Management
2023
Vol. 27, No. 1
DOI: **10.58691/man/169579**

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The method of multi-criteria analysis for the prioritization of innovations in the construction industry

1. Introduction

Turbulent variability, openness and improper conditions mark the organizational reality of the 21st century. These factors essentially hinder an enterprise's ability to compete on the market and cause it to struggle with market positioning. Therefore, a compulsion to build and strengthen the innovative potential of entities and their reliable assessment emerges. This goal can be achieved through substantively compatible, reliable and friendly (simple) methods that reflect the actual state of affairs. Such a change is ensured by the peregrination of numerous methods included in classic methods for multi-criteria analysis (Bross, 1965; Duchaczek and Skorupa, 2013). The Authors of this paper reach for Bellinger's multi-criteria[1] method, believing that this simple method based on

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1 Prof. Bernhard Bellinger, who died in 2016, was the method's creator; he used it to assess the credibility of customers applying for loans in Swiss banks. As a result, customers who collected the highest points could obtain loans, allowing them to qualify for the reliable group.

basic arithmetic effectively confirms its usefulness in ranking the potential of innovative areas in a construction company.

The construction industry is an essential sector because it significantly contributes to economic development and shapes the labour market (Madyda, 2018; Anaman, 2007). This industry uses 50% of all raw material (Hu et al., 2010). Hence, construction processes and technologies affect the natural environment (Madyda, 2018) due to using resources and producing a large volume of emissions and waste (Hussain et al., 2019). The construction industry also uses the “take, make, dispose” approach: The materials are used for construction and disposed of at the end of life since they cannot be reused (Benachio et al., 2020). The industry is, thus, put under pressure to develop and adopt new technologies, tools and practices (Jelodar et al., 2018). For example, the need for innovation in house building has been widely acknowledged (Yusof et al., 2010).

Multiple-Criteria Decision Analysis (MCDA) is widely used in various fields and disciplines (Watrobski, 2019). The increasing complexity of economic and social systems causes the need for methods and systems that support decision-making (Steward et al., 2013). There are many approaches to MCDA. They differ in computational complexity, level of stakeholder engagement, and time and data requirement (Esmail and Geneletti, 2018). A general grouping of MCDA approaches consists of three theories: 1. utility function, 2. outranking relation and 3. sets of decision rules (Slowinski et al., 2002; Greco et al., 2004). The first theory includes methods of synthesizing the information in a unique parameter. The outranking relation theory involves methods based on comparisons between pairs of options to verify whether “alternative a is at least as good as alternative b”. The last theory originates from the artificial intelligence domain and helps derive a preference model through classification or comparison of decision examples (Cinelli et al., 2014). Some papers deal with innovation evaluation with MCDA methods. For instance, in the study of Nalmpantis et al. (2019), the ranking was determined through an analytic hierarchy process using three criteria: feasibility, utility, and innovativeness.

The article has an applied nature and is a result of the analysis and diagnosis of the state (innovative potential) of Polish construction companies and contains a proposal to organize them. The MCDA tool for construction companies is proposed. This method deals with innovation evaluation.

2. Materials and methods

In her research, Madyda (2018) identified the factors that influence the implementation of innovation in Polish construction companies. Table 1 shows the factors that determined the implementation of innovations in construction companies. Table 2 shows the factors that constituted an important premise for implementing innovations in construction companies.

Table 1. Factors that determined the implementation of innovations in construction companies

Factor	Percentage of indications
access to new techniques and technologies	15
taking care of the company's image	16
possibility of obtaining funds	18
ideas of experienced staff	20
enterprise development	48
increasing the company's potential	51
demand for services	58
demand for products	60
increasing the efficiency of processes	70
cost minimization	77
implementation of the contract specifications	88

Source: Madyda 2018, p. 274

The implementation of the contract specifications is the most indicated factor, which is unsurprising. For construction companies, construction project implementation is the subject of the contracts. The project is imposed by contractual conditions based on the customer's preferences. In other words, innovativeness may be limited by the customer's expectations.

Cost minimization is also significant. The competitive advantage gained through innovations supports the price advantage (Kostic, 2018). In the Polish market, the Public Procurement Law imposes the criterion of selecting the offer based on the lowest price. The contractors, hoping to win the contract, try to lower the price but face the dilemma of profitability (Trzcinski, 2016). Here is where innovation is required.

Process efficiency is the ratio between the input and output of the process; it is often expressed in percentages. The higher the ratio, the higher the efficiency.

Demand for product and service factors could be understood as a demand-driven perspective that highlights the key role of consumers' unmet needs in the innovation process (Zhao and Wang, 2018).

The company's potential is a multidimensional category. It concerns specific possibilities built on abilities, competencies and skills contained in the possessed resources as well as on the skilful use of the resources in the environment. Resources include but are not limited to marketing and manufacturing capabilities.

Enterprise development is not a clear concept (Suszynski, 2007). However, for this paper, enterprise development was defined as the qualitative and quantitative changes that occur within a company.

Having experienced staff means having employees who can generate exciting ideas. Customers' expectations force companies to have employees with technical skills and knowledge of new technologies in the industry too (Madyda, 2018).

The ability to obtain funds is also important because innovation is only possible with money.

The literature assumes that image significantly influence consumer behaviour (Loudon and Della-Bitta, 1995). For example, Barich and Kotler showed in their research the effect of image on increasing sales (Palacio et al., 2002). However, according to Madyda's (2018) research, this factor has only 16% indications.

Similarly, new techniques and technologies have only 15% of indications. However, the literature shows that, since the 1980s, technological innovation in manufacturing companies has been one of the main reasons for national development and industrial competitiveness (Freeman, 1982; Porter, 1985).

Table 2. Factors that constitute an important premise for the implementation of innovations in construction companies

Factor	Percentage of indications
risk reduction	12
maintaining the stability of the company	31

publication on applied innovations	31
trainings, conferences, workshops	38
support from external units	47
creative management staff	52
increasing the dynamics of the company's operations	60
access to EU funds	65
access to external funds	82

Source: Madyda 2018, p. 276

Access to unlimited funds is similar to access to European Union (EU) funds. Albors-Garrigos and Barrera said that the public nature of innovation results from its broad-ranging external effects, knowledge spillovers and private investment's limiting consequences (Albors-Garrigos and Barrera, 2011). So, government stimulation and other public funds are necessary.

Increasing the dynamics of the company's operations is also important. Organizational dynamics involves continuously strengthening resources and enhancing employee performances. A creative management staff seems to be a necessity to create innovations. With innovations, it will be easier to find new solutions.

Moreover, support from external units is crucial, especially for small and medium companies. Innovation activity is limited (especially in small companies) because SMEs are challenged by resource constraints, need guidance on realizing benefits, lack links between science and the economy and have a general distrust of changes (Barann et al., 2019; Parkitna, 2020).

Training, conferences and workshops offer companies the opportunity to deepen their knowledge about new technologies. The same can be said about publication on applied innovations.

Maintaining the company's stability is the next factor, and it is connected with risk. Stability can be understood as resistance to fluctuations.

Finally, there is risk reduction. The presence of risk is an enduring attribute of business ventures, too, in the process of innovation. In addition, proper risk management is helpful here.

The authors decided to combine some factors based on their similarities and create a new list. The first factor is access to external funds; it contains EU and other funds. Then we have creative management staff and ideas of experienced staff. The two factors mentioned before creating a new factor called creative stuff. Support from external units (we believe R+D units are crucial here) also contains training, conferences and workshops, and publication on applied innovation is here too. Finally, risk should be considered too.

Bellinger's method to analyse Polish construction companies' potential was used. Bellinger's analysis consists of the following successive steps (Malara, 1995):

1. Determination (selection) of variants (objects) subject to evaluation and determination criteria.
2. Determination of measuring units and the desired direction of numerical changes within a given criterion.
3. Definition of the lower and upper limit of changes for individual criteria.
4. Subjective selection of a decision-maker, consisting of determining the meaning of criteria by assigning appropriate weights wherein the sum of all weights is equal to unity.
5. Creation of a table containing actual values of corresponding criteria for individual assessment facilities.
6. Presentation of each number from the table created in step 5 as a percentage of the path from the least desirable state to the most desirable state. The determination of the size of this path for a given criterion is calculated by the differences between these states. Then the least desirable value is subtracted from the actual value of the criterion for a given object, thus calculating the distance travelled, and finally, the percentage of the total path is the previously calculated distance actually travelled.
7. Multiplication of numbers received during stage 6 through the weights that have been adopted in step 4.
8. Determination of the best variant by summing the assessments granted after particular facilities from the point of view of each criterion.

The Bellinger's method belongs to a group of multi-criteria methods, making it possible to organize objects (decisions) based on a total assessment, selected from a set of adopted partial criteria (components), based on which data is evaluated. For each adopted criterion, these are required: appropriate weight (ranking in total to unity), data used for the needs of the assessment (including the border states of the corresponding values) and the desired direction of their changes (from the most desirable). Then for everyone, the obtained decision variant (object) is calculated to assess each criterion, consisting of a fraction of the road calculated as the difference between the states. The method of calculations can be found, among others, in work examples created with the participation of the article authors (Malara, 1990; Malara, 1995; Malara 1999; Malara et al., 2019).

3. Results

The authors decided to use a hypothetical example to illustrate how the method should be used, and how it works. Then we followed steps on Bellinger's method which was presented in section 2. In the beginning, we name criteria (we described it in section 2), measuring units and the desired direction of changes for those criteria:

1. Access to external funds will be measured scale 1-10, and growth is desired.
2. Creative management stuff will be measured by profits, and growth is desired.
3. Support form R+D units will be measured scale 1-10, and growth is desired.
4. Risks will be measured by probability, and decline is desired.

Now weights should be given. It is a subjective selection of a decision-maker. In order to objectify, it is advisable to take into account the views of the experts who make their determination committee (council of consultants). The chances of increasing the credibility of the assigned weights then increase.

1. Access to external funds – 0.5
2. Creative management stuff -0.2
3. Support form R+D units – 0.1
4. Risks – 0.2

The fifth stage demands a table with actual values of corresponding criteria for individual assessment facilities.

Table 3. Actual values of criteria

	Access to external funds	Creative stuff	Support form R+D units	Risks
Project 1	5	15	3	35%
Project 2	6	12	3	40%
Project 3	5	11	4	30%

Source: own work

The following stage is about the presentation of each number from the table created in step 5 as a percentage of the "path" from the least desirable state to the most desirable state.

Table 4. A percentage of the "path"

	Access to external funds	Creative management stuff	Support form R+D units	Risks
Project 1	0	1	0	0.5
Project 2	1	0.25	0	0
Project 3	0	0	1	1

Source: own work

Finally, we should include weights (multiplication of the results from the table by the adopted weights).

Table 5. A percentage of the "path"

	Access to external funds	Creative management stuff	Support form R+D units	Risks	Sum
Project 1	0	0.2	0	0.1	0.3
Project 2	0.3	0.05	0	0	0.35
Project 3	0	0	0.1	0.2	0.30

Source: own work

Project 2 (0.35) turns out to be the most useful, given the given evaluation criteria. It should be the chosen one.

The case used in the article is an example and comes from the organizational practice used in the research of other authors. The authors used it to show the legitimacy of the Bellinger method, confirming its usefulness and efficiency concerning the problem solved. The authors would like to point out that the number of criteria used results from the need to ensure their completeness and complementarity; they are - on the one hand - sufficient and make a reliable and consistent description of the problem (they are not excessive) - on the other - they do not penetrate they complement, and this means that they are mutually stopped but separating (they do not contain each other). In addition, the so-called accuracy of selection enables them to take their importance into account (scales, rank) - stage 6, which ensures clear differentiation of final results.

4. Discussion and conclusions

The authors do not prejudge the presented proposal or treat it as the final one. Other suggestions are also possible, but their usefulness will be determined by practice and time - which is the best judge. Based on the above considerations, the authors make four remarks - two of a general nature and two of a complex nature.

Firstly, in the face of the multitude of possible indicators for assessing innovative areas, there emerges the urge and temptation to look for a tool for organizing innovative priorities, which makes the undertaken subject seem justified.

The authors' intention was not to discuss the principles of computation but to encourage the use of multi-criteria analysis methods, including those of Bellinger, especially since it comes down to solving several organizational problems.

The choice of evaluation criteria remains an open issue. Those used in the article are exemplary, not binding, and may (should) differ depending on the area where the innovative activities are carried out.

The authors of the article also notice specific difficulties in the selection of experts, judges and the method of assigning validity to the adopted criteria. However, the activities in this area are unlimited.

B. Bellinger's analysis may be a helpful tool for facilitating decision-making, especially when implementing an innovative solution. The advantages of the method are simplicity, as it does not require complicated calculations, and ease of use. However, the method has disadvantages, mainly arbitrary weighting. The solution may use the Delphi method, expert opinions based on data collected and aggregated historically.

As shown above, the method has a number of advantages, and above all, it is efficient, and effective. It becomes desired by a modern manager who expects a simple tool to obtain reliable, fast results. However, the necessary conditions must be met: providing complete and complementary criteria, namely substantively accurate weights, awarded by competent specialists and the use of reliable data from reliable sources of information. In modern realities, this requirement should not be a problem. Vast databases of R&D departments "burst at the seams" from the overabundance of reliable data used by supercomputers. All this speaks for the legitimacy of disseminating the results obtained with its help to organizational practice for the purpose of prioritizing decision-making choices, and to the needs of assessing the innovative potential of enterprises.

Abstract

The construction industry is a vital sector that contributes to the economy's development. On the other hand, it also contributes to the natural environment through emissions and waste. Moreover, the construction industry is under pressure to develop and adopt new technologies, tools and practices. A proper tool for selecting innovation is needed. This paper presents MCDA tool for construction companies, namely the Bellinger method. The proposed tool facilitates decision-making because it helps to choose between alternatives.

Keywords: *MCDA; innovation; construction sector.*

JEL Classification: O30, D81.

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