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*Research paper*

# RESEARCH LINES IN THE FIELD OF CONVERSION OF VACANT OFFICE BUILDINGS: USE OF MULTI-CRITERIA DECISION-MAKING MODELS

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**Abstract**

*The field of conversion of vacant office buildings includes several aspects, and consequently, various research lines have been identified. The studies focus on the causes of abandonment of office buildings, possibilities for their conversion into temporary and permanent housing, analysis of desirable characteristics of office buildings from the users' perspective, the impact of land policies on the conversion process, the influence of the regulatory framework, the conversion of buildings with cultural heritage status, and so on. All research is aimed at improving the efficiency and cost-effectiveness of the conversion process of vacant office buildings in practice. The research relies on the analysis of existing multicriteria decision making models and the comparison of their structures and criteria. Based on the analysis of the selected models, a structure has been identified that can be applied to form new multi-criteria models of this type. The goal is to highlight the potential for applying such models in contemporary architectural and urban practice.*

**Key words:** *office buildings, platform, criteria, evaluation*

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# 1. INTRODUCTION

With the increasing number of different forms of reconstruction represented in contemporary architectural and urban practice, this topic has become the subject of interest of many researchers. Several different lines of research have been recognized in the field of repurposing. In Table 1 the lines of research related to office buildings out of use are presented.

*Table 1: Research lines in the field of conversion of business facilities*

| Research lines | Authorities |
|---|---|
| Criteria for evaluating the potential of a business object for conversion | H. Remoy, T. J. M. Van der Voordt, H. de Jonge, T. P. Heath, R. Mackay |
| The impact of legislation on the process of office building conversion | H. Remoy, E. Street, P. A. Bullen, P. E.D. Love, J. Barlow, D. Gann, R. Olivadese, C. Berizzi, F. Hobma |
| Adaptability in the design of office buildings | H. Remoy, P. de Jong, W. Schenk, M. Ouf, W. O'Brien, B. Gunay, S. Slaugther, J. Gosling, P. Sassi, R. Lark, J. Douglas |
| Aspects of sustainability in the process of conversion of office buildings | H.Remoy, S. Wilkinson, E. H.K. Yung, E. H.W. Chan |
| Causes of the abandonment of office buildings | H. Remoy, P. Koppels, C. van Oel, H. de Jonge |
| Historical aspect – the development of conversion | B. Plevoets, J. Sowinska – Heim, K. Van Cleempoel |
| Multi-criteria models for evaluating the potential of office buildings for conversion | C.Langston, R. Geraedts, T. van der Voordt, D. Caccavelli, H. Gugerli, C.A. Balaras, G. Ding, F. Flourentzou, J.L. Genre, C. A. Roulet, A. Kaklauskas, E. Kazimieras Zavadskas, S. Wilkinson |

Remoy investigates various aspects of the abandonment of commercial buildings and their conversion into temporary and permanent residential buildings, which relate to the necessary interventions on commercial buildings to adapt them to the needs of the new purpose, the causes of the general disuse of commercial buildings, the analysis of the supply and demand of the purpose in the market and the analysis of the desirable characteristics of the location and the commercial building as a physical structure [1]. Research of van der Voordt are focused on the benefits and risks of converting a commercial building into a residential building, legal, financial, technical, functional and architectural criteria based on which the potential of a commercial building for conversion into temporary or permanent housing can be assessed, economic feasibility and the influence of the target group of future users on decisions in the conversion process [2]. Heath deals with the revitalization of city centers by converting commercial buildings into residential ones, and examples include the cities of London and Toronto [3]. Mackay researches the costs of repurposing a business building through modeling, considering the share of the value of interventions on individual elements concerning the final costs [4]. Remoy and Street consider the impact of land policies on the process of repurposing commercial buildings using the examples of England and the Netherlands [5], and Remoy, Olivadese, Berizzi and Hobma explore the advantages and disadvantages of regulations in Italy and the Netherlands concerning the efficiency of the process of converting commercial buildings into residential buildings [6].

Bullen and Love consider the conditions for the conversion of commercial buildings that have been declared cultural assets and are under a certain degree of protection, for example, in the city of Perth in Australia [7]. The influence of the legislative framework on the process of repurposing and the flexibility of regulation are among the focuses of the research by authors Barlow and Gann [8]. Remoy, de Jong and Schenk's research considers guidelines for designing commercial buildings to increase their potential for conversion into temporary or permanent housing in the future [9]. Ouf, O'Brien, and Gunay analyze the adaptability of objects to variability in purpose by measuring adaptability based on the characteristics of the object as a physical structure [10]. Slaughter examines design strategies that result in increased building flexibility [11]. Research by Gosling, Sassi, Naim, and Lark is aimed at considering the most important factors of a building's adaptability and developing an instrument for measuring adaptability and potential costs during conversion. [12]. Douglas considers the adaptability of a building from the aspect of the compatibility of spatial characteristics between typologies [13]. Another line of research in the field of commercial property conversion is the sustainability aspects. Remoy and Wilkinson [14] consider the environmental and sociological aspects of sustainability in the process of repurposing a commercial building. Yung and Chan explore an environmentally sustainable approach to repurposing and striking a balance between economic feasibility, environmental impact, and social benefits [15]. The reasons leading to the cessation of the use of a business facility were considered to identify the characteristics of business facilities that are considered advantages or disadvantages within the market and from the perspective of users, to their (changed) expectations directed towards the workspace. Remoy, Koppels, van Oel and de Jonge investigate the characteristics of business facilities using the Delphi method [16]. Researchers who analyze the historical aspect of conversion as a form of architectural and urban action, such as Plevoets, Sowinska-Heim and van Cleempoel, consider forms of planned and unplanned conversion throughout history and the presence of this form of recycling of the built stock [17-19].

In order to create a structural platform suitable for developing a new multi-criteria decision-making model, the focus of the research presented in this paper is on identifying key criteria and a structure of this type of model, based on comparative analysis of existing multi-criteria decision-making models.

## 2. EXAMPLES OF MULTI-CRITERIA DECISION-MAKING MODELS

Depending on the problem being 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 [20]. In these cases, participants use techniques, which can be formal (cost analysis, multi-criteria decision analysis, decision trees, etc.) and informal (not covered by the research) to assist in decision making. All formal decision-making techniques are similar in that they contain a set of clearly defined rules based on which certain criteria are selected and evaluated. Multi-criteria decision-making models are mathematical instruments that are one of the formal techniques used to solve problem tasks in various fields [21].

Multi-criteria decision-making models that are applicable in the processes of various adaptations of business facilities are presented.

## 2.1. Conversion meter model

The first version of this model, named the Transformation meter, was formed at the end of the twentieth century in the Netherlands when a large number of office buildings were out of use [22]. The model was tested through case studies by students of the Delft School of Architecture and other universities and then further developed. The structure of the model includes several checklists of criteria that are used to assess the potential of an unused commercial building for conversion into a residential building. The assessment takes place in the following steps:

- Database overview;
- The first, "quick" assessment, which includes four criteria, which have a "veto" character. If at least one of the criteria is assessed negatively, the facility is considered to have no potential for conversion and the assessment is not continued.
- The next step in assessing the potential for conversion of commercial premises into temporary or permanent residential premises is to complete two checklists of criteria relating to the location and characteristics of the facility. Positive responses are added up and multiplied by a specific weighting factor. The resulting value is recognized within one of the categories determined on the formed scale of potential for conversion. Belonging to one of the five categories represents the final result. Weighting factors and “veto” criteria are subject to change depending on the specifics of individual cases, and the criteria can be adapted to different target groups of potential users.
- The fourth step refers to the assessment of the financial feasibility of the conversion process of a specific business facility.
- The fifth step considers possible risks and problems that may arise during the conversion process itself [23].

The assessment of the potential for conversion of commercial to residential properties in this model is based on the evaluation of criteria related to the characteristics of the location and the property. The evaluation system is a method of assessment through checklist scales: each fulfilled criterion brings a point - the more fulfilled criteria, the greater the conversion potential [24].

## 2.2. TOBUS model

*TOBUS* is a multi-criteria model for assessing the current state of a business facility and evaluating the potential for different types of adaptation, estimating the cost of these processes and the amount of energy required. It was developed within the framework of the European research program *JOULE III* and is the result of joint research by experts from Denmark, France, Greece, Switzerland and the Netherlands [25]. The model contributes to a better organization of the adaptation process by the chosen method. Two basic tasks of the model have been recognized: diagnostics, the aim of which is to assess the current state of the business facility, and intervention, within which the type of adaptation is defined. In order to simplify the use of this model, the software of the same name has been developed. The software uses data related to Switzerland, but the possibility of adapting the software to data from other countries that participated in the creation of this model has been left [26]. Choosing the appropriate type of adaptation of a business building takes place through four steps:

- *Assessment of the physical condition of the building* and the degree of degradation of the building's elements, which are grouped for easier consideration;
- *Assessment of the functional obsolescence of installation systems* in a building involves assessing the possibility of improving installation systems to meet current standards;
- *The assessment of the required amount of energy* is based on data on the current energy characteristics of the facility, to propose energy-saving measures, and
- *The assessment of the quality of the interior space* takes place through the evaluation of sub-criteria that describe comfort [27].

The selection of the appropriate type of adaptation is based on the assessment of criteria that are selected based on practical experience. The set of criteria contains quantitative criteria that are measurable and numerically expressed, but also qualitative criteria that are more flexible and immeasurable. To obtain a single result, it is necessary to translate qualitative values into a numerical and comparable form. In multi-criteria and multivariate models, such as this one, methods based on different families of algorithms are used to evaluate the proposed criteria and assign weighting factors. The evaluation of criteria in this model is carried out using the *COPRAS* method. The method was used to evaluate criteria that describe potential interventions for each segment of the facility [28]. The model was first tested within the framework of a pilot project for the development of the application process. It was then tested on individual buildings located in the countries participating in the study [27]. It is important to note that, since it suggests many different combinations of interventions, this model includes a large number of criteria and indicators that are not used every time, so the process of assessing the adequate type of adaptation of a business building is different for each building.

## 2.3. ARP model

This multi-criteria model is intended to assess the potential of a building for conversion and is based on an assessment of the lifespan of the building as a physical structure and its current age, expressed in years [29]. The assessment of the lifespan of a building as a physical structure is based on the consideration of a list of criteria related to the environment, the way the building is used and its structure characteristics. Individual criteria are separated and their values are duplicated [14]. A template from MS Excel is used to assess this part of the assessment. The assumed lifespan of the building as a physical structure is one hundred years, and then this time frame is reduced or increased depending on the value of the criteria. This assessment is based on a literature review, ISO standards, and the experiences of the model authors [30]. Further assessment is based on considering the period of use of the facility as the period of the facility's duration as a physical structure, reduced by different types of obsolescence, which are also the basic criteria of the model. The types of obsolescence that affect the period of use of the facility are proposed: physical obsolescence, economic obsolescence, functional obsolescence, technical obsolescence, social obsolescence, legislative obsolescence, and political obsolescence [14].

The criteria are scored in percentages from 0% to 20%. This multi-criteria model is expressed in a diagram that shows that the maximum potential for conversion of each facility is at the end of the exploitation period of the original purpose [31].

Score values above 50% are interpreted as high potential, values between 20% and 50% as moderate potential, and values less than 20% as low potential for the facility to be converted [14]. When it comes to evaluation, this model uses the *SINDEX* methodology [32], which is based on multi-criteria analysis to calculate a sustainability index and rank projects [29].

## 2.4. iconCUR model

The multi-criteria model *iconCUR* uses criteria to visually present the characteristics and capabilities of an existing building at any point in its life, through a spatial diagram [14]. The model is based on three main criteria:

- *The current condition of the building* is a criterion that refers to the physical characteristics of the building;
- *Use value* is a criterion that describes the way an object is used;
- *Benefits* considered through *collective utility* and *stakeholder interests* (potential financial, social, and environmental benefits). *Collective utility* reflects the net benefit of the facility to all stakeholders, describing the level of financial contribution from the facility. *Stakeholder interests* are considered through a short-term perspective that considers utility in the first five years, a medium-term perspective that considers utility in the next fifteen years, and a long-term perspective that refers to the remaining life of the facility [33].

The evaluation is shown in a spatial model. The criteria are represented through axes with evaluation scales from 0 to 5. The values relating to the current state of the facility are on the x-axis, the utility value of the facility on the y-axis, and compliance with standards on the z-axis. Based on the consideration of the current state of the facility and its utility value, some type of intervention is proposed: maintenance, renovation, extension, reconstruction, conversion,... The third criterion evaluates the feasibility of the proposed intervention. If there are several facilities whose potential for some type of adaptation is assessed simultaneously, using this model, their results can be compared. It is also possible to show the change in the potential of the same facility after certain interventions. The spatial model has the shape of a cube. Each vertical edge of the cube represents one of the potential interventions. Each object is positioned within this spatial model by its coordinates – the values of the criteria. Given this, the criteria must be quantified in a certain way. For this reason, each of them is presented through several key sub-criteria that are evaluated according to a defined scale from 0 to 5 and within certain categories [14]. The model uses a weighted matrix approach that assigns weighting factors to each sub-criterion, according to their importance, proportionally to each group [33]. In different cases, the same sub-criterion may have a different share. By changing the share of the sub-criterion in the final value of the criterion, the value of the criterion itself changes [14]. The evaluation system used in this model belongs to the group of visual methods for multi-criteria decision-making and is based on the *PROMETHEE* family of algorithms [33].

## 2.5. PAAM *(Preliminary assessment adaptation model)* model

The *PAAM* model is a multi-criteria model designed to assess the potential of different types of commercial buildings for retrofitting [34]. Although the model focuses on a different type of adaptation than the one that is the subject of this research, the methodological approach applied in this model has an impact on the process of forming a new model [35].

Part of the research related to the development of this model is a very extensive literature review that identifies criteria that are significant for different types of adaptation. The criteria are grouped into six categories: economic, physical, location, legislative, social, and the category of criteria related to the environment [34]. Based on statistical analysis, criteria and indicators for this model were selected from the list of criteria that are significant for each type of adaptation of commercial buildings. The *PAAM* model contains three basic criteria: physical characteristics and size, land, and social factors.

The model does not consider criteria that, according to the model authors, equally affect the potential of the facility for this type of adaptation in all analyzed cases [34]. The valorization principle applied in this model is based on the statistical analysis of data collected from a large number of case studies of facilities that have already been treated with the type of adaptation in question (retrofitting). The starting point is a set of criteria, indicators, and the estimated impact of each indicator on the criterion, and then each criterion on the process of implementing the adaptation project as a whole. The impact of criteria and indicators is determined using the *PCA* method [34]. The basic idea of this technique is to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while preserving, to a large extent, the variations present in the data set [36]. The outcome of the analysis is a table of identified factors. Within the *PAAM* model, the qualitative assessment of the adaptation potential of each criterion is based on the percentage frequency of that attribute at a given value in many previous cases of adaptation. The percentage values of the identified potentials are standardized on a scale consisting of five levels. This scale valorizes all indicators to obtain the values of the individual criterion, and then valorizes the criterion to obtain the final assessment [34].

# 3. STRUCTURE OF MULTI-CRITERA MODELS

As a result of the analysis related to multi-criteria models used as an aid in the decision-making process and their elements, and the consideration of specific examples of multi-criteria models applicable in the process of adapting business facilities, a platform for creating a new model was formed, shown in Table 2. The platform represents a structure within which four parts are recognized, recognized as significant within the previous models. The established platform contains: influential factors, evaluation, defining the form of results, and the method of using the multi-criteria model.

## 3.1 Part I: Influential factors

The first part of the platform for the new multi-criteria model presents several factors that have an impact on the potential for conversion, selected based on the analysis of the presented multi-criteria models and relevant literature. General influential factors are grouped (location of the building, characteristics of the building, quality of the interior space, financial justification, energy sustainability and market), specific influential factors determined by the type of adaptation (capacity of the building, current standards for the new purpose and expected profit during the exploitation period) and specific influential factors that are a consequence of the specificity of the context in which the multi-criteria model was developed and/or for which it is intended (location of the building in the context of the urban development in which the building is located and the surrounding area of the building) [35].

Table 2 shows the influential factors that were observed in the analyzed multi-criteria models, and may become (not necessarily all) parts of new multi-criteria models. It is expected that new multi-criteria models will contain a larger number of influential factors within each group, which will be defined through the specifics of the research that resulted in them.

## 3.2. Part II: Criteria evaluation

The second part of the platform presents the basic steps related to the evaluation of selected influential factors. The first step is to define the type of problem: is it a relative evaluation in which several options (alternatives) are compared to selected criteria and the most suitable solution for a given problem is selected among them, or is it an absolute evaluation, where one or more options are evaluated through selected criteria and compared with predefined categories or prototypes. The second step is to introduce a hierarchy among influential factors by assigning weights or determining priorities. This is followed by the selection of the appropriate *MCDA* method and determining preferences.

## 3.3. Part III: Defining the result form

Among the presented multi-criteria models, it was noted that the forms of the results are different. In the *Conversion meter* model, the result is numerical and represents the sum of points assigned to the selected answers (during the filling in of the checklists). In the *TOBUS* model, the result is a set of recommendations that suggest certain stucture interventions. In the *ARP* model, the result is shown numerically, as a percentage, but also through a two-dimensional graphic display. The spatial graphic display is the form of the result in the *iconCUR* model. The "qualitative" sum is the result of the evaluation in the *PAAM* model - descriptive values are summed up, and the result is one of the terms from a defined scale of possible results. Given that multi-criteria models of this type contain both quantitative and qualitative criteria and represent a type of assessment of a certain potential or opportunity, the numerical forms of the solution may be insufficiently precise and reduce the range of possible solutions and the differences between them. When defining the form of the results, it is necessary to consider which form of results is most suitable for potential users of the multi-criteria model. Depending on the specifics of the individual multi-criteria model, a set of recommendations, with the possibility of visual (two-dimensional or three-dimensional) display, is considered an adequate form of results.

## 3.4. Part IV: Method of application of multi-criteria decision-making models

As a way of applying the multi-criteria model, based on the conducted analysis of multi-criteria models and relevant literature, it is proposed to create software within which checklists composed of indicators and their proposed values will be filled out.

*Table 2. Proposal for a platform for creating a new model*

| | | |
|---|---|---|
| Part I: Influential factors | | |
| *Group 1:* general influential factors | Location | Infrastructure |
| | | Distance from different types of content |
| | Building's characterstics | Adaptability |
| | Quality of interior space | Several types of comfort |
| | Financial feasibility | Investments |
| | Energy sustainability | Possibilities for improving the energy properties of a building |
| | Market | Feasibility of a (new) use |
| *Group 2:* specific influential factors for a certain type of adaptation[4] | Building capacity | Number of units of a new use |
| | Current legislative standards for new use | Provisions from current legislative standards that may initiate (additional) structure interventions |
| | Expected profit during the exploitation period | Value per square meter (for sale and rent) |
| *Group 3*: influential factors based on the specificities of spatial context | Building location (urban area) | Distance from different types of content [5] |
| | Building environment | Presence of certain contents near the building |
| Part II: Evaluation | | |
| Defining the type of problem | Relative (choice/ranking) or absolute (sorting) evaluation; | |
| Parameters: weights | Establishing a hierarchy among influential factors – assigning weights or priorities; | |
| Choosing a method for multi-criteria decision-making | The multi-criteria decision-making method (ELECTRE, PROMETHEE, phases,…) is determined based on the type of formulated problem; | |
| Preference system | Determining preferences regarding the selected method for multi-criteria decision making; | |
| Part III: Defining the result form | | |
| Potential result form | Numerical values (sum of points or percentages);<br>Visual representations – diagrams;<br>Set of recommendations/ comments | |
| Part IV: Application of new multi-criteria decision-making models | | |
| Potential way of application of new multi-criteria decision making models | Software – entering data about a building through checklists | |

[4] Criteria and indicators within this group are proposed for conversion as a type of adaptation.
[5] It refers to distances that are considered acceptable, which varies depending on the regulations of a particular city.

## 4. CONCLUSION

Various aspects of repurposing brownfield sites are the focus of numerous researchers. In the *Introduction* several research lines were identified, clearly defined focus. One of the recognized lines of research is devoted to multi-criteria decision-making models, which represent formal decision-making techniques. In the second part of the paper, several multi-criteria models have been considered that are intended to evaluate the potential of office buildings for various types of adaptation. Groups of criteria (sub-criteria) and indicators have been identified, with their representation in the models. In the third part of the paper, the result of the comparative analysis of the selected multi-criteria models is a platform (shown in Table 2) that can be used for creating other multi-criteria models that are intended to evaluate the potential of different purpose buildings for various types of interventions.

The findings of this research establish a basis for future development of advanced MCDM models applicable in similar domains.

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