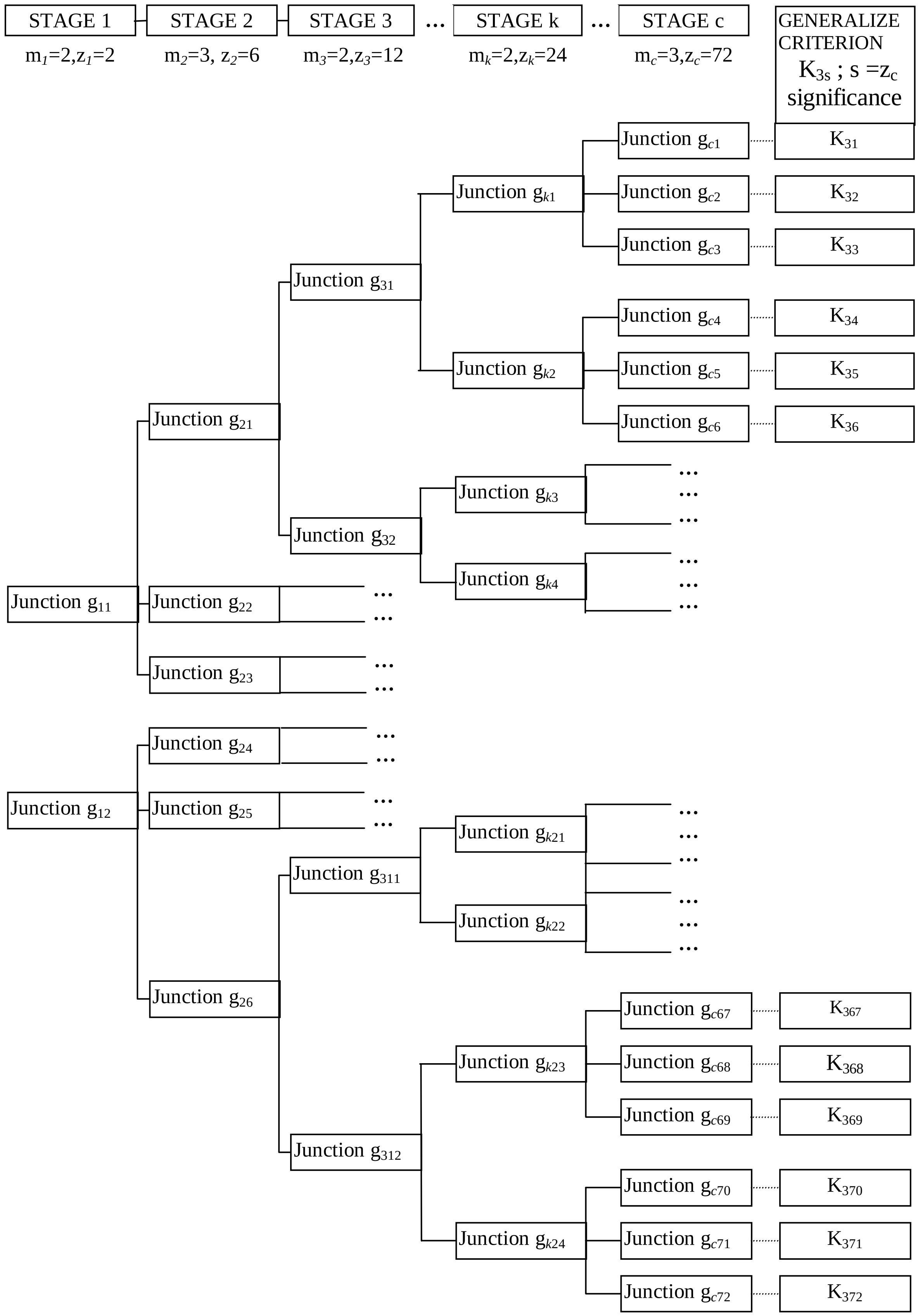
The structure of the decision support system applying multicriteria synthesis methods (DSS_MS) in construction is based a systematic-technical assessment of the projects (PSI) [3, 4], expert assessment [4, 5], and the multicriteria decision synthesis methods proposed by the author [2]:

- a method of project synthesis by a compromise compensation model (SKK3) [2, 6];
- a method of project multicriteria decision synthesis (DSS1) on the basis of decision success criterion (PSS1) [2, 7];
- a method of project multicriteria decision synthesis (DSS2) according to average weighted decision-making success (VSPSS1) [2].

The aim of a decision by these methods is to combine for the investigated construction complex, the alternatives of the several analysed construction processes or projects into a general construction system decision tree (DT) (Fig).

By this it is sought to avoid possible errors arising in future construction, which is already in the stages of the establishment of its future purposes and in the design stage. Then investigating also properly and complexly the design questions related to future construction, performing a complex analysis of possible construction materials and equipment used for construction, analysing the possibilities of the construction labour market, and resolving many of the quantity questions connected with construction, it is possible to accumulate a large amount of time and material resources connected with construction processes. These questions were and are very important at the level of each state, each firm, and each individual person. For the solution of these questions, a great deal of time and force is allocated worldwide. Thus, the author, after investigating current situation, has noted a tendency in the creation of the existing and newly created decision support systems that most of DSS created systems in Lithuania and the world are developed to pursue only one or another specific aim. Huge expenditures of time and funds are allocated to create every DSS system.

The created systems work only in very concrete, specific areas of construction, economics, environmental protection, etc. Mostly solve questions at one level of the area being investigated. A solution can be made only in a concrete and so assigned direction of DSS activity. It is not foreseen in the system to perform complex, multilevel decision except the existing variant



Fragment of decision tree (DT) formation structure with multicriteria project synthesis methods design methods and practical application examples found in the work of E. K. Zavadskas and A. Kaklauskas [3], C. L. Hwang and K. Yoon [4].

The author, through his three multicriteria decision synthesis methods, has sought:

- to investigate the possibilities of multilevel decision execution and the problems connected with it;
- to eliminate the gap created in the system of multicriteria decision methods and to create three multilevel multicriteria decision synthesis methods integrated into a DSS;
- to adapt the system being created together with the integrated synthesis methods to the solution of as great a diversity of complex questions as possible.

4. Practical application of the scientific research

In order to check the reliability of the newly created system, there was created a decision support system computer model, applying multicriteria synthesis methods (DSS_MS), which is designated to solve equipping design problems of component parts of a building, combining them into a general totality with the assistance of synthesis methods. In this system additional programming measures are used for solving undefined questions: methods of expert assessment and pair comparison. Various methods for project system technical assessment are proposed for solving single level multicriteria assessment tasks.

DSS_MS in construction is designated for engineers, experts, construction technology-management students, and other users. As a teaching aid, this system should assist students to better understand as well as to independently master and learn new concepts and the methods connected with the multicriteria decision methods that are becoming ever more popular. As an applied system, the programme can analyse multilevel tasks for the most complex structures, which frequently arise in the complex construction industry. The control of the software system part as well as the creation and filling of the database structure is simple and do not need a large additional expenditure of labour. The system has an internal control mechanism for self-control with certain author assigned parameters.

The packet provides the possibility of:

- systematically storing the initial data connected with various technical decisions;
- performing an analysis of the initial data possessed and processing it;
- solving problematic questions of the management of undefined data by the expert method;
- according to the analysis performed, making effective decisions in both single level (proximity to the ideal point, multicriteria complex proportion assessment methods for projects) and multilevel (multicriteria decision synthesis methods) systems created from multicriteria decisions;
- protecting the results of realised projects in a database and providing this data for repeated analysis as well as for the creation of other initial databases;
- printing the initial data and results in the shape of forms specially prepared for it.

By applying the DSS_MS computer model created by the author, there are presented 2 actual examples, solved by the author with the assistance of multicriteria analysis synthesis methods, of several construction elements and construction processes as well as of ongoing construction:

1. The selection of the most effective construction elements of Polish Houses using the method of synthesis and compromise compensation models (SKK3). By this method the most effective construction solution variant was calculated. It includes exterior walls, foundation, roofing, windows and partitions. An initial DSS_MS construction base was also created.
2. The selection of the most efficient construction elements and the construction process of a 6-floor administration building in Vilnius were made using the multicriteria decision synthesis (DSS1) method.

With this specific case were solved the questions of investigation projects, 4 constructive elements (building skeleton, glass partitions and automatic doors, ventilation and air conditioning system, building facade finishing) as well as the selection of a contractor.

3. The selection of the most efficient construction variant for a one-flat residential house using the project of the multicriteria decision synthesis method (DSS2) according to average weighted decision-making success (VSPSS1) criterion was made.

5. General conclusions

1. A new decision support system management procedure in construction was created. It assures a correct decision selection process, especially taking into consideration a selected explanation method for decision multitask problems.

2. Three multicriteria synthesis methods were created:

a) a method of project synthesis, using a compromise compensation model (SKK3) was improved;

b) a method for project multicriteria decision synthesis (DSS1), on the basis of decision success criterion (PSS1) was created;

c) a method for project multicriteria decision synthesis (DDS2), according to average weighted decision-making success (VSPSS1) criterion, was improved.

3. The method of proximity to the ideal point was improved by introducing the absolute mutual significance of single level of alternatives (TOPSIS_A).

4. A new term was introduced: single level, alternative absolute mutual significance.

5. A theoretical and computer model for a decision support system applying multicriteria synthesis methods (DSS_MS) with the aforementioned system elements integrated were created.

6. The reliability of all three synthesis methods was tested by calculated experiments. The results of the assessment of two methods were applied in the concrete projects actually implemented.

All this allows one to assert that multicriteria decision synthesis methods are theoretically fully described and mathematically grounded. All three synthesis methods created are part of the classification scheme of project technical assessment methods and are designated to solve problems through multiple level multicriteria decisions.

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SPRENDIMŲ PARAMOS SISTEMA, TAIKANT DAUGIAKRITERINIUS SINTEZĖS METODUS STATYBOJE

V. Šarka

Santrauka

Autorius savo mokslinių tyrimų pagrindu pasirinko daugiakriterinių sprendimų priėmimo metodiką, šios metodikos problematiką ir tyrimo metodų plėtrą.

Nagrinėjami esami vienpakopiai daugiakriterinių sprendimų priėmimo būdai statybos technologijos srityje bei autoriaus siūlomi daugiapakopiai daugiakriterinių sprendimų sintezės metodai.

Atskirų struktūrų sujungimo į bendrą sistemą kartu sprendžiant skirtingose pakopose esančių alternatyvų tarpusavio ryšių suderinamumo problemas nagrinėjimas yra labai svarbus daugiakriterinių sprendimų srityje. Sprendimo šiais metodais tikslas yra nagrinėjamame statybos komplekse sujungti kelių analizuojamų statybos procesų ar projektų alternatyvas į bendrą statybos sistemą. Tuo yra siekiama dar tikslų nustatymo bei projektavimo stadijose išvengti galimų klaidų būsimoje statyboje.

Autoriaus patobulinti ir sukurti projektų daugiakriterinių sprendimų sintezės metodai yra nauja daugiakriterinių sprendimų metodų šaka. Pagal sukurtų daugiakriterinių sprendimų sintezės metodų algoritmus parengti kompiuteriniai metodų modeliai yra integruoti į naujai sukurtą sprendimų paramos sistemą statyboje SPS_DS.

Pagal SPS_DS sistemą atlikti praktiniai tyrimai. Pateikti autoriaus išspręstų dviejų realiai pastatytų pastatų kelių konstrukcinių elementų bei statybos procesų daugiapakopės daugiakriterinės analizės sintezės metodais pavyzdžiai. Taip pat sukurta pradinė SPS_DS statyboje kai kuriuos konstrukcinius elementus (pastato karkasą, išorines sienas, pertvaras, fasado apdailą, langus, stogą ir t. t.) bei statybos procesus (projekto, rangovo parinkimą) aprašanti duomenų bazė (DBS).

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Vaidotas ŠARKA. Doctor (technological sciences). Vilnius Gediminas Technical University (VGTU), Saulėtekio al. 11, LT-2040 Vilnius, Lithuania. E-mail: E_Raud@centras.lt

A graduate of Vilnius Technical University (1993). Doctor (2000). Author of 7 publications. Research interests: decision support systems, multicriteria decision methods, project management, and computerised design.

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MULTICRITERIA ANALYSIS OF THE VARIANTS OF THE OLD TOWN BUILDING RENOVATION IN THE MARKETING ASPECT

S. Jakučionis, L. Ustinovičius

Vilnius Gediminas Technical University

1. Introduction

In the literature of economy there is no unified opinion concerning the stage of every investment project as well as for the whole project estimation. The majority of the authors [1, 2] evaluate social, ecological and technical indicators separately and do not include them into the general system of the indicators of the investment estimation while considering the dominating economic result as the priority.

One of the most difficult problems of the modern urbanism is the combined estimation of the old town building renovation according to technical-economical and social-economical indicators. This estimation is closely related to social requirements and perspectives of city development. One of the best models in the evaluation of investment projects is used by the USA company *Continental Group.* The projects are being estimated in two aspects: commercial attractiveness and project realization in the enterprise [3].

The system of old town building renovation that investigates variants of building usage and helps defining the most effective ones could help speeding up renovation and expand the volumes of old town regeneration, also would positively influence the construction companies' and investors' activity.

One of the principal targets while renovating old towns is the adaptation of architectural monuments to contemporary necessities so as the monuments of the past could continue their active existence as part of the developing town and the historical centre.

At the optimisation of the building use, a variant calculation of investment needs is being executed [4].

Under the nowadays conditions the possess of the big practical experience and good engineering intuition is not enough for the building renovation. Well-founded decisions can only be taken after the variant projection is done evaluating projects realized earlier and after the main directions of the decisions are defined. The methods of multi- criteria analysis play the main role when solving the real life tasks [5]. These methods are being applied more and more often. There are no absolutely reliable methods of multicriteria analysis; nevertheless, they can help the consumer to avoid main contradictions in the analyzed sphere.

The application of methods of multicriteria analysis for reviving an old town expands the possibilities of its regeneration planning and marketing, also lets to quicken reviving work.

A complex of methods of multicriteria analysis was created (Fig 1). It is aiming at finding the way of how to raise the efficiency of the investments for the old town revival, also at increasing fidelity to the calculations.

2. The marketing principle of renovation of old town buildings

Before the purchase of buildings their estimation is being done. The first step is to define the technical status of the building. The dimensions are gotten during this process and they serve for evaluating parts of the building. The next step is the estimation of the value of the whole object. It is possible to define the market price of the building according to its real estate value. The market price evaluates the market juncture, which is determined by factors of supply and demand. The estimation methods are based on the analysis of factors that define the building value, in general. These factors are: features of the object, comparable value of the object, real money power of the purchase. Besides it is a must to estimate heaps of additional factors – area, appearance, the character of the use of the object, legal rights of ownership, etc.

Several variants of the building use are being projected. For example, the apartments, café or the hotel can be fitted out. The estimation of expenditure is being made up for every variant. When the expenses for all variants are known, marketing calculations are performed: which variant is cheaper, what profit is possible after the sales or rent of the building, what price of the sales should be ensured for getting the invested means back and receipt of the planned profit. Using the way of comparison, possible price of the sales is being carried out. If crediting is part of the plan, the stages of credit taking and investment are prospected taking into consideration the growth of interests.

According to the system of efficiency indicators and applying methods of multicriteria analysis the best variant is chosen. Then the building is being renovated and sold.

3. Complex of the multicriteria analysis methods

The theory of multicriteria analysis is applied for the decisions while evaluating indicators that are most often contradicting each other. The problems of multicriteria analysis are very different, though all these tasks have some common features [6]: the problems have several indicators, the estimation criteria usually contradict each other, the estimation indicators have different measuring units. The solution result of such a problem is to find the best alternative or to choose the one of the alternatives. The methods of multicriteria analysis create or search for the variant that corresponds to all criteria in the best way. Because of the contradictions of the indicators to each other, a smart compromise must be found.

The decision-making consists of 3 stages:

Making the list of alternatives;

Preparing alternatives;

Choosing alternatives [7].

During the first stage the alternatives are defined and they will be used while solving tasks. These alternatives are called the solution variants.

In the second stage, variants of the solutions are analyzed.

The choice of the best variants is based on the differential estimation of variants according to the results of the second stage.

As the methods of management and the technique of the determination are growing modern, the methods of multicriteria analysis are becoming more important in management spheres. There are no possibilities to solve problems while investigating difficult systems of technology and marketing using just the one-time estimation methods. Only the multicriteria analysis, which takes into account diverse efficiency indicators, allows to create effective methods for solving difficult problems.

Several methods of multicriteria analysis are described in literature. However, there is no sense in using only one method of multicriteria analysis for solving sophisticated problems. Grouping, linking of the methods, also applying them in turn becomes a must. The offered complex of the methods of multicriteria analysis is presented in Fig 1.

First of all, the potential variants of the building renovation are carried out. The efficiency indicators are made up and they will make the ground for comparing the analyzed variants. After questioning the experts, significances of the indicators are defined, using the method of the expert pair comparison.

Numerical values of weights $q_j (j=\overline{1,n})$ are defined by solving the optimization problem:

$$\min\left\{\sum_{i=1}^{n}\sum_{j=1}^{n}\left(b_{ij}q_j - q_i\right)\right\}, \tag{1}$$

when unknown quantities $q_j\left(j=\overline{1,n}\right)$ satisfy limitations:

$$\sum_{i=1}^{n} q_i = 1, q_i > 0; \left(i=\overline{1,n}\right), \tag{2}$$

where $b_{i,j}$ – values of criteria pairwise comparison given by experts.

The problem is solved in a traditional way – Lagrangian function is determined. The optimal proposition is got by solving a set of $(n+1)$ linear equations with $(n+1)$ unknowns:

$$C \cdot Q = \overline{m}, \tag{3}$$

where $Q=(q_1, q_2, ..., q_n, \lambda_l)^T$; q_i – weights of criteria; λ_1 – Lagrangian multiplier; $\overline{m} = \underbrace{(0,0,...,0,1)^T}_{n\ times}$; n – amount of criteria.

$C=[l_{ij}]$, $i,j=1,...,n,n+1$ matrix with elements l_{ij};

$$l_{ii} = (n-1) + \sum_{j=1}^{n} b_{ji}^2, i, j = 1, ..., n, \quad (4)$$

$$l_{ij} = -(b_{ij} + b_{ji}), i, j = \overline{1,n};\ i \neq j, \quad (5)$$

$$l_{k,n+1} = l_{n+1,k} = 1,\ k = \overline{1,n}, \quad (6)$$

$$l_{n+1,n+1} = 0. \quad (7)$$

The pair comparison method is useful because the experts have the possibility to compare the indicators in couples, what is really important when comparing big amounts of indicators. The group estimation can be considered to be reliable only when the opinions of the experts interrogated are reconciled. Therefore statistical processing the information supplied by the experts, conciliation of their opinions should be appraised and the reasons for multivaluation of the information should be defined.

The pair comparison method, presented by T. Saaty, does not include the test for conciliation of the experts'opinionss. Therefore the offered expert method to test the conciliation of the experts'opinionss is the one that was presented by L. Evlanov.

In order to avoid accidental mistakes, three methods of variants usefulness function are offered: TOPSIS (*Technique for Order Preference by Similarity to Ideal Solution*) [8], SAW (*Simple Additive Weighting*) [9, 10] and LINMAP (*Linear Programming Techniques for Multidimensional Analysis of Preference*) [11, 12]. LINMAP method for construction problems was applied for the first time.

Using this method, the values of every indicator are constantly increased or constantly reduced. Then we can have the possibility to define the "perfect" solution, which is made up of the best values of the indicators, and the "negatively perfect" solution, which is made up of the worst values of the indicators.

The relative closeness of each alternative in respect of the ideal solution is defined as follows:

$$K_{BIT} = \frac{L_i^-}{L_i^+ + L_i^-}, i = \overline{1,m}, \text{ when } K_{BIT} \text{ [0, 1]}, \quad (8)$$

where L_i^+ – separation of each alternative from the ideal one, L_i^- – separation of each alternative from the negative-ideal one, m – number of alternatives.

A set of alternatives can now be preferebly ranked according to the descending order of K_{BIT}.

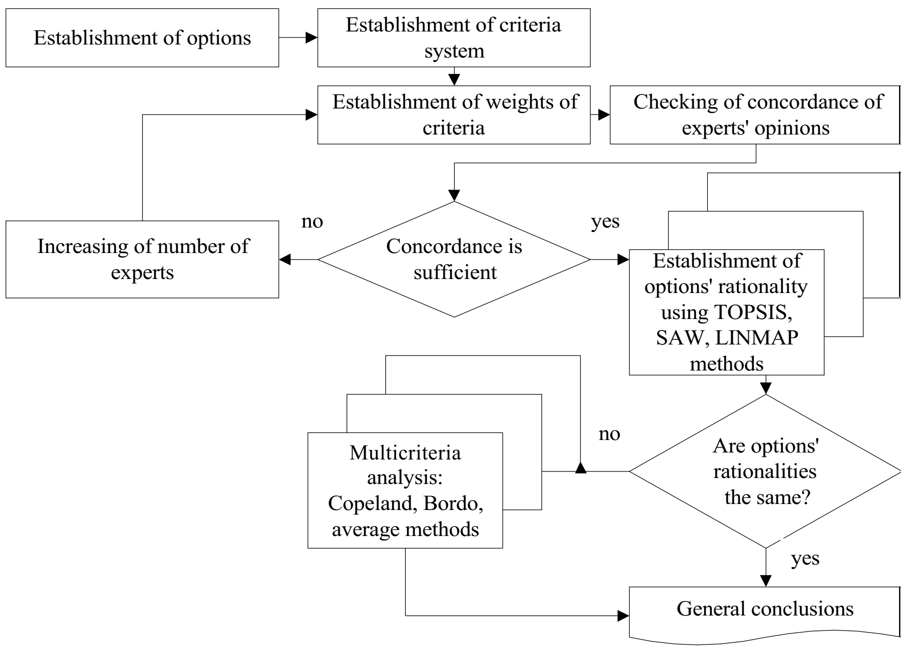

Fig 1. Complex of multicriteria analysis methods

SAW is probably the best known method of multiattribute decision-making. Attribute values must be numerical. There are two steps of analysis:

1) Matrix is normalised;

2) The decision-maker can then obtain a total score for each alternative simply by multiplying the scale rating for each attribute value by the importance weight assigned to the attribute and then summing these products over all attributes. The alternative with the highest score is the one prescribed to the DM:

$$A = \left\{ A_i \left| \max_i \sum_{j=1}^{n} q_j \overline{x_{ij}} / \sum_{j=1}^{n} q_j \right. \right\}, \qquad (9)$$

where q – importance weight of the attribute, $\bar{x}_{ij}$ – the outcome of the i^{th} alternative about the j^{th} attribute with a numerically comparable scale, n – number of alternatives.

In LINMAP method, m alternatives composed n attributes (decision matrix with elements x_{ij}) are represented as m points in the n-dimensional space. The weighted Euclidean distance, d_i, of the A_i from the ideal point is given by

$$d_i = \left[\sum_{j=1}^{n} q_j \left(x_{ij} - x_j^* \right)^2 \right]^{1/2}, \; i = 1,2,...,m, \qquad (10)$$

where x_j^* is the ideal value for the j^{th} attribute. The square distance, $s_i = d_i^2$, is given by

$$s_i = -\sum_{j=1}^{n} q_j x_{ij}, \qquad (11)$$

where x_{ij} are at least intervally scaled, and the larger x_{ij}, the larger preference.

Let $\Omega = \{(k,l)\}$ denote a set of ordered pairs (k,l) where k designates the preferred alternative on a forced choice basis resulting from a paired comparison involving k and l.

Then we have

$$s_l - s_k = \sum_{j=1}^{n} q_j (x_{kj} - x_{lj}). \qquad (12)$$

$$z_{kl} = \max\{0, (s_k - s_l)\}. \qquad (13)$$

Now the corresponding model is:

$$\left.\begin{array}{c} \min \sum_{(k,l)\in\Omega} z_{kl} \\ when \;\; \sum_{j=1}^{n} q_j (x_{kj} - x_{lj}) + z_{kl} \ge 0, \; when \;\; (k,l) \in \Omega; \\ \sum_{j=1}^{n} q_j \sum_{(k,l)\in\Omega} (x_{kj} - x_{lj}) = h; \\ q_j \ge 0, j = 1,2,..., n; \\ z_{kl} \ge 0, \; when \;\; (k,l) \in \Omega. \end{array}\right\} . \qquad (14)$$

The existence of several methods of the research implies a question, which of these methods should be used. The question “which method suits the problem best” is the most important but again it is difficult to answer. It is much harder to evaluate the quality of the methods of multi-criteria analysis that examines limited discrete mathematically described figure of the variants in comparison with the methods of the finite element mathematics. As every method of multicriteria analysis has its own advantages as well as disadvantages, there is no absolute answer to this question.

The choice of methods in a common case is determined by:

1) physical value of the indicators;

2) level of the mathematical and program maintenance;

3) subjective circumstances of a different level.

Besides, there is a possibility to get different results of the calculation (the line of priority) when reckoning by different methods.

The model of the estimation of multicriteria methods is based on the average use of the *Borda* and *Copeland* methods [13, 14]. The common conclusions can be made out after the multicriteria analysis has been fulfilled.

The risk of the renovation variants is determined in matrix way. Let’s assume that the investor wants to evaluate the risk level for each variant. That requires to calculate the standard deflection and the coefficient of the variation for each variant.

The standard deflection for every case is determined by the formula:

$$s_i = \sqrt{\sum_{i=1}^{t} \left[\left(S_i - S_0 \right)^2 \cdot p_i \right]}, \qquad (15)$$

where S_i – the solution result, conforming the i situation development scenarios, S_0 – expected result of the probability, p_i – the probability of situation development scenarios, t – the figure of scenarios of situation development.

The risk level of the assets is expressed as a function of liquidity, profit level and income stability:

$$R = L \cdot D \cdot C\,, \qquad (16)$$

where L – level of liquidity, D – level of profitability of the assets, C – levell of the income stability.

On the ground of the system of multicriteria analysis methods, the authors have developed the computer program *WinDeterminator* for solving the multicriteria tasks. The program should be useful for students of various specialties, scientists and manufacturers.

Usually the work with the program is processed in two stages: first of all the values of efficiency indicators are determined, later the variants priority row is being defined using the values of efficiency indicators based on SAW, TOPSIS or LINMAP methods.

The programmed block of the experts opinions pair comparison is assigned for determining the efficiency of indicators estimation (Fig 2). The program allows to save and to load again the data of separate tasks: experts' forms and solution matrixes. All the data, which consist of the values of efficiency indicators of all variants that are examined, the values of weights of criteria, the information showing whether the efficiency indicator is minimized or maximized, are included into the matrix. Data are saved on the special format used by the program.

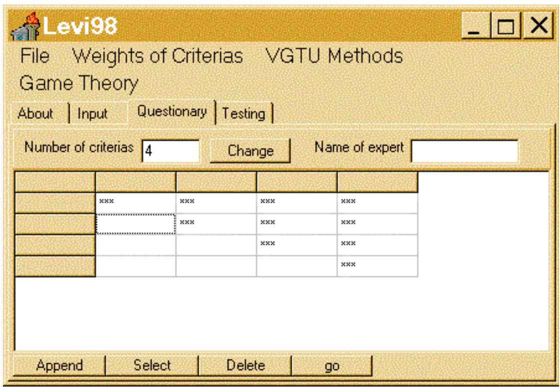

Fig 2. Form for filling in questionary results

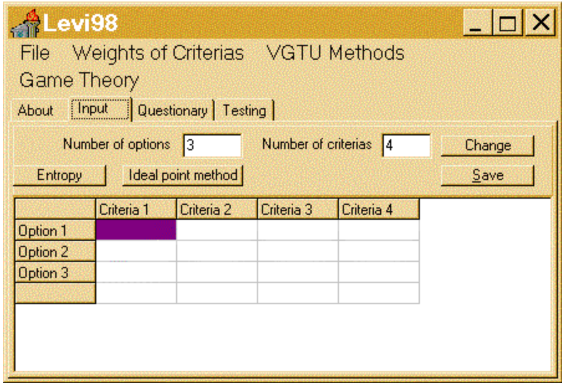

Fig 3. Form for filling in values of criteria

The definition of the variant priority to the TOPSIS, SAW and LINMAP methods is also programmed. To make the system control more primitive for the consumer, decision matrix for the determination using TOPSIS, SAW and LINMAP methods, are filled in the same form (Fig 3).

The facilities of the method created were shown solving a real comparison task of the old town building renovation. The method was applied to the investment project of the building in Vilnius old town. Various variants of this building renovation were examined according to this method, the most perspective ways of utilizing this building were defined. This project now is implemented and economical indices are similar to calculated ones. More information about case studies will be published in next number of STATYBA (Civil Engineering).

4. Conclusions

1. A new system of efficiency indicators and methods was built up for solving the old town building renovation tasks. It helps define the rationality of the investment projects for the old town buildings renovation.

2. The offered scheme presents the way of the old town building renovation. Several variants of utilizing the building have been developed. For example, apartments, café or the hotel can be arranged in the building. An estimate of expenditure is done for each variant. When the necessary expenses are clear for a variant, marketing calculations are performed: which variant is cheaper, what profit is possible after the building is sold or rented, what price of the sales must be

for getting back the invested money and ensuring the planned profit. Possible price of the sales is defined in a comparison way. If the crediting is part of the plan, the stages of the credit taking, investment itself and the growth of the interest are foreseen. The best variant is chosen in accordance to several criteria. Further stages of the process: the building is being renovated and sold, rented or put in service.

3. A system for estimating the investment variants of the old town building renovation was built up in a marketing aspect. The variants are estimated according to: profitability, durability, maintenance expenses, business perspectives, location of the building, period from the start of the renovation till realization, parking place existence, appearance of the building.

4. The improved expert method of pair comparison is used to determine the values of efficiency indicators. The method of pair comparison is useful because it allows to compare indicators in couples, what is important when comparing a big amount of indicators. The group estimation can be considered to be reliable only when the opinions of the experts interrogated are reconciled. Therefore statistical processing the information supplied by the experts, conciliation of their opinions should be appraised and the reasons of multivaluation of the information should be defined. The pair comparison method, presented by T. Saaty, does not include the test for conciliation of the experts' opinions. Therefore the offered expert method to test the conciliation of the experts'opinionss is the one that was presented by L. Evlanov.

5. Recommendations regarding the definition of 12 calculated values of efficiency indicators were presented.

6. For the first time the LINMAP method was assigned to solve building investment tasks.

7. The complex of multicriteria analysis methods was made up. It is used to solve the analytical tasks of the investments for the old town renovation.

8. The computer program *WinDeterminator* was created and is used for solving multicriteria tasks. It is useful for students of various specialties, scientists and manufacturers. The program computes the values of efficiency indicators using the expert pair comparison method, solves the multicriteria tasks on the basis of TOPSIS, LINMAP and SAW methods.

9. The facilities of the method created were shown solving a real comparison task of the old town building renovation. The method was applied to the investment project of the building in Vilnius old town. Various variants of this building renovation were examined according to this method, the most perspective ways of utilizing this building were defined.

10. The methods of multicriteria analysis are to be applied for examining variants of the old town renovation in marketing aspect; they make the process more effective and reliable.

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SENAMIESČIŲ PASTATŲ RENOVACIJOS VARIANTŲ DAUGIAKRITERINĖ SELEKTONOVACIJA RINKODAROS POŽIŪRIU

S. Jakučionis, L. Ustinovičius

S a n t r a u k a

Nustatytas senamiesčių pastatų renovacijos rinkodaros principas. Senamiesčių pastatų renovacijos investiciniams uždaviniams spręsti sudaryta ir pasiūlyta nauja efektyvumo rodiklių sistema ir metodai. Patobulintas ekspertinis porinio lyginimo metodas, taikomas efektyvumo rodiklių reikšmingumams nustatyti. Pirmą kartą statybos investiciniams uždaviniams spręsti pritaikytas LINMAP (*Linear Programming Techniques for Multidimensional Analysis of Preference*) metodas. Pateiktas selektonovacijos metodų kompleksas (1 pav.), skirtas investicijų į senamiesčių pastatų renovaciją analizės uždaviniams spręsti. Sukurta programinė įranga *WinDeterminator* (2, 3 pav.) selektonovacijos uždaviniams spręsti. Metodo galimybės buvo parodytos sprendžiant realų senamiesčio pastato renovacijos variantų lyginimo uždavinį.

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Leonas USTINOVIČIUS. Doctor (technological sciences), Associate Professor. Dept of Civil Engineering. Vilnius Gediminas Technical University. Saulėtekio al. 11, LT-2040 Vilnius, Lithuania. E-mail: nomstata@rl.lt

MSc (1982), Doctor (1989), Assoc Professor (1993). Author of more than 70 articles and manuals. Research interests: old town regeneration, IT in construction, multicriteria analysis.

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Sigitas JAKUČIONIS. Doctor (technological sciences). Dept of Civil Engineering. Vilnius Gediminas Technical University. Saulėtekio al. 11, LT-2040 Vilnius, Lithuania. E-mail: s@rl.lt

MSc (1996), Doctor (2000). Research interests: old town regeneration, IT in construction, multicriteria analysis.

Dr Audrius Banaitis

On 28 August 2000, at the Vilnius Gediminas Technical University (VGTU) Audrius Banaitis defended his doctoral thesis "Model of Rational Selection of Housing", technological sciences, civil engineering. This research presents an analytical model of complex analysis of selection of efficient housing, following the variable factors of micro- and macro-level surrounding which are settling effective selection of housing, describes them comprehensively taking into consideration the gained experience and knowledge in advanced countries and countries of Central and Eastern Europe (CEE), invites the methods of multiple criteria analysis to help in solution of problems of micro- and macro-level of housing, presents comparative systems of indices comprehensively describing the housing.

A. Banaitis was born on 21 May 1971 in the town Akmenė. After finishing eight grades in the local secondary school, he entered in 1986 the Panevėžys Polytechnic School. In 1990 he finished it with the qualification of civil technician/engineer and for almost half a year worked in a construction firm. In the same year he entered the Vilnius Technical University (from 1996 VGTU) and in 1994 graduated from it with a Bachelor's degree in civil engineering (BSc). The same year he started his Master degree studies in the VGTU Department of Construction Technology and Management and in 1996 graduated with a Master degree in construction science (MSc). From 1996 to 2000, he continued his studies for a Doctor's degree (head of the Doctoral studies committee was Prof Dr Habil Edmundas Kazimieras Zavadskas).

At the moment A. Banaitis works in the VGTU Department of Construction Technology and Management where he holds the position of an Associate Professor and a vice-dean of the Faculty of Civil Engineering.

The trend of his scientific research is building economics and policy, management of construction, multiple criteria complex analysis of construction industry.

A. Banaitis is member of the International Council for Research and Innovation in Building and Construction (CIB) as well as member of the editorial board of the international journal "Property Management" (until 2000 "Real Estate Valuation and Investment"). Together with co-authors he has published a number of articles in the international journals "Statyba", "Real Estate Valuation and Investment" and presented his scientific research reports at a number of international and national conferences in Aachen, Belgrade, Vienna, Athens, Timisaora, Vilnius, Kaunas, etc. In cooperation with his colleagues A. Banaitis has written 4 ordered scientific reports aimed at enhancing the efficiency of the complex construction.

A. Banaitis was a member of steering committees of the following international scientific conferences arranged by the VGTU: "Property Valuation and Investment in Central and Eastern Europe during the Transition to free Market Economy" (1997), "Facilities Management in Central and Eastern Europe and Commonwealth of Independent States" (1998), "Modern Building Materials, Structures and Techniques" (1999). He is a secretary of the steering committee of the currently organised 7th international conference "Modern Building Materials, Structures and Techniques".

In 1999 – 2000, A. Banaitis obtained a scholarship granted by the Lithuanian State Science and Studies Fund.

We wish the young vice-dean and scientific degree holder further enhancement of his knowledge and success in pedagogical work.

Prof Dr Habil ***Artūras Kaklauskas***

Dr Nerija Kvederytė

On August 28, 2000 at the Vilnius Gediminas Technical University Nerija Kvederytė defended her Doctoral thesis "Efficiency of single-family houses in harmonisation of interests of participants of their life cycle" (technological sciences, civil engineering). This is a research aimed at complex solving problems of the single-family house life cycle and efficiency with the help of a model, the methods of multiple criteria analysis and decision support system. Having discussed an international experience gained in this sphere, the author proposed a methodology allowing a complex valuation of the single-family house life cycle, ie by taking into account the entirety of different stages of a building life cycle together with the interested parties involved in the process and factors of environment. The suggested model of analysis has been realised by developing an original decision support system of the single-family house life cycle. Having applied the decision support system, the participants of a building life cycle are able to make efficient decisions. The system provides the user with all the necessary support that is required to argue upon the decisions taken: in information terms – receipt of quantitative and conceptual information describing a building life cycle, gathering and use thereof, in terms of selection of efficient variants – management and processing of such information applying methods of multiple criteria analysis.

Nerija Kvederytė was born on April 15, 1970 in Marijampolė town. In 1988, after finishing the J. Žiugždos Secondary School with the gold medal, she entered the Civil Engineering Faculty of the Vilnius Civil Engineering Institute (from 1996 VGTU) where she studied industrial and civil engineering and in 1993 acquired the qualification of a civil engineer. The same year she entered the VGTU Department of Construction Technology and Management and in 1995 graduated with a MSc degree. From 1995 to 2000 she continued her studies for a Doctor's degree (Chairman and work supervisor of the Doctoral Committee was Prof Dr Habil Artūras Kaklauskas).

In 1999–2000, N. Kvederytė obtained a scholarship granted by the Lithuanian State Science and Studies Fund.

At the moment, N. Kvederytė works in the VGTU Department of Construction Technology and Management where she holds the position of an Associate Professor and delivers lectures to BSc and MSc students (project management, quality management systems).

Together with co-authors N. Kvederytė has published a number of articles in the research journal "Statyba" and presented her scientific reports in a number of international and national conferences in Aachen, Minsk, Kaunas, Vilnius, etc. In cooperation with her colleagues N. Kvederytė realised her theoretical research results by implementing 2 ordered research projects.

The trend of her research is building life cycle, multiple criteria decision-making, decision support systems.

N. Kvederytė combines her scientific work at the University with her organisational activities. In 2000, she was a member of the steering committee of the "Construction" section of the 3rd conference of Young Lithuanian Researchers "Lithuania without Science is Lithuania without Future". She is also a member of the steering committee of the currently organised 7th international conference "Modern Building Materials, Structures and Techniques".

We wish the young and promising researcher N. Kvederytė luck and success in her scientific and pedagogical activities.

Prof Dr Habil ***Artūras Kaklauskas***

Dr Vida Malienė

Vida Malienė was born in Vilnius on 13 July 1971. In 1989, upon finishing the secondary school No 16 Vida Malienė entered Vilnius Civil Engineering Institute, the specialization of the applied geodesy. In 1994, she graduated from Vilnius Technical University, Faculty of Urban Engineering, and was granted the qualification of a geodetic engineer. In the same year she started the MSc geodesy studies, the specialization of geo-information systems (GIS). During her MSc studies V. Malienė got interested in property valuation and by the way of exception she was allowed to defend her thesis statement for the MSc degree, titled *Analysis of the Land Market in Lithuania*. In 1996, upon completion the MSc studies at Vilnius Technical University, V. Malienė continued her research work by publishing different articles and participating in the international and Lithuanian scientific conferences. In 1997, she started Doctoral studies at Vilnius Gediminas Technical University and became a Doctoral student at the Department of Building Technology and Management (Civil Engineering Faculty). During her PhD studies V. Malienė for one year learned and worked in the field of property valuation at Bonn Wilhelm-Friedrich University (Germany). Having learnt about the German and Western European legal framework, valuation methodology, she practiced in the Committee of Property Experts of the Bonn City, the Agency for Land Management and Territorial Planning in Bonn, Land Management Agency and private property company in North-Rein Westphalia. V. Malienė also made a research visit to the Leipzig Higher School of Technology, Economics and Culture (Germany) where she studied the market changes in the former Eastern Germany and the application of the valuation methodology in the transitional economies. During her Doctoral studies V. Malienė was an active participant at Lithuanian and international scientific conferences; she published twelve scientific articles in most prestigious publications of scientific conferences and other publications.

Alongside with her research activities, V. Malienė has been permanently engaged in professional activities, which were closely interrelated with the scientific work. Since 1994, she has been working as a senior engineer-property valuer at the State Land Management Institute. She has passed the qualification exams of the property valuer and has been granted the certificate of the valuer's qualification, which gives the right to engage in property valuation in Lithuania. In addition to the practical work, she has also had a teaching practice. She worked as an assistant at Lithuanian University of Agriculture and offered an academic course in property valuation. She also taught land management at Vilnius Construction College.

Vida Malienė acquired extensive scientific and practical knowledge and prior to the end of her Doctoral studies, on 1 December 2000, defended Doctoral dissertation *Property Valuation by the Methods of Multiple Criteria Analysis*. Theoretical and practical results of the dissertation were included into the curricula of the BSc and MSc degree studies, as well as in the international property valuation practice.

Prof Dr Habil ***Artūras Kaklauskas***

Dr Vaidotas Šarka

Vaidotas Šarka was born on June 29, 1970 in Birštonas. In 1988, he was enrolled on Vilnius Civil Engineering Institute and in 1993 completed the civil engineering programme with honours.

For three months in 1993, V. Šarka did research at Glamorgan University, Wales. There he collected materials for his MSc thesis. In 1995, he was awarded MSc degree in construction at Vilnius Technical University. For a month and a half of 1995, he continued research at Glamorgan University. He studied project management, construction management, and construction technology, was interested in software for solving construction technology and organisation tasks, and improved his knowledge of English. From 1995 to 2000, at Vilnius Gediminas Technical University (VGTU), he worked on Doctoral thesis "The multicriteria decision synthesis when selecting rational technological-organisational variants of buildings" (research adviser Prof E. K. Zavadskas). In 2000, he was awarded Doctor's degree (technological sciences). His research area is decision support systems, multicriteria decision methods, project management, and computerised design.

V. Šarka is broadly interested in information technologies. In 1993, he created a flow sheet computerised design system, in 1993 participated in creating the computer model "Rodiklis" ("Index"), designated for solving multicriteria variant tasks. In 2000, he prepared a computerised model and initial database for a decision support system, applying multicriteria synthesis methods (DSS_MS) in construction. The VGTU students are using the system as a teaching aid. The system has been also used by two real practical construction projects for selecting basic construction elements (foundations, frameworks, exterior walls, roof, windows, etc) and several construction processes.

In addition, V. Šarka worked: from 1991 to 1992, at Vilnius Technical University as an operator for the Department of Construction Technology and Management (CTM), from 1992 to 1994, as an assistant for the CTM department. From 1994 to 1995, he was head of laboratory at this department. Besides his Doctoral studies, he won in 1996 a competition for the position of a construction supervision engineer at the UAB "Bitė GSM" base exchange and is still working there at present. In this way he has also acquired practical work experience. He has been certified as a supervision manager for the construction of especially important structures.

While studying by the Doctoral programme, V. Šarka delivered lectures and guided practicums for Bachelor students and engineers in construction. He guided final theses for future engineers. Since 2000, he has been an assistant at the CTM. He has lectured on administration fundamentals, the organisation of construction, construction business and economics for CTM Bachelor students and engineers and has guided final theses for Bachelor students and future engineers.

V. Šarka is co-author of 7 publications in some Lithuanian and foreign research work collections and in the prestigious publication "Construction". He has also presented his research results at international and national conferences. He has compiled, together with joint authors, the methodological instructions in low-rise building construction for students "The possibility of using paroc rock wool in Lithuania".

Assoc Prof Dr ***Leonas Ustinovičius***

Dr Sigitas Jakučionis

Born September 14, 1972 in Vilnius, he was a student at Vilnius Technical University from 1990 to 1996, Civil Engineering Faculty. At secondary school and university he took part in a folklore company *Kodravas*. In 1994 he obtained BSc degree at Vilnius Technical University. Preparing his final paper "Trade Centre in Vilnius" he used computer calculations and he has got interested in programming and IT application in construction since. In 1996 he obtained MSc degree at Vilnius Technical University. During 1995–97 S. Jakučionis was working as a site manager at construction company UAB Repetys, in 1997–98 as a manager in International Office at Vilnius Gediminas Technical University. In 1997-98 he was working as Information and Analysis Department director at Environment Ministry (former Construction Ministry) of Lithuania.

In 1998–2000 he held the position of an estimator (site manager) in construction company UAB PROMENADO STATYBA (former UAB PROMENADAS).

From 1996 to 2000, he was Doctoral student at Vilnius Technical University. In 1998 he participated in training program INTERNATIONAL CONSTRUCTION MANAGEMENT at the Lund Centre for Habitat Studies (Lund University), Sweden. During his Doctoral studies, he had also several training programs at Leipzig University of Applied Sciences. In 2000 at Vilnius Gediminas Technical University he obtained Doctor's degree of technological sciences (civil engineering). The subject of dissertation was "Multicriteria analysis of old town buildings restoration in the aspect of marketing" (scientific advisor Prof Dr Habil E. K. Zavadskas). A system for estimating the investment variants of the old town building renovation was built up in marketing aspect. A complex of multicriteria analysis methods was made up. It is used to solve the analytical tasks of the investments to the old town renovation.

The computer program *WinDeterminator* was created and used for solving multicriteria tasks. It is useful for students of various specialties, scientists and manufacturers. The program computes the values of the efficiency indicators using the expert pair comparison method, solves multicriteria tasks on the basis of TOPSIS, LINMAP and SAW methods.

The created method was applied to the investment project of the buildings in Vilnius old town. Different variants of this building renovation were examined according to this method, the most perspective ways of the utilization of this building were defined.

S. Jakučionis is the author of 9 publications in different Lithuanian scientific journals and proceeding works of the international conferences.

His research interests include problems of old town regeneration, IT in construction, multicriteria analysis.

Assoc Prof Dr ***Leonas Ustinovičius***

ABSTRACTS

O. Kapliński. Changes and achievements in *CM* research and *CM* education at the Poznań University of Technology // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 385–396.

A review of problems, conditions and trends in changes in construction management education and research is presented in this paper. It describes a typical cause and effect chain (financing, programme of studies and research) in Poland. This paper also presents certain aspects of specialisation in Construction Engineering and Management. A new tendency in education in the Chair at Poznań University has appeared within the profile of post-graduate courses in real estate estimation and management. The PhD dissertations reach towards the field modelling of construction processes, and are tied to a research database, using some elements of artificial intelligence.
Refs 32. Figs 6. Tables 2.

E. K. Zavadskas, A. Kaklauskas. Efficiency increase in research and studies while applying up-to-date information technologies // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 397–414.

The article contains the description of achievements of Prof E. K. Zavadskas and Prof A. Kaklauskas in the field of research and studies within the period of 1997 to 2000. The following major researches have been carried out during this period: development of a model for a complex analysis of a building life cycle; development of methods of multiple criteria analysis; development of multiple criteria decision support systems; total life analysis, modelling and forecasting of construction in Lithuania; efficiency increase in e-commerce systems applying multiple criteria decision support systems. Changes carried out in study process have been mostly connected with development of two post-graduate distance (Internet) study programmes and implementation thereof in the Department of Construction Technology and Management at the VGTU. The article includes a brief description of the above-mentioned work.
Refs 113. Figs 3.

J. Pasławski. Methods for risk management in concreting at low temperatures // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 415–419.

The theoretical background of risk management is firstly presented. In the second part, a cause study concerning decision-making in concreting at low temperatures is analyzed. Some elements of the COLCON advisory system for making decisions in concreting at low temperatures are presented.
Definitions or risk and uncertainty, which are key terms variously approached in references, are provided. Methods of procedure specific for application in conditions of risk and uncertainty are proposed, based on which strategies of risk management in concreting at low temperatures are formulated. The mutually compensating character of two key strategies: risk retention and risk reduction, is pointed out. Cost analysis as the key element in making-decisions concerning their contribution to the general strategy is indicated.
Refs 11. Table 1.

T. Thiel. Application of multicriteria decision-aid methodology in building production engineering // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 420–430.

The article presents a concise approach to the basic issues of the MCDA methodology, and the issues related to the group of methods of multicriteria analysis. A decision problem as such has been discussed, leading to the final ranking of the chosen alternatives of a solution of road surface structure and design (from the best to the worst). The chosen alternatives of a solution can be implemented in practice, under specific Polish conditions. An appropriate method of calculation has been selected, the method classified as a multicriteria analysis method which made the solution of the problem feasible (the ELECTRE III method). A sensitivity analysis has been carried out with regard to the final ranking of the compared alternatives, arrived at by means of the chosen calculation method and accepted by the decision-maker. The solution of the problem under analysis proves that it is possible to use the MCDA methods and methodology at the stage of investment planning, and at the stage of initial design (feasibility study).
Refs 8. Figs 3. Tables 3.

A. Fojud. Multidimensional data analysis in construction industry // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 431–435.

We have recently seen an impressive development of advanced technologies in construction industry, and a multiplicity of designs and solutions, which are available at every stage of erecting a building or structure. In consequence, a problem has emerged, regarding the optimisation in decision-making, and presenting appropriate arguments to support certain solutions in the engineering work. Therefore, in the engineer's practice, one of the tools available is a system using multidimensional analysis of the information in store. This paper aims at presenting a spectrum of possibilities of using multidimensional data analysis in construction industry, and is meant to stress the increasing role of multi-dimensional information analysis in the daily work of an engineer, as well as its role in property management. The paper presents modelling which uses multidimensional data, and the analysis of such data used in technical design. The second part of the paper presents the usage and significance of the multidimensional analysis in advisory systems supporting people involved in taking decisions about property management.
Refs 3. Figs 9.

T. Wiatr. Capital expenditure and receipts analysis in construction project management (description of the model) // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 436–439.

The article describes the general model of project control in aspects of cash flows - in relation to schedule of production planning and schedule of financial planning. In this model, cash events have discrete character, but value of works has a continued form of an S-curve. Discrete form of expenditure is in the opposition to actual knowledge. Proposed name of the model is IVO (Inflow-Value-Outflow) according to this feature. The model enables to analyse problems using special software. In a narrow sense, the model may be a base of sensitivity analysis in effect of change a single variable within a project. In a wider sense, the model may be a simulation tool. In the widest sense, the model with probability calculations may be a tool for risk analysis. The article promotes integrating of production planning and financial planning into one system of management. This system concentrates directly on project but indirectly on construction firm (firm like a portfolio of projects).
Refs 11. Figs 2. Table 1.

S. Mitkus, T. Dėjus. Multiple criteria evaluation of construction tenders in accordance with the law on public procurement of the Republic of Lithuania // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 440–444.

At least several criteria should be taken into account in order to properly evaluate construction tenders. Despite of the fact that methods of multiple criteria evaluation of tenders have been widely analysed in scientific papers, such evaluation according to the Public Procurement Law of the Republic of Lithuania has not been researched as yet.
The term "multiple criteria evaluation" is not used in the law, but research shows that one of the allowed criteria of evaluation according to the law of "economic usefulness" in principle represents the method of multiple criteria evaluation.
Studies of the law and further government decisions show that the process of tender evaluation may be divided into three stages.
The article deals with possibilities of using multiple criteria evaluation of tenders, according law on public procurement and normative by-laws.
Refs 5. Tables 5.

N. Kvederytė. Analysis of efficiency of single-family house life cycle // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 445–450.

To design and achieve an effective process of life cycle of a single-family house it is necessary to take care of the house's efficiency starting from determination of its needs and objectives and ending to its usage. In each stage of the life cycle of a building many interested parties are involved: clients, designers, contractors, manufacturers and suppliers of construction materials and products, users, etc. While designing the life cycle of a building and making decisions it is necessary to take into account the interests of all interested parties. The life cycle of a single-family house has to be designed and implemented taking into consideration its stages, objectives and opportunities of the interested parties involved in the process.
The paper proposes a model for complex analysis of efficiency of the single-family house life cycle, in which various factors and circumstances are described by a set of criteria. Following that model, the interested parties involved in design and realisation of a project are able to design alternative variants of a single-family house life cycle, to evaluate them and determine the most efficient decision for the existing situation. On the basis of the model, a decision support

system is developed. This system helps the participants of the building life cycle to seek successfully their objectives, to increase efficiency of the life cycle. While applying the methods of multiple criteria analysis in decision support system, it is possible to settle the problem of optimisation of the intended objectives required for their implementation. Refs 16. Fig 1.

A. Banaitis. Model of rational housing in Lithuania // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 451–456.

The current state of housing and the trends of its development have been analyzed from various conceptual and quantitative perspectives by a number of scientists. Researchers from various countries use conceptual and quantitative forms of analysis while studying the effect of certain factors on the efficiency of housing. However, the papers mentioned did not deal with a complex approach to housing when discussing economic, quality, social, technological, legislative and other factors.

The main objective of this paper is to present an analytical model of complex analysis of rational housing. A model in the paper is considered as the system of specific rules in presence of whose the housing of Lithuania would apply its potential opportunities. Prospects of future Lithuanian housing and the principal trends of its development are linked with analysis of experience and knowledge gathered by advanced and CEE countries, and application thereof evaluated the specific features of Lithuania. Having used expert methods and analysis of scientific literature, the micro- and macro-level factors are being determined as well as the systems and sub-systems of indices describing them, describing housing in the initial stage. In accordance with the made systems of indices the situation of housing in Lithuania, CEE and advanced countries is being described conceptually and quantitatively. Following the gathered information, a database is made describing variable indices of micro- and macro-level of various countries and their influence on housing. Inviting the information gathered in the database to help, the trends of development of housing of advanced, CEE countries, differences of these countries and Lithuania in this field are determined.
Refs 20. Fig 1. Table 2.

V. Malienė. Valuation of commercial premises by the method of multiple criteria analysis // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 457–463.

A number of problems in the valuation of real property can be eliminated by the methods of multiple criteria analysis, which came into existence only at the second half of the 20th century. Currently, they have become very important in the international practice of the real property valuation. In most cases they are based on market modeling and economic assumptions. Therefore, sometimes they are referred to as separate valuation methods, and classified as modern ones. This article describes a new method of multiple criteria analysis. This method, based on the market analysis and valuation principle, is in line with the traditional comparative value method, therefore it can be attributed to the group of the indirect comparative value methods. These methods facilitate the universal and more extensive multiple criteria analysis of the property, since they take account of a number of different criteria, ie qualitative, quantitative ones, market conditions. The proposed method can meet the demands and needs of many interested groups since it enables to estimate not only the market value of the property, but also other values, eg investment value, value of use, market value of the current use of the property, etc. This article describes the theoretical model of the method, which was used to estimate the market value of the commercial premises.
Refs 7. Fig 1. Table 3.

V. Šarka. A decision support system applying multicriteria synthesis methods in construction // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 464–468.

The subject of the research is multicriteria decision theory and decision support system. The author's purpose was to investigate the current decision support systems and the mathematical models used in them as well as to improve them by introducing several multilevel, multicriteria decision synthesis methods.

A new decision support system applying multicriteria synthesis methods (DSS_MS) is being created to implement joint projects. The decision support system is designated to accumulate and process initial data using mathematical and logical models including multicriteria assessment methods. The primary focus of this research is to clarify the possibilities of using multicriteria decision selection method in an effort to solve the problems of decision-making connected with the construction industry.

The structure of the DSS_MS in construction is based on a systematic technical assessment of projects, expert assessment, and the multicriteria decision synthesis methods proposed by the author. The aim of a decision by these methods is to combine the alternatives of several analysed construction processes or projects into a general construction system decision tree.

In order to check the reliability of the newly created system, there was created a decision support system computer model, applying multicriteria synthesis methods (DSS_MS), which is designated to solve equipping design problems of complex parts of a building, combining them into a general totality with the assistance of synthesis methods. In this system are used additional programming measures for solving undefined questions: methods of expert assessment and pair comparison. Various methods for project system technical assessment are proposed for solving single level multicriteria assessment tasks.

DSS_MS in construction is designated for engineers, experts, construction technology management students, and other users. As a teaching aid, this system should assist students to better understand as well as to independently master and learn new concepts and the methods connected with the multicriteria decision methods that are becoming ever more popular. As an applied system, the programme can analyse multilevel tasks for the most complex structures, which frequently arise in the complex construction industry. The control of the software system part as well as the creation and filling of the database structure is simple and do not need a large additional expenditure of labour. The system has an internal control mechanism for self-control with certain assigned parameters.

Refs 7. Fig 1.

S. Jakučionis, L. Ustinovičius. Multicriteria analysis of the variants of the old town building renovation in the marketing aspect // STATYBA (Civil Engineering). Vilnius: Technika, 2000, Vol VI, No 6. P. 469–475.

A new system of efficiency indicators and methods were built up for the purpose of solving the old town building renovation tasks. The way of the old town building renovation was offered. An improved expert method of pair comparison is used to determine the values of efficiency indicators. For the first time the LINMAP method was assigned to solve building investment tasks. The complex of methods of multicriteria analysis was made up. It is used to solve the analytical tasks of the investments to the old town renovation. The computer program *WinDeterminator* was created and it is used for solving the multicriteria tasks. It is useful for students of various specialties, scientists and manufacturers. The program computes the values of the efficiency indicators using the expert pair comparison method, solves multicriteria tasks on the basis of TOPSIS, LINMAP and SAW methods. The facilities of the method created were shown solving the real comparison task of the old town building renovation.

Refs 14. Figs 3.

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