FACTORS AND MULTI-CRITERIA ANALYSIS CONDITIONING THE SELECTION OF WAREHOUSE LOCATIONS

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Abstract
Decisions about the location of the company or logistic hub are a complex process that requires thorough analysis of various factors. The aim of this paper is to identify the most important factors which influence the location of the storage facility. The theories and methods of choosing localization are discussed in the theoretical part of paper. In empirical research, via method of AHP, the attractiveness of the localization of various Polish cities was compared. Selected municipalities were collated in terms of the following criteria: price of land, access to infrastructure and to qualified personnel, costs of labour, distance to sales and supply markets.

Keywords: Warehouse, location factors, Analytic Hierarchy Process

1. INTRODUCTION

The location of a new production facility, warehouse or a distribution centre, requires careful investigation of a variety of conditions which may impact the efficiency of the entire venture [1]. Decisions concerning the location of one's own logistical facility are always long-term in nature. This stems from the fact that the cost of constructing or acquiring an appropriate facility or warehouse is always high and it is settled throughout many years of expected usage [2].

Literature on the subject contains many theories and methods pertaining to the selection of the location of logistical nodes. The first person to deal with location theory was von Thünen, who created a model in which respective types of agricultural production were arranged around metropolitan areas. The main assumption of this model (the ring theory) was that the type of production performed on agricultural farms is influenced by the amount of costs related to transport [3]. Von Thünen's model concerned mainly agricultural activity. Location theory in the field of industry has been formulated first by Launhardt, who postulated that an optimal location is the one that minimizes transport costs per unit of production [4]. Launhardt's research was continued by Weber, who claimed that an enterprise's optimal location is the one allowing to achieve the lowest transport costs based on specific assumptions [5]. Another standpoint was presented by Lösch, who claimed that the main criterion for locating enterprises should be the maximization of profit and viewed the optimal location as the one ensuring maximum sales with the lowest possible total costs. According to Lösch companies seek locations near the most absorptive markets [6].

The theory was also significantly developed by Hoover and Florence who stressed the importance of the role of concentration of production in industry location. Moreover, Hoover developed a classification of costs in which he paid particular attention to changing the means of transport during shipping as well as related handling works which may impact the general transport costs [7].

Modern location theories often assume that not only economic premises are significant, but also psychosocial factors. When compared to classic theories, modern location theories examine the issue of location in a significantly wider scope. In addition to sales and supply markets and transport costs, which are the main factors shaping the optimal location in classic theories, modern theories also comprise psychological factors and advantages stemming from cooperation within a region or sector [8]. The behavioural approach refers to

the limited rationality of the governing bodies, the incomplete scope of knowledge possessed by them as well as their lack of expertise to properly utilize such knowledge. Such views were held by Törnqvist and Ramström who viewed direct personal contacts of representatives of various organizations as the main factor impacting the location of economic activity [9]. Another theory of location is the one authored by Klaassen, who claims that investors locate enterprises in attractive regions, i.e. those with emerging or existing growth poles [10].

This paper's research objectives are both cognitive and methodological in nature. The cognitive objective is to specify the factors significant for making decisions about the location of logistical facilities from the point of view of entrepreneurs. The methodological aim concerns the use of the AHP method in order to establish a ranking of selected cities with regard to their attractiveness in scope of logistical (economic) activity location.

2. MATERIAL AND METHODS

The source material for the research originated from primary and secondary sources. Accumulation of primary data included conducting a survey questionnaire among 20 entrepreneurs. The aim of the survey was to acquire an opinion of entrepreneurs as to the factors significant with regard to making a decision on locating new facilities. By contrast, using secondary GUS (Central Statistical Office of Poland) data and resources collected from the Internet allowed to acquire information necessary to perform an analysis of the attractiveness of cities with regard to locating new facilities with use of the AHP method.

Warehouse location was evaluated based on the AHP (Analytic Hierarchy Process) method. The AHP method is a multiple objective ranking procedure focused on the hierarchical analysis of the decision problem [11]. The method is based on the multiattribute utility theory [12] and allows to rank a finite set of variants *A* from the best to the worst. Through the definition of the overall objective, evaluation criteria, subcriteria and variants the method constructs the hierarchy of the decision problem.

On each level of the hierarchy, based on the pair-wise comparisons of criteria, subcriteria and variants, the DM's preferential information is defined in the form of relative weights w_r [11]. Each weight represents the quantified strength of the compared element against another, on the standard "1 - to - 9" measurement scale, in which: 1 corresponds to the elements that are equally preferred; 3 and 5 denominate - weakly and strongly preferred element, respectively, while 7 and 9 represent strongly and absolutely preferred element, respectively. The intermediate judgments like: 2, 4, 6, 8 can be also used. All weights have a compensatory character, i.e.: the value characterizing the less important element (1/2, 1/5, 1/9) is the inverse of the value characterizing the more important element in the compared pair (2, 5, 9) [13].

The algorithm of the AHP method focuses on finding a solution for a, so called, eigenvalue problem [Satty, 1980] on each level of the hierarchy. As a result a set of vectors containing normalized, absolute values of weights w_a for criteria, subcriteria and variants is generated. The sum of the elements of the vector is 1 (100%). The absolute weights w_a are aggregated by an additive utility function. The utility of each variant *i* - U_i is calculated as a sum of products of absolute weights w_a on the path in the hierarchy tree (from the overall goal, through criteria and subcriteria) the variant is associated with. The utility U_i represents the contribution of variant *i* in reaching an overall goal and constitutes its aggregated evaluation that defines its position in the final ranking. The final result of the AHP method algorithm is the ranking of variants from the best to the worst based on the decreasing values of their overall evaluations.

The important element of the AHP algorithm is the investigation of the consistency level of matrices of relative weights w_r on each level of hierarchy. Through the calculation of a, so called, consistency index *CI* one can measure how consistent is the preferential information given by the DM. If the value of *CI* is close to 0 the preferential information given by the DM is considered to be almost perfect. The acceptable level of *CI* is below 0.1 [14].

3. RESULTS

The first stage comprised research conducted on the basis of the survey questionnaire. It involved 20 entrepreneurs in the period between December 2015 and April 2016. The most numerous group of respondents was constituted by representatives of production companies. The scope of economic activity of the surveyed enterprises was as follows: 75% of surveyed companies had an international footprint, 15% of respondents conducted activity only in Poland and 10% were regional enterprises.

In scope of the research the persons responsible for locating facilities and / or warehouses had to decide which of a set of predetermined factors have, in their opinion, the strongest influence on the selection of a location for a facility (warehouse). The factors have been evaluated on a scale of 1 (factor not impacting the selection of a location) to 5 (factor with significant impact on the location of the company). The average rating of the entrepreneurs has been presented in **Table 1**.

TABLE 1 Evaluation of the significance of location factors according to the respondents

Factor	Average rating
Labour cost	4.58
Access to road transport facilities	4.53
Possibility to expand the facility	4.47
Utility infrastructure	4.11
Access to qualified personnel	4.05
Price of production resources	3.94
Local fees	3.84
Vicinity of supply market	3.78
Vicinity of sales market	3.63
Tax provisions	3.63
Price of land or lease cost	3.58
Possibility to integrate with other entities	3.58
Cost of utilities	3.47
Access to rail, air and maritime transport	3.16
Local community acceptance	3.16

Source: Own research

The factors which achieved the highest average ratings according to entrepreneurs are labour cost, access to road transport facilities and possibility to expand the facility. The lowest average score was attributed to the cost of utilities, price of land or lease cost, infrastructure other than road infrastructure, possibility to integrate with other entities and local community acceptance (**Table 1**).

Factors omitted in the survey, but significant from the point of view of respondents are: existence of Special Economic Zones, subsidization (e.g. European Union grants), succession, attachment to place of residence, use of existing structures, topography, soil conditions, atmospheric conditions, access to water, image of the location and distance from inhabited areas.

The second stage of research involved the use of the AHP method in order to formulate a ranking of selected cities with regard to their location attractiveness related to constructing or acquiring new warehousing areas. The surveyed sample consisted of 5 Polish cities: Nidzica, Konin, Legnica, Tarnów and Świdnik (variants from V1 to V5). The analysis was conducted for the year 2016.

The objective of the multiple criteria analysis of Polish cities is to evaluate them from different perspectives. The multiple criteria evaluation of cities is envisaged by the author of the paper as an extensive benchmarking analysis, resulting in the recognition of the diversification of access to transport infrastructure, land prices, distance from supply and sales markets, access to qualified labour and the costs of labour.

The decision maker (DM) in the analyzed decision making process is represented by the entrepreneur. An entrepreneur being the decision-maker in this analysis conducted production activity in central Poland and considered establishing a new warehouse in one of the five locations enumerated above. What was important to the entrepreneur was to create a ranking of 5 cities with consideration of the following criteria:

- C1 - access to infrastructure (road, maritime, rail, air),
- C2 - price of land (purchase / lease),
- C3 - distance to sales / supply markets,
- C4 - cost of labour (taking into account the average wages in the region),
- C5 - access to qualified personnel.

Computational experiments have been carried out with the application of AHP method implemented in the specialized software called MakeItRational. In the first stage the hierarchical structure of the decision problem has been defined, including the definition of the overall goal, criteria and variants. In the next step the model of the DM's preferences has been constructed. This has included the definition of the importance of individual criteria and the recognition of the DM's sensitivity to changes of their values. On the basis of pair-wise comparisons between criteria the relative weights w_r ranging between 1/9 to 9 have been generated.

The results of calculations of relative weights w_r for criteria, applied in the evaluation of Polish cities, have been presented in **Table 2**. This matrix is characterized by pair-wise coherence. In the course of comparing the criteria the author has considered the preferences of entrepreneurs with regard to the advantages of individual factors. It can be seen that criterion 4 (cost of labour) is more important than all others (relative weights are higher than 1).

Table 2 Relative weights w_r for criteria generated by the AHP method

	C1	C2	C3	C4	C5
C1	1	1/6	5	1/2	2
C2	6	1	1/2	1/7	1/4
C3	1/5	2	1	1/6	1/3
C4	2	7	6	1	3
C5	1/2	4	3	1/3	1

Source: Own research

In the next step the eigenvalue problem has been solved, which resulted in the generation of normalized absolute weights w_a on all levels of the hierarchy i.e. for criteria and variants in the form of weight vectors all, above mentioned components of the hierarchy. As can be observed in **Figure 1**, the most important criterion - with the highest value of weights (w_a = 0.44) is criterion 4 - cost of labour. The next places are held by: criterion 1 - access to infrastructure and criterion 5 - access to qualified personnel. Criteria 2 - price of land and 3 distance to sales / supply markets belong to the least important characteristics. Their absolute weights are 0.04 and 0.06, respectively, which is presented in the graphical form (see **Figure 1**).

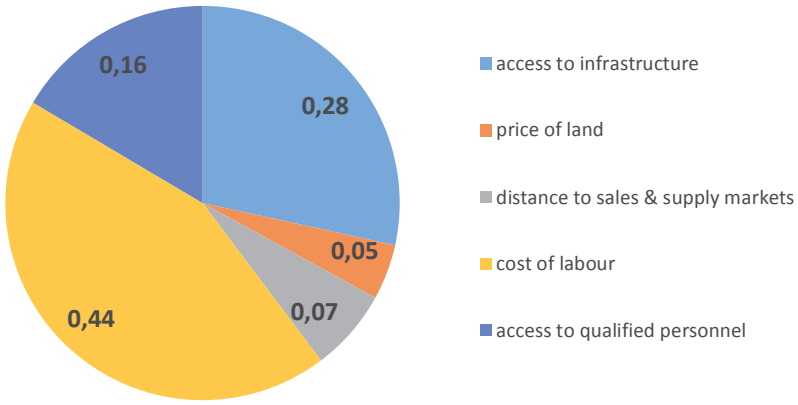

Figure 1 Absolute weights of criteria in accomplishing the main purpose generated in the AHP method
Source: Own research

Further analysis lead to mutual comparisons of variants for all individual criteria. The relative weights of individual variants specify the relative position of a given variant (city) in relation to its competitors (other cities), evaluated by the specific criterion. The values of the relative weights also reflect the direction of preference of this criterion. Similarly to previous computations a vector containing normalized, absolute values of weights for variants has been generated.

In the next step for each matrix on hierarchical levels. i.e.: criteria and variants, consistency indexes *CI* have been computed. In all matrices the values of the consistency indexes *CI* have not exceeded 0.1, which proved that the acquired preferential information has been appropriately defined. This allowed the author to continue the computational experiment.

The next stage consisted in aggregating the absolute weights w_a of the elements of the hierarchy tree by means of an additive utility function. As a result the utility of each variant U_i. has been calculated. **Figure 2** presents the final ranking of variants (cities) from the best to the worst based on their decreasing utilities. Thus, city with the highest utility is placed at the top of the ranking, while the city with the lowest utility is placed at the bottom. The utility of each variant also provides information on its participation in achieving the overall goal of the analysis.

In accordance with the analysis conducted on the basis of the Analytic Hierarchy Process method the city with the most advantages with regard to the examined factors was Legnica (**Figure 2**). This result stemmed from the fact that it achieved a very good score with regard to access to qualified personnel and infrastructure, i.e. the factors with the highest weights. The city ranked second with regard to location attractiveness was Nidzica, in spite of its unfavourable infrastructure. The vital factor here was an especially advantageous cost of labour when compared to other cities. In the survey research the cost of labour was indicated by the respondents as the key factor determining the location of facilities. The third place was taken by Tarnów, which achieved the best result in scope of access to qualified personnel. In accordance with the analysis Konin ranked fourth despite achieving a good result in scope of access to qualified personnel and favourable infrastructure. The reason for such a low rank was a rather high cost of labour when compared to other cities. The last place in the ranking was occupied by Świdnik. This stemmed mainly from high wages and significant distances to supply and sales markets.

It is also worth mentioning that Legnica prevailed over the other cities with regard to access to infrastructure and distance to supply and sales markets. The advantages of Nidzica were low costs of labour and the price of land, while Tarnów stood out because of its qualified personnel. Konin and Świdnik did not achieve any advantage over the other cities in scope of any of the examined factors.

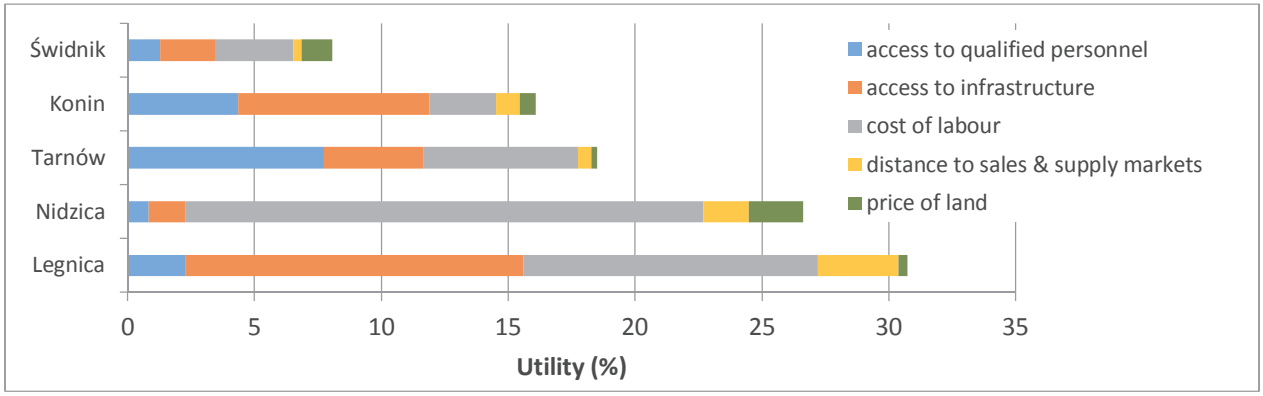

Figure 2 Final ranking of Polish cities based on AHP method
Source: own study

4. CONCLUSION

The theoretical section of the paper presented various location theories which were formulated and developed in order to clarify and plan the spatial organization of various categories of economic activity.

Empirical research based on the opinions and ratings given by 20 entrepreneurs allowed to specify the most important factors taken into account in relation to making decisions about locating logistical or production facilities. In the respondents' opinion the most important factors are cost of labour, access to road transport facilities and possibility to expand the facility.

The second stage of research consisted of using the AHP method and considering the preferences of entrepreneurs in order to select 5 criteria, i.e. access to transport infrastructure, land prices, distance to supply and sales markets, access to qualified personnel and costs of labour. Those criteria served as the basis for the comparison of 5 cities (Legnica, Nidzica, Tarnów, Konin and Świdnik). The AHP analysis conducted for the purposes of preparing this paper allowed the author to create a ranking of those cities with regard to their attractiveness as locations for new logistical facilities. Legnica was ranked first owing to its wide access to infrastructure and closeness of supply and sales markets.

REFERENCES

[1] KRAWCZYK S. Metody ilościowe w logistyce, Wydawnictwo C. H. Beck, Warszawa 2001, p.180-181.

[2] BARAN, J., WYSOKIŃSKI, M., STAS D., SAMOJLEVA A., LENORT, R., Efficiency of Polish Metallurgical Industry Based on Data Envelopment Analysis, Metalurgija, 2016, No 55(2), pp. 245-248.

[3] DRAMOWICZ E. Teorie lokalizacji rolnictwa, „Przegląd geograficzny", t. 50, z. 1/1978, p. 57-58.

[4] PINTO J. V. Launhardt and Location Theory: Rediscovery of Neglected Book, Journal of Regional Science, vol. 17, no. 1/1977, p.17.

[5] BARAN J., MACIEJCZAK M., PIETRZAK M., ROKICKI T., WICKI L. Logistyka wybrane zagadnienia, Wydawnictwo SGGW, Warszawa 2008.

[6] LÖSCH A. Gospodarka przestrzenna, PWE, Warszawa 1990, p. 35-39.

[7] MISZCZUK A. Teoria a praktyka lokalizacji przemysłu w warunkach polskich na przykładzie województwa lubelskiego „Annales Universitatis Mariae Curie Skłodowska - Sectio H, vol. XX(8)/1986, p. 134.

[8] SANIUK S., SANIUK A., LENORT R., SAMOLEJOVA A. Formation and planning of virtual production networks in metallurgical clusters, Metalurgija, R. 53, No 4, 2014, p. 725-727.

[9] TÖRNQVIST G. Contact Systems and Regional Development, Lund Studies in Geography" Series B., Human Geography 35/1970, p. 148

[10] KLAASSEN L.H. Kilka dalszych uwag o analizie przyciągania [in:] A. Kukliński (red.) Problemy i metody ekonomiki regionalnej, PWE, Warszawa 1978, p. 121-140.

[11] SAATY T. The Analytic Hierarchy Process, McGraw-Hill, New York 1980.

[12] KEENEY R., RAIFFA H. Decision with Multiple Objectives. Preferences and Value Tradeoff. Cambridge University Press, Cambridge 1993.

[13] BARAN J., Economic development versus transportation development in Poland, CLC 2013: Carpathian Logistics Congress - Congress Proceedings, Cracow, Poland, TANGER, 2014, pp. 343-350.

[14] BARAN J., ŻAK J. Multiple Criteria Evaluation of Transportation Performance for Selected Agribusiness Companies, Procedia - Social and Behavioral Sciences, vol. 111, 2014, pp. 320-329.