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Models and methods for technical and economic decision-making with link to sustainable development of industrial settlements

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Abstract The model tools and methods for technical and economic decision-making may contribute to solution of a wide range of social and technical issues including, among others, the issues of sustainable development of industrial settlements. Achieving of a quality decision with elimination of an attitudinal factor is the goal of each decision-making process. The use of multi-criterion analysis is one of the options employable in the decision-making process. The issues are documented on a case study of prefab block of flats meant for rehabilitation and reconstructions, and that are located in the industrial territories.

Keywords Industrial area, multicriterion analysis, sustainable, buildig-up

1. INTRODUCTION

The fundamental task of all models and methods for technical and economic decision-making is to contribute to an unbiased decision-making without substantial impact from attitudinal influences and criteria. Not any differently it is in the construction industry with link to sustainable development of the industrial settlements. The application of multi-criterion analysis, which is based on mathematical modelling, is one of the options. The essence of all tasks of the multi-criterion analysis is a decision, which is final, optimal, which means picking up one variant from the list of said decision-making situation of potentially feasible options.

The multi-criterion decision-making occurs where a decider evaluates consequences of their selection usually based on multiple criteria, in particular the quantitative criteria (usually expressed in natural scales; also known as the numerical criteria), or qualitative (an appropriate scale is usually involved, e.g. classification scale or very high-high-average-low-very low scale). At the same time, a direction of improved assessment is defined, i.e. whether maximum or minimum value is better. A case of a formulated task may be a request for ordering of the decision-making variants by ranking [1].
The essential motifs for employment of exact approaches in the decision-making process lie in particular in areas with the need of reducing the risks of incorrect decisions, and enabling of experimenting in the economic, technical-economic, and social areas. The economic, social, cultural, and technical area is a constituent of the fundamental pillars of the sustainable development. We define the decision-making based on a single criterion or multiple criteria, and compile a mono-criterion or multi-criterion solution.

2. METHODOLOGY OF MULTI-CRITERION EVALUATION AS A PART OF THE TECHNICAL AND ECONOMIC DECISION-MAKING

The tasks of the multi-criterion decision-making are divided by information aspect into four basic categories.

They include:

- Tasks with information, which enable scalaring of the optimization criterion (the information enables summing of multiple criteria into a scalar criterion);
- Tasks without information, which enable scalaring (the base is the non-dominated solution term);
- Tasks with information obtained during solution (information is obtained during dealing with the task);
- Parametric solutions (illustration that indicates an optimum solution as a function of input information).

A set of the decision-making variants has a finite number of elements in the tasks of the multi-criterion evaluation of variants (1). A task of multi-criterion evaluation of the variants is characterized as a criterion matrix (2), where columns and rows of the matrix correspond to the criteria and evaluated variants, respectively [2].

Should we identify the elements of the criterion matrix:

$$y_{i,j},\ i=1,2,3\ldots p;\ j=1,2,3\ldots k, \qquad (1)$$

the criterion matrix may be took down generally as:

$$\begin{matrix} a_1 \\ a_2 \\ \cdot \\ a_3 \end{matrix} \begin{bmatrix} f_1 & f_2 & \cdot & f_3 \\ y_{11} & y_{12} & \cdot & y_{1k} \\ y_{21} & y_{22} & \cdot & y_{2k} \\ \cdot & \cdot & \cdot & \\ y_{p1} & y_{p2} & \cdot & y_{pk} \end{bmatrix} \quad (2)$$

We assume that all criteria are defined as maximizing, which means the criteria are defined so that an option is better with higher value of the criterion. However, should the criteria in the original data input be defined as minimizing, we transform them into the maximizing ones.

We can employ Saaty's procedure, paired comparison method, utility function method, preferential relations, and more for the multi-criterion analysis. These methods, however, require more demanding transformation of data and demanding compilation of a model for data transformation.

A factor influencing comprehensibility and clarity of the evaluation and decision-making is its objective complexity. Therefore, the decision-making must include important criteria with a reference character, and apply to the purpose of the decision-making and evaluation, combined with pinpoint rules for evaluation thereof.

The ways of technical and economic decision-making and evaluation in practice shall for the purposes of each entity differ in particular in selection of criteria and how the criteria are worked with. Therefore, we should always define in the models for technical and economic decision-making related with the sustainable development of the industrial settlements the criteria that come under the essential pillars of the sustainable development and consider the territory where the building is located.

The proposed method of the technical and economic decision-making related to the sustainable development of the industrial settlements is based on the multi-criterion evaluation theory, adherence to principles of the sustainable development, and definition of criterion in this area. A simple method is used to enable evaluation of the presented variants, and no sub-criterion data are loaded on the evaluation.

3. SUSTAINABLE DEVELOPMENT AND THE ISSUES OF THE INDUSTRIAL SETTLEMENTS

The issues of the industrial settlements in general are greatly extended, and reaches several disciplines. An industrial settlement may be referred to as a limited territory, settlement where heavy industry's facilities were operated; following termination of the industrial activity, a brownfield remains (soil contaminated from industrial activity, drop basins due to run-down of deep mining, increased groundwater level, methane leakage, and more) [3]. These territories often have a couple of buildings built on it, be they of industrial or residential buildings, or buildings for civic amenities of the town. An integral part of regeneration of each industrial settlement is the keeping of the buildings located in the territories hit by increased industrial activity. These buildings are meant for reconstructions and rehabilitation, and conversion, if possible, under the programme for regional and municipality development.

The territories hit by increased industrial activity stand for a significant problem across Czechia not only with respect to damage to the territory in question, but also building standing thereon. According to available expert sources, restructuralization of the industry and run-down programs in Czechia after 1990, swapping of owners of the industrial facilities and premises, also radical change to value criteria and technical development, and the need to recover the environment, have initiated the discussion "what to do with the industrial heritage" (B. Fragner, 2006). Obviously, the industrial settlements-related issues are topical, and dealing with it is called for. The issue is current not only in the Czechia, but throughout the world.

Should we get involved in the issues of the industrial settlements and the issues of the sustainable development, we come to an area of evaluation of a new construction and energy conception of buildings located in the industrial territories, be they the civic amenities buildings or residential buildings. The buildings require rehabilitation to comply with the parameters defined by the European Communities, and follow the strategy of energy conception with the outlook to 2030 and further [4, 5], [6-11].

4. CASE STUDY

An example for documenting of the issues related to the sustainable development and industrial settlements may be reconstruction and rehabilitation of prefab blocks of residential flats in the industrial territory in Ostrava, Czechia, which was hit in the past by the industrial activities, deep mining, and iron production. Ostrava is characterized by that the industrial territory crosses the residential territory (the area of the region with long-term deep black coal mining and that we can see as an industrial territory covers over 170 km^2). The arrangement does not come from urbanistic considerations but the black coal mining. Rich deposits of black coal were located near the city centre; the first deep mines were built near the city centre in 1842, and the mining continued uninterruptedly to roughly 1990. The run-down of the deep mining started thereafter. Historically, the residential zones are tightly interwoven with the industrial zones.

After 1990, the municipalities attempted to convert the buildings and use the industrial territories as a cultural and social background. A great and successful example is conversion of a gasholder structure in Dolní Vítkovice in Ostrava by architect J. Pleskot into a cultural and social universal hall, or conversion of a blast furnace into a lookout tower known as Bolt Tower.

Another Ostrava's phenomena related to the developing post-war technologies being the prefabrication. In the last century, specifically between 1955 and 1995, most of the prefab flats were built right in Ostrava (70% of total residential buildings were in Ostrava were built with the prefab technology). Also after the World War II, Ostrava remained the main centre of heavy industry. Development and reconstruction of flats including infrastructure required were immediately needed. Just the assembled panel technologies enabled to speed up the housing development and reconstruction [12].

At this moment, the panel blocks of flats need to have a new construction and energy conception defined to extent the lifecycle of these prefab blocks of flats by at least additional fifty years. To have a prefab block of flats rehabilitated and reconstructed successfully, a goal, what, and for what capital expenditures is required to achieve this. New trends in the development with respect to the principles of sustainable development need to be considered as well. Should we focus on the issues of the construction and energy conception of the prefab blocks of flats as part of the principles of sustainable development, we shall be primarily interested in the construction-technical and material measures aimed at reduction of heat loss from a prefab block of flats, and energy savings [13]. The result of the actions taken shall be information about capital expenditures for improvement of the construction and energy conception, return rate, savings ratio with respect to actions taken, and effectiveness expressed by the share of total savings to expenditures. We can apply the method of multi-criterion evaluation in the process of decision-making about what prefab blocks of flats are to be rehabilitated to this end in the location in question.

4.1 Multicriterion evaluation

Example below may convince you of suitability and applicability of the multi-criterion decision-making in the technical and economic area (K. Barták, 1998) related to the issues of the sustainable development. Methodology was established according to K. Barták (1998).

The subject of the evaluation is 6 existing prefab blocks of flats (3) evaluated by six criteria (4). For specification of the criteria, refer to Table 1.

For reconstruction and rehabilitation of the prefab blocks of flats, we shall focus on improvement of heat-technical parameters of cladding including glazed areas, improvement of roof function with potential construction of penthouses and green roofs with rest zones, return of investment, and more.

Possible conversions of the prefab blocks of flats can be focused on as well. Theoretically, the selected part of the prefab blocks of flats shall undergo a conversion, and shall be newly used for civic amenities of the city (e.g. unused existing utility rooms or pram rooms conforming typologically to the era of construction of the flats from the second half of the last century shall be successfully reconstructed into shops, service areas, and more; not only reconstruction of the prefab blocks of flats but contribution to improvement of urbanization of the blocks of flats is attempted).

Let’s identify the blocks of flats:

A = {a1, a2, a3, a4, a5, a6}, (3)

Six criteria shall be applied to evaluate the blocks of flats:

F = {f1, f2, f3, f4, f5, f6}. (4)

Table 1. Specification and description of criteria.

Criterion	Description of criterion
f1	Number of floors to be reconstructed; number of ground floors (min).
f2	Reconstruction costs; First ground floor: thousands CZK (min).
f3	Floor area obtained after the reconstruction; m^2 (max).
f4	Return on investment; years (min).
f5	Surface area obtained for green roof; m^2 (max).
f6	Surface area converted obtained after the reconstruction; m^2 (max).

The compiled criterion-based matrix shall be:

f	f1	f2	f3	f4	f5	f6
a	min	min	max	min	max	max
a1	5	450	87	18	250	100
a2	8	240	57	10	200	50
a3	7	350	87	12	300	120
a4	5	320	56	15	200	150
a5	4	550	110	25	150	200
a6	4	480	95	20	100	250

(5)

The matrix (5) is then adjusted to make all criteria maximized, and the least favourable values are defined (8);

f1=8, f2=550, f4=25, (6)

Transform the criteria how much the variants are better than unfavourable variants, and monitor the maximizing criterion (7); the post-transformation criterion matrix looks like:

f	f1	f2	f3	f4	f5	f6
a	min	min	max	min	max	max
a1	3	100	87	7	250	100
a2	0	310	57	15	200	50
a3	1	200	87	13	300	120
a4	3	230	56	10	200	150
a5	4	0	110	0	150	200
a6	4	70	95	5	100	250

(7)

Assign identical weight to the criterion and define the order (8). A prefab block of flats with the least order calculated by plain addition comes best with respect to the pre-defined criteria.

f	f1	f2	f3	f4	f5	f6	–	–
a	min	min	max	min	max	max	Σ	pořadí
a1	3	3	3	3	2	5	19	3.
a2	1	6	4	6	3	6	26	5.
a3	2	4	3	5	1	4	19	3.
a4	3	5	5	4	4	3	24	4.
a5	4	1	1	1	5	2	14	1.
a6	4	2	2	2	6	1	17	2.

(8)

The decision situation is shown in (9) for single decider:

R = {1, a1, a2, a3, a4, a5, a6, f1, f2, f3, f4, f5, f6},

F = {f1, f2, f3, f4, f5, f6} → max,

A (m, n) matrix type, (9)

(m, n ∈ N); A (m, n) → max f1 - f6.

The evaluation principle is simple but it may provide first important information about suitability and purposefulness of the expenditures made in the first phase of the technical and economic decision-making [14].

5. DISCUSSION

Every decision influences results from the long-term point of view. Not any differently it is in case of evaluation of the prefab blocks of flats of the industrial settlements, and capital expenditures for the rehabilitation and reconstruction of the buildings in relation to application of principles of the sustainable development.

Practical use of the theory of multi-criterion evaluation and analytical hierarchic process is irreplaceable in the capital expenditure projects, and assists us to deal with a range of specific problems from simple tasks up to complex hierarchic structures. Current economic situation requires new tools, methods, and trends to capture as much as possible factors having impact on result, acting on achieving of the goal, and consistency of conclusions and considerations for achieving of valuable conclusions [15]. However, the evaluation tools should not be complex to enable evaluation of trained persons only. This can be applied for more complex technical and economic studies and big projects [16]. The mathematical operations with a reference character for the evaluator how to proceed in the decision-making or performance of the defined strategic goals may be advantageously used in the first phase of the technical and economic evaluation and decision-making.

The technical and economic evaluation, which uses the multi-criterion analyses, must be always used in compliance with the purpose of the evaluation. The criteria must be defined clearly, and the decision-making process must not be encumbered by useless criteria that both increase laboriousness of the evaluation and decrease accuracy of the evaluation as well.

6. CONCLUSIONS

The issues of the sustainable development, industrial settlements, conversion of buildings, conversion of industrial areas is extensive and vast. Therefore, focusing on the issues of technical and economic decision-making and evaluation in a wider context is required. Determination of the mathematical models is needed folloving their successful bringing to practice, from the simpler models up to those more complex ones.

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