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A METHOD FOR CHOOSING THE LOCATION OF PRODUCTION SYSTEMS USING A MULTIDISCIPLINARY APPROACH

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Abstract

Choosing a location for production companies is a complex task due to various factors that influence the choice of both wider (macro) and narrower (micro) locations. A macro location is defined as an area that is most suitable for establishing a company with minimal labor cots, whilst a micro location is a specific place that is part of a macro location where the company will be built. Location is one of the most crucial factors, which in the future will affect the perfomance of the company. This paper presents a method that results in a well-rounded decision-making process, enabling an informed choice of location that aligns with a company's operational needs, financial goals, and strategic vision, ultimately leading to the selection of the most suitable location for production companies. As for the wine production system, where the given method was applied, it was shown that it is of crucial importance to select a suitable location because it is a key factor in such a specific production system. The results underscore the method's effectiveness in identifying the most suitable site for a production facility.

Keywords*: location, production system, multi-criteria decision making (MCDM), AHP method.*

1. Introduction

Facility location selection is a multi-criteria decision problem and has a strategic importance for many companies (Ertuğrul & Karakaşoğlu, 2008). Companies often opt to set up their factories abroad rather than domestically due to factors such as frequent market changes, the evolution of market economies,

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improved international communication, easier capital flow between countries, and significant disparities in labor costs (Rikalović, 2014).

Geographical information systems (Xu et al., 2020) and other methods make it easier to make decisions about choosing locationsy (Abdel-Basset et al., 2021; Yong, 2006).

Choosing a site for a new winery necessitates clearly defining the criteria that the location must meet. Given that the primary consideration is the raw material over the finished product, it is crucial for the winery to be situated near the vineyard to minimize transportation costs. Therefore, the criteria for selecting the location should prioritize the ability to cultivate grapes of sufficient quality for wine production. The quality requirements for grapes vary by variety, with climatic adaptability being one of the most crucial factors. To determine the most suitable location, it is essential to identify all products that will be manufactured within the production system to ensure the integrity of the production process.

The term "representative product" refers to the primary focus of the company's operations. By defining this product, the necessary location criteria for the company can be established accordingly. In the context of wineries, the representative product should be wine made from grape varieties that are most adaptable to the conditions in Serbia.

1.1 Literature review

Identifying the optimal location for a specific purpose is a complex task that demands a multidisciplinary approach and the application of cutting-edge technology. Today, this scientific discipline relies heavily on computers and specialized software to analyze and solve location-related challenges

The choice of location significantly impacts a company's overall risk and profitability (Heizer J. and Render B., 2011).According to Zelenović (Zelenović D, 2003), the process of selecting a location involves:

- Identifying a set of influential factors pertinent to the location selection.
- Predicting and assessing the magnitude, direction, and impact of these factors under specific environmental conditions at a given time.
- Evaluating various potential solutions and selecting the optimal one.

Autschbach proposes a three-step approach to site selection: country selection, preliminary analysis, and detailed analysis of potential sites(Autschbach J, 1997).Goethe suggests a five-stage process: concept development, country evaluation, macro analysis, micro analysis, and decision-making(Goette T., 1994).Based on gathered data, a decision is made regarding the methodology to be employed for selecting both broad and specific locations for the production system. The foundation of all decision-making processes involves the following steps (Monks, 1982):

1. Clearly defining the problem and its parameters.
2. Establishing decision criteria or objectives to be achieved.

3. Formulating relationships between parameters and criteria (model creation).
4. Generating alternatives or actions.
5. Selecting the action that best aligns with the established criteria.

Zak and Weglinski (Zak & Węgliński, 2014) introduced a two-stage procedure for solving logistics center location selection problems.

The Multiple Criteria Decision Making (MCDM) approach is widely used across various fields and disciplines, particularly for resolving location selection challenges(Chien et al., 2020; Løken, 2007; Wang et al., 2018; Zhou et al., 2006).

1.2 Methods

When evaluating a broader location for a business, typically referring to the country or region where the business will be established, several crucial factors must be carefully considered:

- Market: Conduct thorough market analysis within the chosen region, including assessment of market size, growth prospects, demand trends, and target demographics. It's essential that the chosen location provides access to your target consumers or clients.
- Workforce: Research the availability of a skilled and qualified workforce with the necessary skills and education pertinent to your business needs. Additionally, examine labor costs and compliance with local labor laws in the prospective country.
- Infrastructure: Evaluate the adequacy of infrastructure crucial for your operations, such as transportation networks, energy supply reliability, communication infrastructure (including internet access), and logistics services.
- Tax Policy: Understand the tax regime in the selected country, as it can significantly impact business costs. Investigate potential tax incentives, subsidies, or other advantages offered to attract foreign investment.
- Regulatory Framework: Familiarize yourself with business regulations, labor laws, environmental protection standards, and other regulatory requirements that could affect operational costs and business conditions.
- Logistical Position: Consider the geographical location of the company in terms of transportation costs and ease of distribution to end-users and other markets.
- Economic Stability: Assess the stability of the economic and political environment in the country, as it can influence business security and long-term planning.
- Cultural Factors: Gain insights into local culture, language, and customs to facilitate effective communication among employees, partners, and customers.

- Competition: Conduct a competitive analysis to understand existing businesses in the target country or region. This assessment helps identify potential challenges and opportunities for your company.
- Risks: Understand hazards such as disasters, political instability, currency risk that may affect business.

Well-studied and analyzed factors will help in choosing a good location for the company.

The narrower location can be selected using various methods, one of which is the Analytical Hierarchy Process (AHP) method, developed by Thomas Satti in the early seventies. The AHP is a decision-analysis toolcreated with the aim of providing assistance to decision makers in solving complex problems (Ćosić I., 2016).

This method represents an adaptation of the linear assignment method and is based on the concept of balance used to determine the overall relative importance of a set of attributes, activities and criteria. This can be achieved by structuring any complex decision problem, involving multiple persons, multiple criteria, multiple hierarchical levels, assigning weights in the form of a series of pairwise comparison matrices.

The modeling process requires 4 stages:

1. Structuring the problem;
2. Data collection;
3. Evaluation of relative weights;
4. Determining the solution to the problem.

After the identified potential alternatives, the choice of the most favorable alternative can be made by considering several criteria imposed by the decision maker.

AHP is a multi-criteria decision-making method that enables consideration of objective and subjective factors in choosing the most optimal location. AHP is based on three principles: decomposition, comparative analysis and synthesis of priorities. The principle of decomposition requires that the decision-making problem should be decomposed into a hierarchy that takes into account the essential elements of this problem (Ćosić I., 2016)

1.3 Method for selecting the location of production systems

In order to choose the most suitable location for production systems, it is necessary to follow the given steps. The authors of this paper defined the steps described in the given method based on their experience.

Figure 1 shows the mentioned model for choosing a company location.

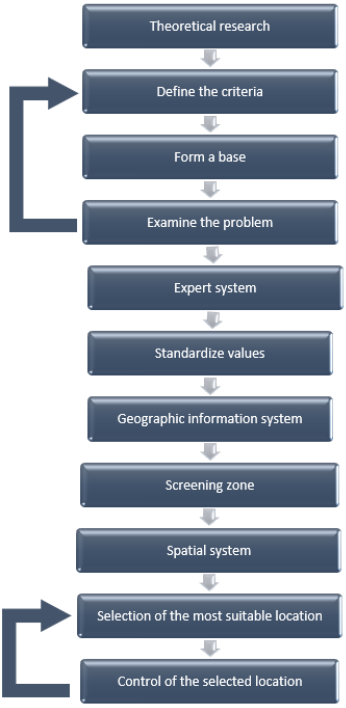

Figure 1: A model for choosing a company location

The results indicate that following the outlined steps for choosing a company location leads to the most suitable site for optimal business performance. Drawing from our analysis of real systems, we have developed a model that guarantees a high-quality selection of company locations:

- A theoretical research on the influence (factors) on the choice of location of the production system;
- Defining decision criteria;
- Forming a unique database of spatial data;
- Examining all possible problems and how they affect the production system and its location;
- Developing an expert system for decision support;
- Standardising the values of all relevant factors for choosing the location of the production system;
- Developing a functional geographic information system for the area of interest;
- Screening zones of interest in order to generate alternatives;
- Developing a spatial system for decision support;

- Performing a mutual evaluation of the criteria using the method of multi-criteria analysis and choosing the most suitable location for the production system;
- Minimizing changes to criteria and parameters to control the selected location.

2. Case study analysis of a wine production system

There are numerous factors that can influence the quality of grapes. Below, we will present the key conditions that a location in the Republic of Serbia must meet for opening a winery with a vineyard:
Exposure and slope: hilly area with south, southwest, southeast exposure; slope up to 10o;
Altitude: 100 - 300m;
Temperature: It should not drop below -20°C in winter or exceed 40°C in summer, as these are critical thresholds. Ideally, winter temperatures should range up to -10°C, and summer temperatures should be between 30°C and 35°C. For optimal yield, temperatures during the fruit ripening period should be between 20°C and 30°C.
Precipitation: An annual precipitation of 700 to 800 mm is optimal."
Winds: Winds in our country do not exceed the permitted limits, the average speed of the strongest wind that blows in these areas, košava, is 25-45 km/h, which the vineyards can handle;
Light intensity: The optimal area receives approximately 2,000 hours of sunlight per year;
Land: The land must not be swampy, and ideally, there should be no groundwater. It should not have been previously used by industry, and perennial woody plants (such as vineyards, orchards, forests, or bushes) should not have been planted before;
Areas required: A total of 7 hectares is needed—5 hectares for vineyards and 2 hectares for supporting buildings. It should be noted that the vineyard and facilities will be located on the same plot;
Infrastructure: Road access, electricity connection, drinking water, and communal waste services are required.

Before embarking on the research to identify potential locations for opening a winery, it is crucial to gather comprehensive information to ensure the selection of the most suitable site. The essential information required includes: technological procedures for wine production, land requirements and spatial layout.

A decision tree can also be used to select regions of interest. It is a decision support tool that uses a tree graph or model of decisions and their possible consequences, including chance of event outcomes, resource costs, and utility. Figure 2 shows the decision tree for selecting a region of interest based on the previously mentioned criteria for selecting a location for opening a new winery.

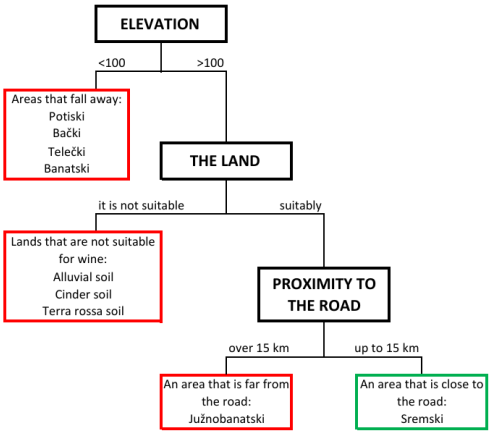

Figure 2: Decision tree when selecting a region of interest

2.1 Plot screening

To select a good area in various areas, screening is usually done in order to find the area that best matches the conditions that are important for location selection (Cazzaro et al., 2022).

In order to select the narrowest location of the winery, it is necessary to screen the plots of the selected wine-growing region.

In order to select plots that are suitable for opening a winery next to the surface, the important characteristics of the plots are:

- Land type (agricultural, construction site) and its purpose (what is currently grown on the plot and what the land class is);
- Infrastructure (is the plot located next to the main road or does it need to build an access to the winery, does it have access to electricity and water);
- Price (sale price of land);
- Labor availability according to data on the percentage of the working-age population by municipality.

Figure 3 shows the screening of the Srem region.

There are no sources in the current document. The screening of the Srem region was carried out along the entire southern side of Fruška Gora in a length of 56 km, the plots were selected based on their locations and crucially their sizes in order to avoid the need for consolidation of smaller plots. Due to the previously defined factors, parcels from three municipalities were finally considered: Inđija, Irig and Šid.

The problem being addressed was selecting the location for the new winery, with the initial focus on finding the best site for planting a vineyard. For the final product wine to be of top quality, the raw materials must also be of top quality.

Therefore, the search for a location was conducted with a primary emphasis on vineyard planting.

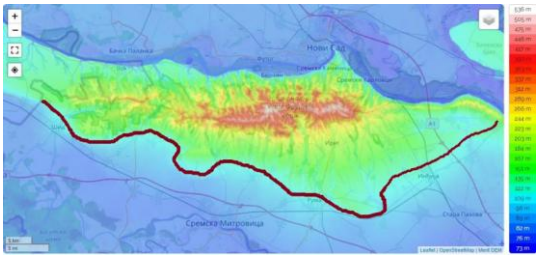

Figure 3: The screening of the Srem region

2.2 Results

The AHP method shown in Figure 4 was used to select the narrowest location, which is used to obtain a plot of land that is most suitable for planting vineyards and building a production system for wine production.

Alternative	Ratings
A1	0.068
A2	0.094
A3	0.059
A4	0.08
A5	0.068
A6	0.165
A7	0.08
A8	0.128
A9	0.159
A10	0.099

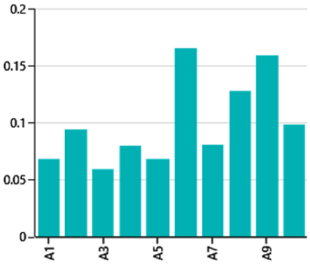

Figure 4: Selecting a narrower location

In the case study, it was necessary to choose the most suitable location for the cultivation of the most widespread white grape variety - Chardonnay.

It was decided that the location of the winery would be the same as the location of the vineyard in order to minimize transport costs.

The decision was made that the region of interest is AP Vojvodina, and by applying the decision tree, the region that is most suitable for finding a narrower location is the Srem region.

Within the Srem region, sub-regions with a potential closer location are: Šid (western sub-region) and Irig and Inđija (eastern sub-region).

The AHP method was used for the final determination of the narrower location. 5 criteria for selecting a narrow location are: plot area, land type and purpose, plot price, infrastructure and available workforce.

Using the criterion preference matrix, it was decided that the most important criterion for choosing a plot is the type of land and purpose. By comparing the

alternatives according to the criteria, the final selection of the narrower location is the alternative A6.

3. Conclusions

This paper presents a method that has proven effective for choosing a company location. One of the most important factors in building and advancing a company is its location, influenced by numerous factors. To ensure the final choice is well-informed, it is essential to implement the appropriate steps presented and explained in the method.

The method is specific in that it has the ability to "roll back" to check previous steps and ensure that the most suitable location for the production system has been selected.

It was tested on a case study that was very demanding and specific. Through the given case study (production system for wine production) it was shown that the method is effective and that it contributes to good results that are visible immediately, but which will only be examined and verified in the future. Attempts were made to skip a step in the method and the results were far worse than when the method was followed in the given order.

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REFERENCES

[1] Abdel-Basset, M., Gamal, A., Chakrabortty, R. K., & Ryan, M. (2021). A new hybrid multi-criteria decision-making approach for location selection of sustainable offshore wind energy stations: A case study. *Journal of Cleaner Production*, *280*(2), 124462. https://doi.org/10.1016/j.jclepro.2020.124462

[2] Autschbach J. (1997). *Internationale Standortwahl*. Deutscher Universitäts-Verlag.

[3] Cazzaro, D., Trivella, A., Corman, F., & Pisinger, D. (2022). Multi-scale optimization of the design of offshore wind farms. *Applied Energy*, *314*, 118830. https://doi.org/10.1016/j.apenergy.2022.118830

[4] Chien, F., Wang, C. N., Nguyen, V. T., Nguyen, V. T., & Chau, K. Y. (2020). An evaluation model of quantitative and qualitative fuzzy multi-criteria decision-making approach for hydroelectric plant location selection. *Energies*, *13*(11), 2783. https://doi.org/10.3390/en13112783

[5] Ćosić I., R. A. (2016). *Lokacija proizvodnih sistema*. Univerzitet u Novom Sadu, Fakultet tehničkih nauka .

[6] Ertuğrul, I., & Karakaşoğlu, N. (2008). Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection. *International Journal of Advanced Manufacturing Technology*, *39*, 783–795. https://doi.org/10.1007/s00170-007-1249-8
[7] Goette T. (1994). *Standortpolitik internationaler Unternehmen*. Deutscher Univer sitäts-Verlag.
[8] Heizer J. and Render B. (2011). *Operations Management* (10th ed.). Prentice Hall.
[9] Løken, E. (2007). Use of multicriteria decision analysis methods for energy planning problems. *Renewable and Sustainable Energy Reviews*, *11*(7), 1584–1595. https://doi.org/10.1016/j.rser.2005.11.005
[10] Monks, J. G. (1982). *Operations Management – Theory and Problems*. McGraw-Hill Book Co.
[11] Rikalović, A. (2014). *Razvoj modela za izbor lokacije proizvodnih sistema* (Doctoral dissertation, University of Novi Sad (Serbia)).
[12] Wang, C. N., Nguyen, V. T., Thai, H. T. N., & Duong, D. H. (2018). Multi-criteria decision making (MCDM) approaches for solar power plant location selection in Viet Nam. *Energies*, *11*(6), 1504. https://doi.org/10.3390/en11061504
[13] Xu, Y., Li, Y., Zheng, L., Cui, L., Li, S., Li, W., & Cai, Y. (2020). Site selection of wind farms using GIS and multi-criteria decision making method in Wafangdian, China. *Energy*, *207*. https://doi.org/10.1016/j.energy.2020.118222
[14] Yong, D. (2006). Plant location selection based on fuzzy TOPSIS. *International Journal of Advanced Manufacturing Technology*, *28*, 839–844. https://doi.org/10.1007/s00170-004-2436-5
[15] Zak, J., & Węgliński, S. (2014). The selection of the logistics center location based on MCDM/A methodology. *Transportation Research Procedia*, *3*, 555–564. https://doi.org/10.1016/j.trpro.2014.10.034
[16] Zelenović D. (2003). *Projektovanje proizvodnih sistema*. Fakultet tehničkih nauka.
[17] Zhou, P., Ang, B. W., & Poh, K. L. (2006). Decision analysis in energy and environmental modeling: An update. *Energy*, *31*(14), 2604–2622. https://doi.org/10.1016/j.energy.2005.10.023