16-17 November, Novi Sad, Serbia

16th International Scientific Conference

integration Novelty Design interdisciplinarity Sustainability

Proceedings

Editors: M. Trivunić, I. Džolev, M. Šešlija

16th International Conference -integration, Novelty, Design, interdisciplinarity, Sustainability - Conference Proceedings

DEPARTMENT OF CIVIL ENGINEERING AND GEODESY

iNDiS2023

16 iNDiS 2023

INTERNATIONAL SCIENTIFIC CONFERENCE

“Integration, Novelty, Design, Interdisciplinarity, Sustainability”

PROCEEDINGS

Novi Sad, Serbia, 16-17 November 2023

Editors:	Milan Trivunić Igor Džolev Miloš Šešlija
Technical organization of the meeting:	Department of Civil Engineering and Geodesy, Faculty of Technical Sciences, Novi Sad
Technical editor of the proceedings:	Miloš Šešlija
Graphic design:	Sara Koprivica
Publisher:	Department of Civil Engineering and Geodesy, Faculty of Technical Sciences, Novi Sad

CIP - Каталогизација у публикацији
Библиотеке Матице српске, Нови Сад

69.05(082)
624(082)
72:502.1(082)

INTERNATIONAL Scientific Conference „Integration, Novelty, Design, Interdisciplinarity, Sustainability" (16 ; 2023 ; Novi Sad)
Proceedings [Elektronski izvor] / 16th International Scientific Conference „Integration, Novelty, Design, Interdisciplinarity, Sustainability" iNDiS 2023, Novi Sad, Serbia, 16-17 November 2023. ; [editors Milan Trivunić, Igor Džolev, Miloš Šešlija]. - Novi Sad : Faculty of Technical Sciences, 2023

Način pristupa (URL): https://indis.gradjevinans.net/. - Nasl. sa naslovnog ekrana. - Opis zasnovan na stanju na dan 28.12.2023. - Bibliografija uz svaki rad.
ISBN 978-86-6022-615-2

а) Индустријска градња -- Зборници б) Грађевинске конструкције -- Зборници в) Архитектура -- Еколошка градња – Зборници

COBISS.SR-ID 134266377

iNDiS 2023

Department of Civil Engineering and Geodesy, Faculty of Technical Sciences, University of Novi Sad, is organizing the sixteenth international scientific conference "iNDiS 2023" - integration, novelty, design, interdisciplinarity, sustainability. From this year, the modified format of the event starts, therefore the conference will be held biennial in the future.

Topic of the first conference, held in 1976, was "Industrial construction of apartments" because of its modernity in that period. Later, conferences were held with a considerably broader theme of "Construction Industrialization", and soon papers from all areas of construction appeared at the conference, from urban planning and design of buildings of various purposes, to maintenance and major interventions on the built construction stock. This led to the expansion of the area of expertise, covered by this conference, in which, in addition to civil engineers, urban planners, architects, engineers of other professions, who work in construction, sociologists, economists and others participate.

This conference, like several previous ones, covers the problems of planning, designing, construction and renovation of construction, geodesy, geoinformatics and risk management of catastrophic events, which have come across to an adequate response from researchers and engineers of various profiles, both from our country and abroad.

Members of the International Scientific Committee actively participated in the preparation of the conference, both as reviewers and authors. It is expected that the presentations of papers and discussions at the conference will enable the definition of the main directions of construction development, in accordance with modern trends, since many ideas and results, experimental and theoretical researches in the fields of construction have been promoted.

For this conference, the Proceedings consists of two books, namely Book 1. Papers in English and Book 2. Papers in Serbian, which enables better and more fruitful communication and exchange of experiences with colleagues from abroad.

Additionally, the possibility of establishing new and strengthening existing professional and collegial ties is also of the great importance. This year, authors from 13 countries are participating in the Conference, and the Proceedings Book 1 contains 94 papers in English, while the Book 2 contains 23 papers in Serbian, in total 117 papers.

The editors express their sincere gratitude to all the authors for the effort invested in writing the papers as well as for their contribution to this event.

Editors of the Proceedings

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THE MULTI-CRITERIA DECISION MAKING MODELS IN ARCHITECTURE: APPROACH DEVELOPMENT THROUGHOUT THE HISTORY

Damjana Nedeljković[1], Tatjana Jurenić[2], Aleksandra Čabarkapa[3]

Summary:

Multi-criteria models for decision-making are an instrument used in various fields within processes that require a choice between several alternatives, and are based on the comparison of various aspects of potential solutions, among which it is possible to establish a hierarchy. A certain number of such models are also applied in the field of architecture, and they are intended, among other things, to evaluate the potential of buildings for various types of adaptations or to select an adequate intervention in relation to the current state and characteristics of the observed object and its location. The paper represents the historical development of models for decision-making and the influence on the creating of contemporary multi-criteria models, the application of experiences from other fields, grouping according to certain criteria and the shaping of elements of multi-criteria models throughout history.

Key words: multi-criteria decision making models, historical aspect, development, types of models, elements

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1. INTRODUCTION

Depending on the problem to be solved, the number and characteristics of the solutions offered and the differences in the interests of the participants, the decision-making process can be very complex. In those cases, participants use techniques, which can be formal (cost-benefit analysis, multiple criteria decision analysis, decision trees, etc.) and informal (which are not the subject of research in this paper) to help making decisions. All formal decision support techniques are similar in that they contain a set of clearly defined rules on the basis of which the necessary data are selected and evaluated. Multi-criteria models for decision-making represent one of the formal techniques for decision-making support. These models represent mathematical instruments that are used to more successfully solve problem tasks in various fields.[1] The research is primarily directed towards multi-criteria decision-making models applicable in architecture, but many findings are general and applicable to all models of this type.
In the paper there are two parts.
The first part of the paper, the development of the approach itself, which preceded the emergence of multi-criteria models for decision-making, is presented, various approaches to aid in decision-making are explained and the structure with basic elements is shown, which applies to all multi-criteria models, regardless of their purpose, while the second part of the paper presents nine multi-criteria models that have different uses in architecture.
The main goal of the research is to improve understanding of how to use multi-criteria models for decision-making and their more frequent application in decision-making processes in all suitable fields.

2. DEVELOPMENT OF THE MULTI-CRITERIA DECISION-MAKING MODELS

2.1. APPROACH DEVELOPMENT

The beginnings of the formal research of the decision-making process are not known, but within the process itself, two lines of research are recognized: the first relates to analyzing the origin of decisions and the second relates to utility theory and multiple objective mathematical programming.
Within the first line, Edgeworth's (Francis Ysidro Edgerworth) early work on the indifference contours from the 1880s, Ramsey's (Frank Ramsey) and Finetti's (Bruno de Finetti) subjective expected utility model from the 1930s and von Neumann's (John von Neumann) and Morgenstern's (Oscar Morgenstern) utility theorem from the 1940s.
Multiple objective mathematical programming was mostly developed during the 1970s. The basic characteristic of this approach is a certain reconsideration of explicit estimates of values or utility functions and the focus is on finding ways to choose the most suitable solution.
The author of one of the first known models that have the form of the multi-criteria decision making model that we know today is the American statesman Benjamin Franklin. His way of making decisions, which he called "Moral Algebra", was based on the formation of a list with arguments in favor of the issue and against it. Then, on both sides of the list, arguments that had approximately equal importance were removed, until all arguments were removed on one side. The result is a position with which a number of unremoved arguments remain.[2]

2.2. DECISION AIDING APPROACHES

In the decision-making process, there are different approaches to problem solving, which depend on the profile of the participants in solving the problem. In this paper it

will be presented four basic approaches: normative approaches, descriptive approaches, prescriptive approaches and constructive approaches.

Normative derive models of rationality from a priori established norms. Such norms are an integral part of rational behavior and can refer to ethical, religious norms and laws. Deviation from these norms would result in errors in the decision-making process from a rational aspect. Models with a normative approach are universal and can be applied to help solve problems in any field.

Descriptive approaches derive models of rationality from the perspective of the decision makers themselves. These models are general and applicable to different types of decision makers who are making a decision on a similar type of problem.

Prescriptive approaches find models of rationality for a particular client by interpreting his answers to questions related to preferences. The model is based on the discovery of the decision maker's value system. Therefore, these models are not general, but closely adapted to a particular decision maker and the specifics of his problem.

Constructive approaches, similar to the previously described approach, derive models of rationality from the answers the decision maker gives to questions about preferences. Nevertheless, the "discussion" between the decision-maker and the analyst he addressed is not neutral, but is part of the decision-making process, forming a presentation of the problem with indications of a potential solution. In this approach, structuring and formulating the problem is as important as arriving at a solution.

Previously listed approaches can be divided into two groups. The first group consists of normative and descriptive approaches that are universal, use general models of rationality that are formed independently of the decision maker, while the second group consists of prescriptive and constructive approaches that adapt the model of rationality to the specific decision maker and the specific problem.

Normative and descriptive approaches differ in the process of model formation. Normative models are based on abstract economic facts, and descriptive models are based on empirical observation. The difference between prescriptive and constructive models is also, to a large extent, in the process of forming the model. Prescriptive approaches seek to reveal the value system that exists in the decision-maker himself, before considering the decision-making process. On the contrary, within the framework of constructive models, the existing value systems are not considered, but the decision-maker forms the value system during the formation of the model, noting that these two processes are mutually conditioned. [1]

2.3. BASIC ELEMENTS OF THE MULTI-CRITERIA DECISION MAKING MODELS

Although multi-criteria decision-making models differ from each other depending on what they are intended for, the same basic elements are recognized in the structure of each of them. The creation of each multi-criteria model begins with the definition of the problem, then the system of preferences is determined, a set of criteria is formed, and one or more outranking methods with a weighting system are determined. Each of these elements will be explained in Table 1.

Tab. 1 Preview of the basic elements of the multi-criteria decision-making models

<table>
<tr><td rowspan="10">Basic elements of the multi-criteria decision making models</td><td colspan="2">Defining a problem</td></tr>
<tr><td>Formulating a problem</td><td>Problem structuring</td></tr>
<tr><td>- to translate the decision maker's problem in decision support language into a "formal" problem so that decision support techniques and methods can be used in solving;
- the formulation of the problem directs the further steps of decision-making.[1]</td><td>- to find a suitable decision and/or evaluation model, based on the previously formulated problem;
- some of the well-known methodologies for structuring problems are: cognitive mapping, strategic choice, soft systems methodology, valued focused thinking, integrating approaches. [1]</td></tr>
<tr><td colspan="2">Preference detection system</td></tr>
<tr><td colspan="2">- recognition of the decision-maker’s preferences over the set of alternatives;
- detection of preference relation among alternatives previously evaluated according to certain dimensions;
- some of the preference detection systems with many variations:
pointwise evaluations on an ordinal scale, pointwise evaluations on an interval scale, pointwise evaluations on a ratio scale, interval evaluations on an ordinal scale, etc.[1]</td></tr>
<tr><td colspan="2">Criteria</td></tr>
<tr><td colspan="2">- different types of criteria and indicators according to which alternatives are evaluated;[1]
- three groups of criteria are recognised in multi-criteria decision-making models used in a field of architecture: general criteria and indicators, specific criteria and indicators determined by the type of adaptation and specific criteria and indicators determined by the specific context.[3]</td></tr>
<tr><td colspan="2">Outranking methods</td></tr>
<tr><td colspan="2">- aggregation methods used for creating a global preference relation which is based on pairwise comparisons of the alternatives;
- some of the outranking methods used in multi-criteria decision-making models are: ELECTRE, PROMETHEE, MAUT, TACTIC,etc.[1]</td></tr>
<tr><td colspan="2">Weighting system</td></tr>
<tr><td colspan="2">- determination of the relative importance of the different criteria using weights – non-negative numbers, which values are independent from measurements units of the criteria.[3]</td></tr>
</table>

3. THE MULTI-CRITERIA DECISION MAKING MODELS IN ARCHITECTURE

After basic steps in decision making process and structural elements of every multi-criteria decision making model, in this part of paper a brief review of nine multi-criteria decision making models used in architecture is presented.

3.1. THE CONVERSION METER MODEL

The *Conversion meter* model is intended to assess the potential for conversion of commercial buildings into permanent and temporary housing. The first version of the

model was created at the end of the twentieth century in the Netherlands, when a large number of business buildings were out of use. The evaluation of the potential is done in several steps, through several lists of criteria, and each positive answer is worth one point. Value ranges are determined on a numerical scale that are linked to a certain level of potential of a business object for conversion. The specificity of this model is the use of "veto" criteria, which, if not met, stop further evaluation.[4]

3.2. THE TOBUS MODEL

The *TOBUS (Tool for selecting office building upgrading solutions)* model is the result of joint research by experts from several European countries (Denmark, France, Greece, Switzerland and the Netherlands) and was developed within the European research program JOULE III. It is intended to assess the current state of the business facility, on the basis of which a set of interventions for improvement is proposed. Essentially, the model has the ability to propose a large number of different scenarios and an analysis of the financial and energy aspects of the realization of a potential adaptation. In order to make it easier to use, the software of the same name was developed, which, initially, uses data related to the territory of Switzerland, but the structure of the software is designed so that it is possible to enter data relevant to other countries.[5]

3.3. THE XENIOS MODEL

The *XENIOS* model or methodology is a multi-criteria model intended to help in the decision-making process related to different scale of adaptations of hotels. The model offers a technical and economic assessment of potential interventions, taking into account the specifics of this group of buildings, while relying on experiences in the field of different types of adaptations of residential and commercial buildings. For potential users of the model, the software which is programmed to estimate the total costs of various scenarios - potential types of adaptation and to recommend related to improving the energy properties of buildings, installation of renewable energy sources can be obtained, was designed. Through special modules for assessing the sustainability of buildings and their impact on the environment, techniques are proposed for the rational use of energy.[6]

3.4. THE MEDIC MODEL

The *MEDIC* model is designed so that it can be used with the *EPIQR* model, which will be explained below. The model divides each object into fifty elements, and, through the use of four codes (which are also used in the *EPIQR* model) an assessment and description of the state of all elements of the object is performed. Based on the experience gathered by analyzing a large number of other objects and data related to a specific object, using the *MEDIC* model , the remaining "expected life" of the object can be calculated. The expected remaining duration of building elements is not only one of the criteria when choosing the type of adaptation, but also when evaluating the energy and environmental characteristics of the building. The above estimates are important when planning investments, since they allow the owner and/or investor to decide what is the most reasonable moment to start the adaptation of the building.[7]

3.5. THE EPIQR MODEL

The *EPIQR (Energy performance indoor environmental quality retrofit)* model is based on a detailed description of the object for which some type of adaptation is being considered. As described in the part with the *MEDIC* model, in the model, the building is divided into fifty elements such as facades, installation systems, etc. Each of the elements is described by one of the four degrees of degradation (represented through the codes discussed in the part about the *MEDIC* model). More than eight hundred potential

descriptors are used to define the state of the object. The assessment of the potential for some kind of adaptation is considered through criteria that are grouped into four aspects: the quality of the interior space, the required amount of energy, potential costs and measures of subsequent equipment. The analysis of these aspects can help when choosing the optimal way to adapt the building.[8]

3.6. THE ARP MODEL

The assessment of the potential for the conversion of commercial to residential buildings using the *ARP (Adaptive reuse potential)* model is based on the consideration of the (temporal) moment in which the building is located in relation to its estimated useful life. In the model, first of all, the physical life of the object is evaluated, that is, the possibility of the object's duration as a physical structure, based on a list of criteria. The useful life, that is, the period in which the object is expected to be used for the purpose for which it was built, represents the physical life reduced by various factors. In this model, result is displayed graphically, through a diagram, and through a numerical scale within which the ranges of values associated with the specific potential of the business object for repurposing are determined.[9]

3.7. THE ADAPTSTAR

The *AdaptSTAR* model is a tool designed to assess the future adaptive potential of buildings under construction. The future possibility of the building adaptive reuse is considered as one of the key criteria during the process of building design. In order to check the adaptive reuse potential of the building, the *ARP* model will be used. The *AdaptSTAR* model is designed as a weighted checklist for different design strategies aimed at high-potential of buildings for future conversion. The list of criteria for the building design was compiled based on the assessment of professionals from the architectural profession. The model is based on the analysis of case studies, interviews with experts and surveys conducted among participants in the processes of adaptive reuse in practice.[10]

3.8. THE ICONCUR MODEL

The *iconCUR* model considers the potential of a business object for various types of adaptations, based on a set of criteria. The evaluation takes place through a diagram, which is designed as a spatial grid, the sides of which are different types of adaptations, and the object is positioned according to certain coordinates. The distance of the object from the sides of the spatial grid is measured. By using this model, it is possible to see the potential of several objects simultaneously or of one object over time. The specificity of this model is the establishment of a hierarchy among the criteria, which has an impact on the final result.[11]

3.9. THE PAAM MODEL

The *PAAM (Preliminary assessment adaptation model)* model is intended to assess the potential of business facilities for upgrading. This paper discusses the large number of criteria that are important for all types of adaptations and the way of establishing a hierarchy among the criteria. The selection of the criteria of this model, as well as the method of valorization, is based on statistical data collected by analyzing a large number of objects on which this type of adaptation was carried out, where the influence (in percentage) of each criterion on the final outcome is estimated, and the percentage share is determined by the mathematical method *PCA (Principle Component Analysis)*. Criteria that affect the object's potential for this type of adaptation to the same extent are ignored in all analyzed cases.[12]

4. DISCUSSION AND CONCLUSION

Multi-criteria models represent one of the formal forms of assistance in the process of solving problems in various fields. Through the analysis of the development of ideas on which multi-criteria decision making models are based, it can be concluded that the need for rationalization and formatting of thought processes and opposing views in the decision-making process existed long before the emergence of today's forms of models in this area.

The first part of the paper is generally aplicable for multi-criteria decision models intended for use in any field and presents the basic ways of thinking on which the logic of multi-criteria decision making models is based and the basic elements recognized in the structure of each of those models. Each of the elements has a number of variations, the combination of which provides the possibility of forming a multi-criteria decision making model that corresponds to the specifics of individual cases.

In the second part of the paper, an overview of multi-criteria decision making models used in different parts of the architectural field is presented. Some of these models are intended for choosing the best solution among the offered alternatives, others are focused on assessing the degree of suitability of one solution in a specific case. It was noticed that some of the analysed models were created together, within the same larger project and that they complement each other. This fact indicates the development of the idea of applying multi-criteria decision making models in architecture, and it is expected that the application of these models in the early stages of decision-making during the design process will greatly contribute to the quality of the final product - built environment.

ACKNOWLEDGEMENT

This research was done at the University of Belgrade – Faculty of Architecture, within the Research Laboratory: *Optimal lighting design in architecture*.

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