SELECTION OF LOCALIZATION - DETERMINING IMPORTANCE OF THE FACTORS USING MADM METHODS AND GIS

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Abstract

Character of the 21st century and continuous changes, in micro and macro environment of the enterprise therefore create the necessity for the enterprises to continuously look for ways how to succeed on the market. When making a strategic decision with respect to the risk and uncertainty it is possible to use various methods and tools, whereas every one of these methodology elements have some advantages and disadvantages and their implementation in practice must correspond to the environment in which the company operates. This paper presents a strategic decision making about the location of the affiliate of the company by using multiple attribute decision making methods; in particular Analytic Hierarchy Process (AHP) for weight estimation and finding the optimal solution Technique for the Order of Prioritization by Similarity to Ideal Solution (TOPSIS) and Complex Multicriteria Optimization and Weighted Sum Approach (WSA) for the location of the affiliate ranking and selection. Then geographic information system (GIS) tools are used for a number of tasks ranging from visualisation and map-making to complex analysis and spatial statistics, which is able to reveal more spatial correlation.

Key words: localization, strategic decision-making, MADM, GIS

JEL Code: C02, M21

Introduction

Business environment, which can be understood as a company's surrounding is one factor that influences companies' competitiveness as a subjects that participate on the creation of new working opportunities and the increase of a country's economic level which is one objective of business policy. Therefore, the quality of business environment represents a key characteristic which is giving the potential economic subjects the information that influences their localization behaviour based in the spatial distribution of economic activities in the country or the region (Boutkhoum, 2015). At the level of macro-environment the environment of economic subjects is especially influenced by the national legislation in a given country. The presence of specific factors in the regions from the viewpoint of their micro-environment does differentiate and therefore they are attractive for potential investors deciding the localization of their entrepreneurial activities. Examples of such factors can be seen in the ability to concentrate man power in their region, create conditions for ensuring the presents of science and research in the regions, in the possibilities of companies' innovation activities or in ensuring the quality infrastructure enabling the entrepreneurs' quick and reliable transportation. Presence of such key factors in the business environment in the region therefore increases its competitiveness in the process of selecting the appropriate locality by a potential business subjects, whose decision about a spatial localization does influence total business development of a particular region. Employing geographical information systems (GIS) into decision making process is getting more interest as the necessity of spatial relations and patterns cannot be omitted. Specific decision support system (SDSS) methods are being widely implemented into GIS software to bring a better environment for decision makers (Goodchild, 1993).

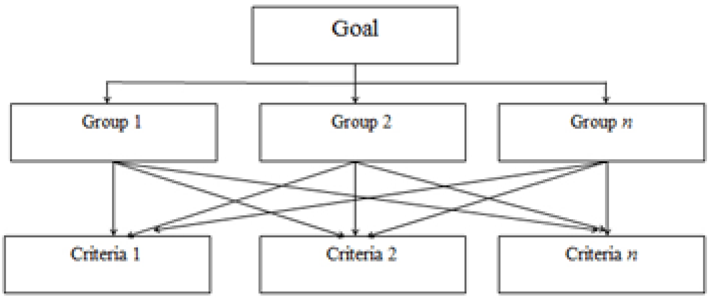
1 Multiple attribute decision making methods

The decision-making process can be described as a process, when we have to make a decision between minimally two or more variants (Brožová et al., 2014). In the multicriteria evaluation of variants models there is a final group *m* variants given, which are evaluated based on *n* criteria. Such decision situation can be described with criteria matrix, which follows (Fiala, Jablonský, Maňas, 1994).

$$\begin{array}{c c} & \begin{array}{cccc} A_1 & A_2 & \dots & A_n \end{array} \\ \begin{array}{c} K_1 \\ K_2 \\ \vdots \\ K_m \end{array} & \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix}, \end{array} \quad (1)$$

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty (1994). The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, subcriteria, and alternatives. The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion.

Fig. 1: General AHP structure



Source: Saaty, 1980

Many various methods exist for weight determination; the simplest ones are linear methods, in which are subjectively determined non-normalized weights of individual criteria in a priory agreed ranking scale. Second group includes so called non-linear methods, e.g. pairwise comparison, where Fuller triangle method or more complex Saaty method belongs. In this paper the aforementioned Saaty's method is used. The criteria weights can be determined very easily by so called approximation methods, which are practically well solvable by determination of normalized weights w_i by the utilization of geometrical mean of lines

$$v_i = \frac{R_i}{\sum_{i=1}^{m} R_i} = \frac{\left[\prod_{j=1}^{m} s_{ij}\right]^{1/m}}{\left[\sum_{i=1}^{m}\prod_{j=1}^{m} s_{ij}\right]^{1/m}}, i = 1, 2, ..., m. \qquad (2)$$

More detailed procedure of the calculation can be found in (Saaty, 1994).

Individual methods, which require cardinal information about criteria, can be divided into three basic groups to: methods based on maximization utility function (weighted sum approach WSA or AHP method), methods based on minimization distance (TOPSIS method) and evaluation based on preference relation method (Klozíková, 2015).

1.1 WSA method

It is a method, which is based on the linear utility function construction at the scale 0 to 1. The worst variant based on given criteria will have utility 0; the best variant will have utility 1 and other variants will have utility between both extreme values. Weighted sum method derives from the principle of utility maximization; however the method presumes only linear utility function.

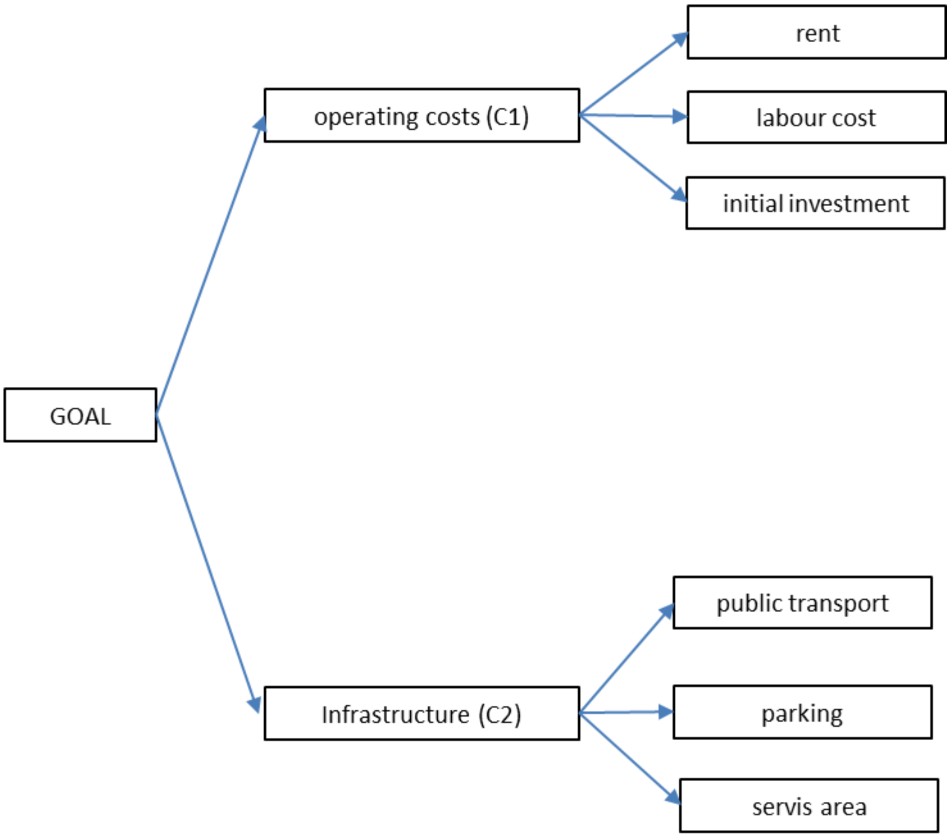
1.2 TOPSIS method

TOPSIS method, proposed by Hwang and Yoon (1981), is one of the most popular methods. It consists in comparison of weighted reference solutions: the positive ideal solution and the negative ideal solution. The total importance of alternatives is calculated by measuring simultaneously their distances from the positive ideal solution and the negative ideal solution. The steps of TOPSIS are as follows. More information pertaining to the computation can be found in (Dočkalíková, Kashi 2013).

2 Applicant's selection

The decision making process itself consists of a several consecutive steps. First of all the decision making situation must be described and the problem must be defined. The subject of this paper is a selection and comparison of chosen localities of the city of Přerov. As the need for considering spatial aspects into decision making process rises, spatial decision support methods are used employing GIS. AHP is one of the methods implemented into GIS software such as ArcGIS and IDRISI and they employ various SDSS. The simplest SDSS is Boolean logic with only binary scale dividing features into two groups – 0 (completely meeting requirements and 1 (not meeting requirement at all). In the need of weighting factors other methods such as Weighted Linear Combination (WLC) or Ordered Weighted Average (OWA) can be used (Ruda, 2016).

Fig. 2: General AHP structure



Source: Own elaboration

Criteria

Between the most important criteria that must be considered to the best variant selection certainly belong: initial investment, rental, transport infrastructure, including the possibility of recruiting a suitable workforce in the region. Locations / variants are then evaluated according to 6 criteria. Two groups of criteria were set, each of them divided into 3 sub-criteria. The criteria structure is shown in figure 2. Criteria selection resulted from the discussion of experts based on the brainstorming method.

Tab. 1: Input criteria data

Criteria group	Weights of criteria's groups	Criteria	Local weights	Global weights
		rent	0,5695	0,4983
		labor cost	0,3331	0,2914
operating costs	0,8750	initial investment	0,0974	0,0852
infrastructure	0,1250	public transportation	0,5861	0,0733

		parking	0,3531	0,0441
		servis area	0,0608	0,0076

Source: Own elaboration

Infrastructure was evaluated according to three sub-criteria – public transport, parking and service area. Different input layers were created, then rasterised, standardized and weighted as show in fig. 3. Weighted linear combination method was used. That means that to each standardized pixel value a local weight is assigned. All pixels in the individual criterion layers are weighted with the same local weight which determinates the importance of each factor (criterion) according to the final goal (see Tab. 1).

The analysis supposed that the ranging acceptable walking distance to the service is 15 minutes so the zones within a 15 minute walking time were created using network analysis (Dermeková, 2013). The zones of 3, 5, 10 and 15 minutes walking time coming out of this analysis were then converted to raster format and values of pixels were standardized. Values ranging from 1 for the most suitable to 0 not suitable were joined according the attribute of the pixel. There are many ways of standardization available in GIS software such as min-max method, maximization utility function or fuzzy membership (Pechanec, 2006). Fuzzy membership with sigmoid function was used for standardizing process, see Tab. 2.

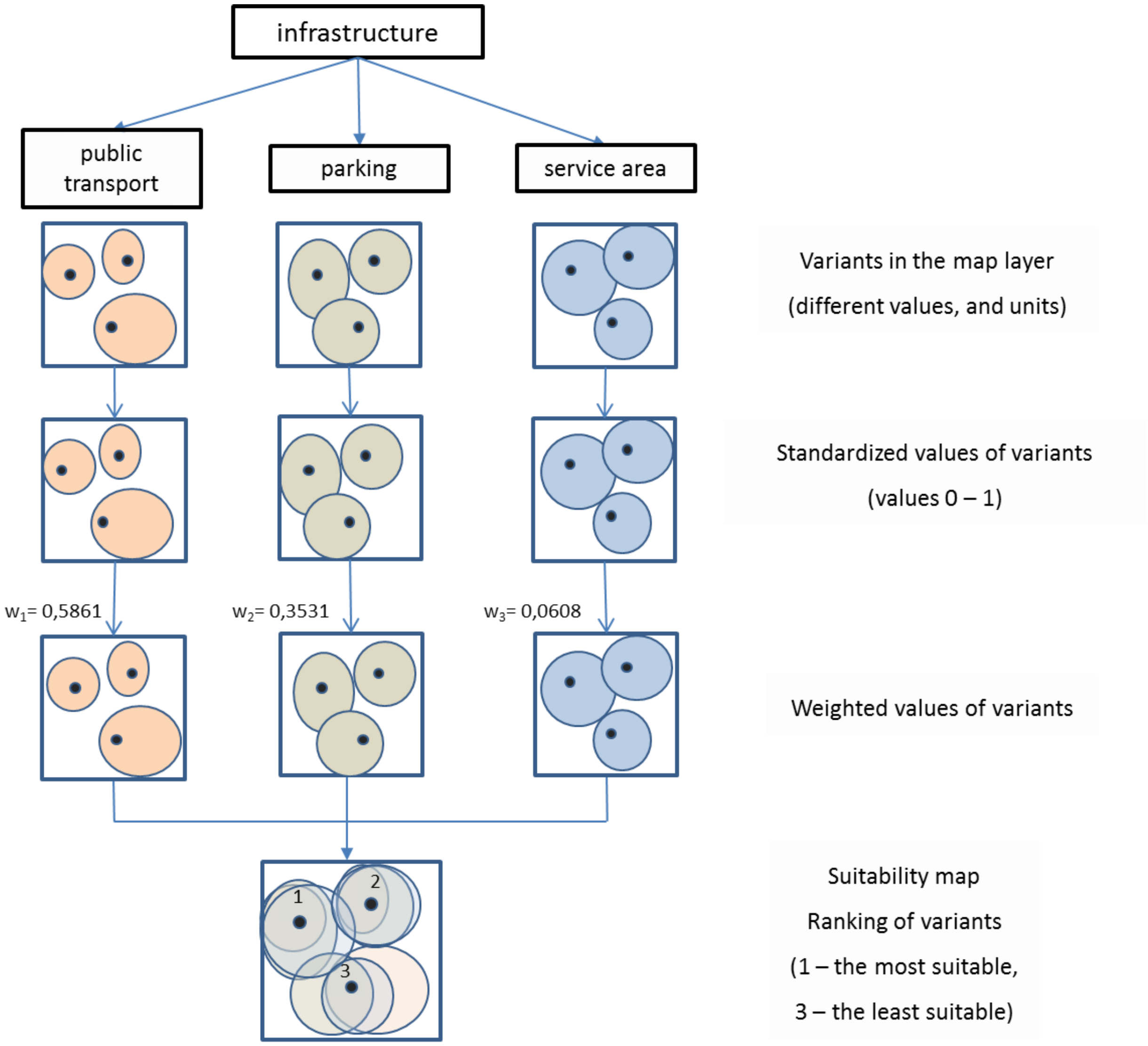
Tab. 2: Standardized values of the public transport criterion

attribute value	standardized value	factor weight	weighted value
> 3 minutes	1,00	0,5861	0,586
3 - 5 minutes	0,78	0,5861	0,457
5 - 10 minutes	0,49	0,5861	0,287
10 - 15 minutes	0,29	0,5861	0,170
> 15 minutes	0,00	0,5861	0,000

Source: Own elaboration

Similar values were used for parking proximity criterion. In the case of service area, areas within 15 minutes walking time were created using network analysis. These areas were evaluated according to population density considering the number of possible customers and employees and then standardized and weighted. Final suitability map was then created and location were ranked according to their appropriateness.

Fig. 3: Process model of WLC method



Source: Own elaboration

Conclusion

In today's turbulent time there is a continuous competition battle among companies. There are many methods for selecting the right places. Multicriteria evaluation of variants methods belong among the mathematical modelling methods used for location tasks. This paper presented AHP (analytic hierarchy process), which is used for multiple criteria decision making and enables to take into account preferences of individual evaluators. Furthermore AHP using GIS was used to get more spatial patterns into decision making process. The WLC method was used which enables weighting input values so that the importance of each factor (criterion) according to the final goal is determinated. The appropriateness of other methods such as WSA, TOPSIS, and VIKOR etc. is a subject to further research.

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