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Research Article

LOCATION SELECTION FOR THE FURNITURE INDUSTRY BY USING A GOAL PROGRAMMING MODEL

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ABSTRACT

The location of a facility plays a significant role in minimizing costs and maximizing the utilization of resources. Therefore, in this study, a goal programming model was proposed to determine an appropriate location for the furniture industry. Seven provinces in the Western Black Sea Region of Turkey were considered as candidate places. The objectives of this study were identified as follows: proximity to raw materials, the number of qualified people, proximity to markets, population, and distances to other provinces in the region. The proposed model was solved using an optimization tool. The results demonstrated that Karabük was the best choice. Consequently, the model proposed in this study can be used as a guideline for furniture firms.
Keywords: Goal programming, facility location problem, furniture industry, Western Black Sea Region, Turkey.

1. INTRODUCTION

The furniture industry is a labor-intensive and dynamic sector. It includes the manufacturing of furniture parts and their assembly with appropriate finishing operations. Wood, medium density fiberboard, plywood, hardboard, and oriented strand board are some basic materials used in the furniture industry [1]. One of the countries that have abundant raw materials for furniture production is Turkey. The emergence of the furniture industry in Turkey dates back to the nineteenth century. The Turkish furniture industry has developed along with rapid globalization. The country's furniture industry is mainly divided into wooden furniture (massive and veneered), metal furniture, and others. The number of companies engaged in furniture production is 33,924 and the number of employees in the sector is 151,904 [2]. The furniture sector has a share of ~10% of the Turkish manufacturing industry [3].

One of the most important problems faced by furniture manufacturing companies is location selection. Facility location selection is the determination of the best geographic location for a facility. The decision-making process includes the identification, analysis, evaluation, and selection among options [4]. Location selection is a vital strategic decision owing to its important effects on the economic operation of plants and the sustainable development of regions [5, 6].

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Wrong selection results in inadequate qualified work forces, unavailability of raw materials, increased operating expenses or disastrous effects due to political and societal interferences [7]. Hence, it is important to develop location strategies for business units such as factories, distribution centers, and stores.

Facility location problems have been studied for many years. Many different decision-making methods have been used to solve these problems. Safari et al. [8] employed a fuzzy extension of the TOPSIS method for facility location selection. Cebi and Kahraman [9] selected an appropriate wind energy plant location by employing the Choquet integral. Ozgen and Gulsun [10] solved the capacitated multi-facility location problem by using the probabilistic linear programming approach and the fuzzy analytic hierarchy process (AHP). Chadawada et al. [11] utilized the AHP-QFD approach to select the best facility location. Güler et al. [12] used the goal programming (GP) approach to determine the optimal location of a feed factory. Mahmud et al. [13] determined the most appropriate location of a mango supplying business by employing the AHP method and the analytic network process (ANP). Bolturk and Kahraman [14] proposed the interval-valued intuitionistic fuzzy combinative distance-based assessment for wave energy facility location selection. Kheybari et al. [15] used the best-worst method to determine the optimal location of a bioethanol facility. Yücenur et al. [16] employed the step-wise weight assessment ratio analysis and the complex proportional assessment to select the best location for a biogas facility. Seker and Aydin [17] evaluated different locations for hydrogen production plants by using the Entropy-TOPSIS approach extended with interval-valued Pythagorean fuzzy sets.

There are also some studies seeking solutions to such problems in the field of wood science. Azizi and Modarres [18] used the ANP method to evaluate different locations for plywood and veneer plants. Imren et al. [19] determined the optimal location of a furniture company by employing the AHP method. Azizi and Ramezanzadeh [20] employed the AHP method to select the best location for the particleboard industry. Üçüncü et al. [21] selected the best location for the furniture industry by employing the TOPSIS method. Azizi [22] used the TOPSIS method for the location selection of solar wood drying units. Yeşilkaya [23] utilized AHP, TOPSIS, and PROMETHEE to determine the optimal location of a paper factory.

In the present study, the GP approach is employed for the location selection problem of a furniture manufacturing company in Turkey. Hence, this study contributes to the existing literature by introducing the use of the GP approach on determining the most appropriate location for the furniture industry. The study will help the furniture industry in improving the effectiveness of decision-making processes on the identification of the best facility location.

2. MATERIALS AND METHODS

2.1. Study Area and Data Collection

This paper focuses on the determination of the most appropriate facility location for the Turkish furniture industry. The Western Black Sea Region of Turkey is selected as the study area. The region consists of the following provinces: Kastamonu, Düzce, Bolu, Zonguldak, Bartın, Karabük, and Sinop. Figure 1 shows the study area.

Within the model, five evaluation criteria are defined as proximity to raw materials, the number of qualified individuals, proximity to markets, population, and distances to the provinces in the region. To analyze the alternatives and to solve the location selection problem, data are required for possible facility locations. The data of this study are obtained from the General Directorate of Turkish Highways [24], the Turkish Statistical Institute [25], and Google Maps [26]. Figure 2 illustrates the criteria used in this study.

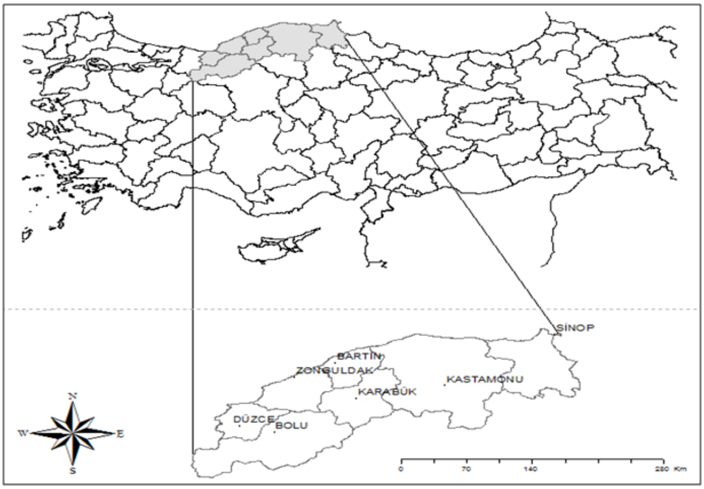
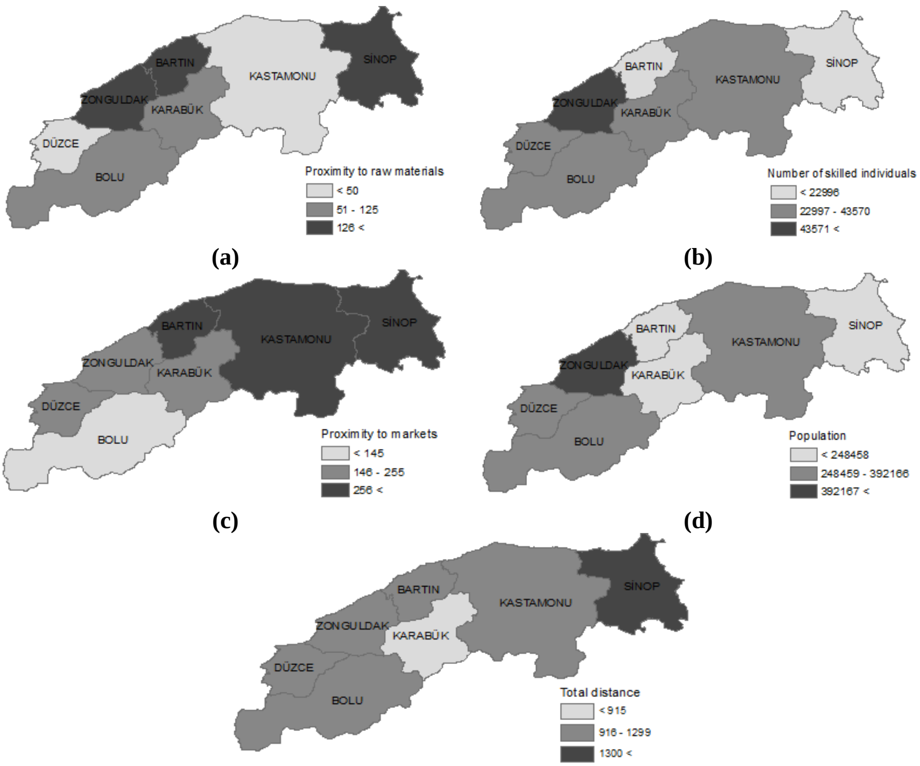


Figure 1. The study area



(a) (b) (c) (d) (e)

Figure 2. The criteria used in this study: (a) proximity to raw materials, (b) the number of qualified individuals, (c) proximity to markets, (d) population, and (e) distances to the provinces in the region

2.2. Goal Programming

GP is an important class of multicriteria decision models. The GP approach can be employed to obtain satisfying solutions for multiple and contradictory objectives [27, 28]. GP attempts to minimize deviations from goals and determines a point that satisfies these goals. The achievement function is the key element of a GP model. This function represents the mathematical expression of unwanted deviation variables [29]. The mathematical structure of a GP model is as follows [30]:

$$\text{Min Z} = \sum_{i=1}^{m} (d_i^+ + d_i^-) \quad (1)$$

$$\sum_{j=1}^{n} a_{ij}x_j - d_i^+ + d_i^- = b_i, \quad i = 1, \dots, m, \; j = 1, \dots, n \quad (2)$$

$$d_i^+, d_i^-, x_j \geq 0 \quad (3)$$

where x_j is the decision variable, a_{ij} is the coefficient of the decision variable, b_i is the aspiration level, and d_i^+ and d_i^- are positive and negative deviations, respectively.

According to Rifai [31], the key steps of the GP structure can be explained as follows: identification of goals, conversion of these goals into constraints, examination of each goal to determine correct deviation variables, and establishing a hierarchy of importance among goals. Once the above-mentioned steps are completed, the decision-making problem can be quantified as a GP model. Table 1 shows the general structure of this model [32].

Table 1. The general structure of a GP model

Goal	Acceptable situation	Deviation variable to be minimized
$a_{ij}x_j \leq b_i$	Underachievement	d_i^+
$a_{ij}x_j \geq b_i$	Overachievement	d_i^-
$a_{ij}x_j = b_i$	Exactly achievement	$d_i^+ + d_i^-$

3. APPLICATION

The GP approach attempts to minimize the total deviation of targets. This approach considers all of the targets simultaneously by establishing an achievement function that minimizes deviations from targets [33]. Therefore, this study employs a GP model to determine the most appropriate facility location for furniture production. The study area is the Western Black Sea Region of Turkey. Kastamonu, Düzce, Bolu, Zonguldak, Bartın, Karabük, and Sinop are considered as candidate locations (see Figure 1). The criteria determined to evaluate the alternative locations are proximity to raw materials, the number of qualified individuals, proximity to markets, population, and distances to the provinces in the region. The proposed approach applied to the location selection problem of the furniture industry is displayed in Figure 3.

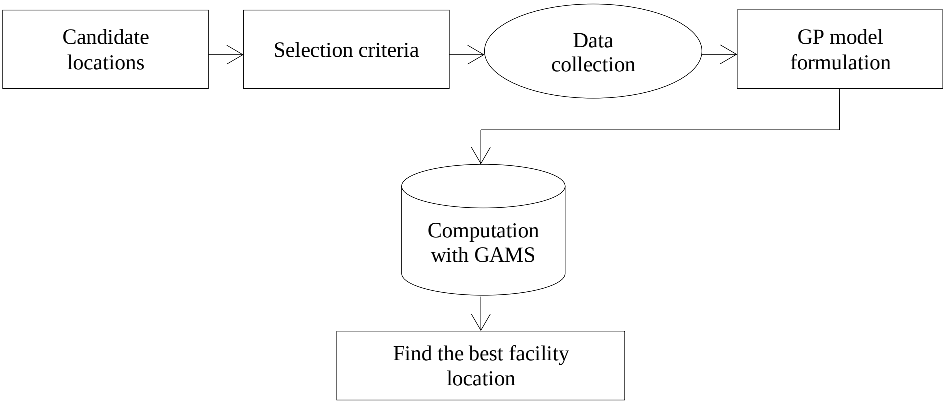


Figure 3. The procedure for location selection

Several objectives are defined to establish the mathematical model. The objectives involved in this study are as follows:

Goal 1: Minimizing the distance between the facility and the source of raw materials
Goal 2: Minimizing the distance between the facility and the market
Goal 3: Minimizing the distance of the facility to the provinces in the region
Goal 4: Minimizing the distance between the facility and the skilled-labor abundant locations
Goal 5: Minimizing the distance between the facility and the densely populated places

Once the objectives of the study are defined, the mathematical model is formulated. The mathematical formulation of the proposed GP model and the notations employed in this model are presented below.

Notations

i, j : provinces
k: goals

$$x_i = \begin{cases} 1 & \text{if there is a facility at location } i \\ 0 & \text{otherwise} \end{cases}$$

d_{ij}: Distance between facility location i and province j
r_i: The distance of facility location i to the source of raw materials
m_i: The distance of facility location i to the market
u_i: The distance of facility location i to the provinces
b_j: The number of qualified individuals in province j
h_j: The population of province j
P_k: Priority level
d_k^+: Positive deviation variable for the kth goal
d_k^-: Negative deviation variable for the kth goal

Mathematical Model

$$\text{Min } Z = \sum_{k=1}^{5} P_k d_k^+ \tag{4}$$

$$\sum_{i=1}^{7} r_i x_i + d_1^- - d_1^+ = 0 \tag{5}$$

$$\sum_{i=1}^{7} m_i x_i + d_2^- - d_2^+ = 0 \tag{6}$$

$$\sum_{i=1}^{7} u_i x_i + d_3^- - d_3^+ = 0 \tag{7}$$

$$\sum_{j=1}^{7} b_j \sum_{i=1}^{7} d_{ij} x_i + d_4^- - d_4^+ = 0 \tag{8}$$

$$\sum_{j=1}^{7} h_j \sum_{i=1}^{7} d_{ij} x_i + d_5^- - d_5^+ = 0 \quad (9)$$

$$\sum_{i=1}^{7} x_i = 1 \quad (10)$$

$$d_k^+, d_k^- \geq 0 \;\; k = 1, \dots, 5 \quad (11)$$

$$x_i \in \{0,1\} \;\; i = 1, \dots, 7 \quad (12)$$

Equation (4) is the objective function of the GP model. The aim of the GP model is to minimize the sum of the positive deviations. Constraint (5) attempts to minimize the distance between the facility and the source of raw materials. Constraint (6) tries to minimize the distance between the facility and the market. Constraint (7) ensures a low distance between the facility and the provinces in the region. Constraint (8) attempts to minimize the distance of the facility location to the skilled-labor abundant locations. Constraint (9) tries to minimize the distance between the facility and the densely populated places. Constraint (10) indicates that the facility will be located in only one location. Lastly, constraints (11) and (12) ensure the non-negativity and binary restrictions on the decision variables.

The GP model described above is used to determine the best facility location. The codes required to solve the facility location selection problem are written in GAMS. The results of the analysis are summarized in Table 2. From Table 2, it is possible to see that the solutions obtained by the GP model are $x_6 = 1$ and $x_1 = x_2 = x_3 = x_4 = x_5 = x_7 = 0$. The results indicate that Karabük is the best place for building a furniture manufacturing plant.

Table 2. The results of the GP model

Variable	Level	Marginal
x_1	0	4.7423E+8
x_2	0	4.2018E+8
x_3	0	4.0485E+8
x_4	0	3.4066E+8
x_5	0	3.9870E+8
x_6	1	3.3145E+8
x_7	0	8.5451E+8

The demand for furniture products has increased in parallel with the increase in human population. Furniture manufacturing companies should choose the most suitable location to meet their customers' expectations at minimum costs and to support their long-term competitive structures. In order to select the best location, decision-makers should apply an appropriate method. The contribution of this paper is the presentation of an effective approach for solving the location selection problem of furniture manufacturing companies. With the help of GP, decision-makers could get an alternative ranking list in solving the problem.

4. CONCLUSION

Selection of the most appropriate location for the furniture industry is an important phase in the construction process because the results of this decision can have long-term effects on various factors such as profitability, accessibility, and sustainability. Developing a location selection model is needed for decision-makers to avoid undesired negative results. In this study, a GP model is proposed to determine an appropriate location for the Turkish furniture industry. Kastamonu, Düzce, Bolu, Zonguldak, Bartın, Karabük, and Sinop are evaluated using the following criteria: proximity to raw materials, the number of qualified individuals, proximity to markets, population, and distances to the provinces in the region. The proposed model is solved via an optimization tool. Based on the results of this study, it can be said that Karabük is the most appropriate location. Consequently, the proposed GP model can present a road map for decision-makers to make a dispassionate and objective location selection. In further research, this model can be combined with different decision-making methods to have an integrated decision support system that may assist decision-makers for the evaluation of candidate locations.

REFERENCES

[1] Gordić D., Babić M., Jelić D., Konćalović D. and Vukašinović V., (2014) Integrating Energy and Environmental Management in Wood Furniture Industry, *The Scientific World Journal* 596958, 1–18.
[2] URL 1. https://www.trade.gov.tr/data/5b8fd5bf13b8761f041fee9b/Furniture.pdf
[3] Karademir D. and Koc K.H., (2020) Evaluating the Work Environment in Turkish Furniture Industry from the Point of Occupational Health and Safety, *Fresenius Environmental Bulletin* 29, 2639–2645.
[4] Ertuğrul İ. and Karakaşoğlu N., (2008) Comparison of Fuzzy AHP and Fuzzy TOPSIS Methods for Facility Location Selection, *The International Journal of Advanced Manufacturing Technology* 39, 783–795.
[5] Govindan K., Garg K., Gupta S. and Jha P.C., (2016) Effect of Product Recovery and Sustainability Enhancing Indicators on the Location Selection of Manufacturing Facility, *Ecological Indicators* 67, 517–532.
[6] Johansson M. and Olhager J., (2018) Comparing Offshoring and Backshoring: The Role of Manufacturing Site Location Factors and Their Impact on Post-Relocation Performance, *International Journal of Production Economics* 205, 37–46.
[7] Mousavi S.M., Tavakkoli-Moghaddam R., Heydar M. and Ebrahimnejad S., (2013) Multi-Criteria Decision Making for Plant Location Selection: An Integrated Delphi–AHP–PROMETHEE Methodology, *Arabian Journal for Science and Engineering* 38, 1255–1268.
[8] Safari H., Faghih A. and Fathi M.R., (2012) Fuzzy Multi-Criteria Decision Making Method for Facility Location Selection, *African Journal of Business Management* 6(1), 206–212.
[9] Cebi S. and Kahraman C., (2013) Using Multi Attribute Choquet Integral in Site Selection of Wind Energy Plants: The Case of Turkey, *Journal of Multiple-Valued Logic & Soft Computing* 20(5–6), 423–443.
[10] Ozgen D. and Gulsun B., (2014) Combining Possibilistic Linear Programming and Fuzzy AHP for Solving the Multi-Objective Capacitated Multi-Facility Location Problem, *Information Sciences* 268, 185–201.
[11] Chadawada R., Sarfaraz A., Jenab K. and Pourmohammadi H., (2015) Integration of AHP-QFD for Selecting Facility Location, *Benchmarking: An International Journal* 22(3), 411–425.
[12] Güler D., Miran B. and Saner G., (2016) Best Location for Animal Feed Manufacturing Company in Izmir Province of Turkey, *Balkan and Near Eastern Journal of Social Sciences* 2(2), 115–122.
[13] Mahmud S., Rayhan D.S.A. and Ahamed T., (2016) Facility Location Selection for Seasonal Product: A Case Study for New Business and a Comparative Study of AHP and ANP, *International Journal of Scientific & Technology Research* 5(5), 239–245.
[14] Bolturk E. and Kahraman C., (2018) Interval-Valued Intuitionistic Fuzzy CODAS Method and Its Application to Wave Energy Facility Location Selection Problem, *Journal of Intelligent & Fuzzy Systems* 35(4), 4865–4877.
[15] Kheybari S., Kazemi M. and Rezaei J., (2019) Bioethanol Facility Location Selection Using Best-Worst Method, *Applied Energy* 242, 612–623.

[16] Yücenur G.N., Çaylak Ş., Gönül G. and Postalcıoğlu M., (2020) An Integrated Solution with SWARA&COPRAS Methods in Renewable Energy Production: City Selection for Biogas Facility, *Renewable Energy* 145, 2587–2597.
[17] Seker S. and Aydin N., (2020) Hydrogen Production Facility Location Selection for Black Sea Using Entropy Based TOPSIS under IVPF Environment, *International Journal of Hydrogen Energy* 45(32), 15855–15868.
[18] Azizi M. and Modarres M., (2007) A Strategic Model for Location Selection of Wood Industry: An Application of ANP, *Journal of Applied Sciences* 7, 326–333.
[19] Imren E., Karayılmazlar S. and Kurt R., (2016) Selection of Optimal Establishment Place Using AHP (Analytical Hierarchy Process): An Application of Furniture Industry, *Journal of Bartin Faculty of Forestry* 18(2), 48–54.
[20] Azizi M. and Ramezanzadeh M., (2016) Location Selection of Agricultural-Residuals Particleboard Industry through Group Decision: The Case Study of Northern Iran, *Economics, Management and Sustainability* 1(1), 14–22.
[21] Üçüncü T., Üçüncü K., Akyüz K.C., Bayram B.Ç. and Ersen N., (2017) Location Selection in Furniture Industry by Using TOPSIS Method: A Case of the West Black Sea Region, *Journal of Advanced Technology Sciences* 6(3), 435–443.
[22] Azizi M., (2017) Strategic Model for Location Selection of Solar Wood Drying By Applying TOPSIS, *Economics, Management and Sustainability* 2(2), 15–23.
[23] Yeşilkaya M., (2018) Selection of Paper Factory Location Using Multi-Criteria Decision Making Methods, *Çukurova University Journal of the Faculty of Engineering and Architecture* 33(4), 31–44.
[24] URL 2. https://www.kgm.gov.tr/Sayfalar/KGM/SiteEng/Root/MainPageEnglish.aspx
[25] URL 3. http://www.turkstat.gov.tr/Start.do
[26] URL 4. https://www.google.com.tr/maps
[27] Gür Ş. and Eren T., (2018) Scheduling and Planning in Service Systems with Goal Programming: Literature Review, *Mathematics* 6(11), 265.
[28] Ruben C., Dhulipala S.C., Bretas A.S., Guan Y. and Bretas N.G., (2020) Multi-Objective MILP Model for PMU Allocation Considering Enhanced Gross Error Detection: A Weighted Goal Programming Framework, *Electric Power Systems Research* 182, 106235.
[29] Diaz-Balteiro L., González-Pachón J. and Romero C., (2013) Goal Programming in Forest Management: Customising Models for the Decision-Maker's Preferences, *Scandinavian Journal of Forest Research* 28(2), 166–173.
[30] Özcan E.C., Ünlüsoy S. and Eren T., (2017) A Combined Goal Programming – AHP Approach Supported with TOPSIS for Maintenance Strategy Selection in Hydroelectric Power Plants, *Renewable and Sustainable Energy Reviews* 78, 1410–1423.
[31] Rifai A.K., (1996) A Note on the Structure of the Goal-Programming Model: Assessment and Evaluation, *International Journal of Operations & Production Management* 16(1), 40–49.
[32] Karagül B.Z., (2018) Financial and Technical Analysis of Insurance Sector with Goal Programming Model, *Sigma Journal of Engineering and Natural Sciences* 36(2), 553–561.
[33] Choudhary D. and Shankar R., (2014) A Goal Programming Model for Joint Decision Making of Inventory Lot-Size, Supplier Selection and Carrier Selection, *Computers & Industrial Engineering* 71, 1–9.