Yönetim Bilimleri Dergisi / Journal of Administrative Sciences
Cilt / Volume: 14, Sayı / N: 28, ss. / pp.: 223-249, 2016

Solving Facility Location Problem for a Plastic Goods Manufacturing Company in Turkey Using AHP and TOPSIS Methods

M. Murat YAŞLIOĞLU* & Emrah ÖNDER**

Abstract

Facility location selection is one of the biggest and most enduring problems that managers face both when companies are being initially set up and undergoing an expansion for various reasons. Since there are many criteria to evaluate for a location the decision making process gets more complicated with every new criterion. Location selection, among all decisions, is one of the most delicate because of its costly and long term effecting nature. Once selected, it is harder than any strategic decision to return from. There have been many debates and try outs to figure out the best practice to choose the right decision making process and tool with along. Our research aims to contribute to the literature with a real life example of facility location selection. The problem and solutions stated herein are actually used and will be concluded with a concrete application, and therefore will help both practitioners and researchers to observe a factual example.

One of the biggest plastics goods producers in Turkey has to decide a location among several options, and asked us (the researchers) to evaluate and find the best alternative for their new plant. There were four different possible locations to evaluate and limited time to come up with a logical option. Given that, criteria for possible evaluation were extracted from the literature and discussed with certain professionals. After the criteria determination, all criteria were enlisted in order to be ranked and compared using AHP method. Throughout the research paper all the steps are explained and shown. The most convenient option was weighted using TOPSIS and presented to the top managers of the company. Consequently the selection is made and the plant has started to be built.

Keywords: *facility location, location selection, multi criteria decision making, AHP, TOPSIS*

* School of Business, Department of Management and Organization, Istanbul University, Istanbul, Turkey

** School of Business, Department of Quantitative Methods, Istanbul University, Istanbul, Turkey

INTRODUCTION

The selection of facility location plays a very important role in minimizing cost and maximizing the use of resources for many companies. In a narrow perspective facility location is where companies carry on their production. In a broader definition; facility location is the most suitable location where companies can perform their logistics, production, procurement functions, keep their inventories and sustain their economic objectives[1]. Facility location selection is an integral part of organizational strategies. The decision involves organizations seeking to locate, relocate or expand their operations. The decision process encompasses the identification, analysis and evaluation of, and selection among alternatives. Therefore, facility location problem commonly starts with the recognition of a need for additional capacity or change[2]. Facility location is one of the popular research topics in decision-making activities. These problems have received much attention over the years and numerous approaches, both qualitative and quantitative, have been suggested. Facility location has a well-developed theoretical background[3]. Generally, research in this area has been focused on optimizing methodology of facility location selection[4].

Therefore, in this context, it is crucial for the companies to find the most suitable facility location for their own purposes, politics, objectives, plans and strategies. A poorly selected location can cause an increase in production and logistics costs as well as difficulties in finding or reaching key resources such as raw material, human resources, other recourses used for processes, governments support, and infrastructure e.g. Perhaps more importantly this mis-choice is not easy to turn back from. Thus, it is utterly crucial for the companies to pay necessary diligence[5]. Since facility loca-

1 Ko, Jesuk. "Solving a distribution facility location problem using an analytic hierarchy process approach." ISAHP Proceedings Honolulu Hawaii, 2005, pp. 1991-1996Rao R. V.ada, 7-10 October 2007.Rao R. V.ada, 7-10 October 2007.

2 Rao, R. V. "Facility Location Selection. Decision Making in the Manufacturing Environment: Using Graph Theory and Fuzzy Multiple Attribute Decision Making Methods", 2007, pp. 305-314.

3 Baumol, W. J., and Wolfe, P. "A warehouse-location problem.Operations Research", 6(2), 1958, pp. 252-263.; Brandeau, M. L., and Chiu, S. S. "An overview of representative problems in location research." Management science, 35(6), 1989, pp. 645-674.

4 Brown, P. A., and Gibson, D. F. "A quantified model for facility site selection-application to a multiplant location problem." AIIE transactions, 4(1), 1972, pp. 1-10.; Erlenkotter, D. Comment on 'Optimal timing, sequencing, and sizing of multiple reservoir surface water supply facilities' by L. Becker and W. W-G. Yeh. Water Resources Research, 11(2), (1975). pp. 380-381.; Rosenthal, R. E., White, J. A., and Young, D. Stochastic dynamic location analysis. Management Science, 24(6), (1978). pp. 645-653.

5 Drezner, Z. (Ed.). "Facility location: a survey of applications and methods." (1995 Springer.); Francis, R. L., McGinnis, L. F., and White, J. A. "Facility layout and location: an analytical approach." (Pearson College Division, 1992); Drezner, Z., and Wesolowsky, G.

tion selection is a long term decision and very hard and costly to go back as aforementioned, it is also important for the development of the companies' objectives and targets. Many of the variable costs such as rentals, logistics, and transportation are fixed to a certain level by facility location selection[6]. Besides the costs of these factors, a poor facility location also can result in difficulty of accessibility to raw materials, market, and workforce. Lack of the ability to reach these critical resources will eventually cause a gap in the competition ability of the companies[7]. While optimum facility location gives the companies the opportunity to carry out their economic purposes and mission effectively, it also supports increase in efficiency and productivity, even strategical advantages in the long term. Therefore, company managers often tend to choose the best location for their facilities, and while doing so they also evaluate many subjective factors such as opportunity to grow, long term revaluation, prestige e.g., as well as they do evaluate more objective factors such as various operational costs[8].

Location selection not only is important for the costs and profits or resource accessibility but also has a strategic role in companies' competitive positioning. For example, a company in which JIT (just in time) is used for production, it is very important to have raw materials or intermediate products on precise time and quality. A company in such situation if manages to locate its facility close to the key suppliers, will have a key strategic advantage in return[9].

Optimum location selection should and will result in five distinct but interrelated factors; productivity, economy, profitability, effectiveness and a mixture of these optimality. Productivity is about the increase in output with the same amount of input compared to preceding period. Economy is related mostly to the costs of the production and fixed costs, suggests the costs to be at the minimum as they can be. Profitability implies the productivity of the capital used, and mostly increase in the capital with income deducted from costs and taxes. Effectiveness is the ability and the

O. "Network design: selection and design of links and facility location." Transportation Research Part A: Policy and Practice, 37(3), 2003, pp. 241-256.

6 Hamacher, H. W., and Drezner, Z. "Facility location: applications and theory." (Springer Science and Business Media, 2002).

7 Ertuğrul, İ., and Karakaşoğlu, N. "Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection." The International Journal of Advanced Manufacturing Technology, 39(7-8), 2008, pp. 783-795.

8 Kostas N.DERViTSiOTiS; "Operations Management", (2005 McGraw-Hill Book Co,New York), p.382

9 Yang, J., and Lee, H. "An AHP decision model for facility location selection. Facilities", 15(9/10), 1997, pp. 241-254.

high success rate of the company to reach predetermined goals. And finally optimality is the most satisfying mixture of efficiency, economy, profitability and effectiveness; therefore any decision meeting above criteria is expected to be the optimum decision[10].

Various research has focussed on the usage of our methodology in facility selection however most of these research has solely been on theoretical basis and had never been put into real life application. This research, in this aspect, is one of a kind where its results were put into action. Facility selection was not only evaluated by its possible application but also was done after the methodological evaluation and eventually results of this real life example. With this end result, it is proved that an academic decision support methodology has a crucial real life use.

LITERATURE REVIEW

Optimum location selection is an issue which many academicians and practitioners has studied on. There are several steps that should be completed in order to choose the optimum location[11]. These steps are; firstly, determination and prioritization of the requirements and therefore criteria for the location selection. Secondly; ranking of the determined criteria considering probable effects on short and long term according to their level of importance. And thirdly making the selection depending on the weighted criteria. However, even these steps are acknowledged by almost all, the method selection has become a long debate and had been practiced in various ways through time. Also methods evolved with the evolving technology and computerized techniques.

There are many factors that affect facility location selection as also mentioned in the literature. The reason there are so many factors evaluated is because there is no one set of solution for different types and combinations of companies, markets, resources needed and time[12]. No manager can evaluate every factor and come up with the ultimate solution, because as the number of factors increase also does the complexity of the problem.

10 Tekin M., "Üretim Yönetimi", Cilt 1, (2005 Nadir Kitap), pp. 48-49.

11 Wang, H., Xie, M., and Goh, T. N. "A comparative study of the prioritization matrix method and the analytic hierarchy process technique in quality function deployment." Total Quality Management, 9(6), 1998, pp. 421-430.

12 Adam E., Ebert R. Production and Operation Management,Concepts,Models and Behaviour, 2nd Edition, (1982 Prentice-Hall), p.201; Ertuğrul, İ., and Karakaşoğlu, N. "Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection." The International Journal of Advanced Manufacturing Technology, 39(7-8), 2008, pp. 783-795.

The suitability of the facility location therefore is dependent on the factors that are determined during the first evaluation step. Some common factors/criteria for location selection are; cost of the land, rents, energy costs, transportation, proximity to raw materials and other production resources, infrastructure, costs of resources, workforce proximity and cost, proximity to white collar personnel and/or technicians, proximity to the market or customers, government policies, initiatives and incentives, tax rates, close industries, water, electricity, surrounding facilities, environmental limits or opportunities e.g[13]. Since the facility location selection consists of many criteria among which may be interrelated or otherwise conflict each other, the solution to this complicated problem requires a delicate decision process. During the optimum decision process, managers have to think and evaluate many criteria at the same time; therefore to overcome this issue many different techniques are suggested and practiced over time. Some of these techniques include mathematical techniques, intuitive techniques, financial techniques, simulations and some contemporary techniques based on hierarchy such as Analytical Hierarchical Processing (AHP), TOPSIS, Fuzzy Logic and Fuzzy TOPSIS, Fuzzy AHP, Analytical Network Processing (ANP)[14].

Baumol and Wolfe have solved the location problem with nonlinear programming[15]. Others have utilized stochastic functions[16]. Other techniques that have been adopted are dynamic programming[17], multivariate

13 R. V. RAO, "Decision Making in the Manufacturing Environment, Facility Location Selection", (SpringerLink, 2007), 305; Farahani, R. Z., SteadieSeifi, M., and Asgari, N. "Multiple criteria facility location problems: A survey. Applied Mathematical Modelling", 34(7), 2010, pp. 1689-1709.; Current, J., Min, H., and Schilling, D. "Multiobjective analysis of facility location decisions." European Journal of Operational Research, 49(3), 1990, pp. 295-307.; Hamacher, H. W., and Drezner, Z. "Facility location: applications and theory." (Springer Science and Business Media, 2002).

14 MacCarthy, B. L., and Atthirawong, W. "Factors affecting location decisions in international operations-a Delphi study." International Journal of Operations and Production Management, 23(7), 2003, 794-818.; Eleren, A. "Kuruluş yeri seçiminin analitik hiyerarşi süreci yöntemi ile belirlenmesi; deri sektörü örneği." Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 20(2), pp. 2006.

15 Baumol, W. J., and Wolfe, P. "A warehouse-location problem." Operations Research, 6(2), 1958, pp. 252-263.

16 Wesolowsky, G. O. Probabilistic weights in the one-dimensional facility location problem. Management Science, 24(2), 1977, pp. 224-229.

17 Geoffrion, A., and Bride, R. M. "Lagrangean relaxation applied to capacitated facility location problems". AIIE transactions, 10(1), 1978, pp. 40-47.; Saaty, T. L. "The analytic network process: decision making with dependence and feedback; the organization and prioritization of complexity." (Rws publications,1996.); Erkut, E., and Neuman, S. "Analytical models for locating undesirable facilities." European Journal of Operational Research, 40(3), 1989, pp. 275-291.; Campbell, James F. "Integer programming formulations of discrete hub location problems." European Journal of Operational Research 72(2), 1994, pp. 387-405.

statistics with multidimensional scaling[18] and heuristic and search procedures[19]. Some uses of the contemporary techniques include: Ballı and Korukoğlu, Liang and Wang's studies, employ using both multi criteria decision techniques with fuzzy cloud computing[20]. Chen's work which seeks optimum solution for distribution center using decision maker's lingual expressions is also another example of the mixed technique aforementioned[21]. Kaboli et.al and Tabari at.al uses the AHP together with fuzzy cloud computing to select the facility location[22]. Çebi and Otay, Yong, Önüt and Soner, Ugo, Asadzadeh et.al. constitute solution to location selection problems using fuzzy TOPSIS[23]. Uysal and Yavuz, Gundogdu, Marbini et.al. adopted ELECTRE method to find optimum location for facility[24]. Athawale and Chakraborty used PROMETHEE II method for the selection

18 Bowen, W. M. "A Thurstonian comparison of the analytic hierarchy process and probabilistic multidimensional scaling through application to the nuclear waste site selection decision." Socio-Economic Planning Sciences, 29(2), 1995, pp. 151-163.

19 Kuehn, A. A., and Hamburger, M. J. "A heuristic program for locating warehouses." Management science, 9(4), 1963, pp. 643-666.

20 Ballı, S., & Korukoğlu, S., Development of a fuzzy decision support framework for complex multi-attribute decision problems: A case study for the selection of skilful basketball players. Expert Systems, 31(1), 2014, 56-69.; Liang, G. S., and Wang, M. J. J. "A fuzzy multi-criteria decision-making method for facility site selection." The International Journal of Production Research, 29(11), 1991, pp. 2313-2330.

21 Chen, C. T. A fuzzy approach to select the location of the distribution center. Fuzzy sets and systems, 118(1), 2001, pp. 65-73.

22 Kaboli, A., Aryanezhad, M., Shahanaghi, K., and Niroomand, I. "A New Method for Plant Location Selection Problem: A Fuzzy-AHP Approach", Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, Montréal, Canada, 7-10 October 2007, pp.582-586.; Tabari, M., Kaboli, A., Aryanezhad, M., Shahanaghi, K., and Siadat, A. "A New Method for Location Selection: A Hybrid Analysis", Applied Mathematics and Computation, 206 (2), 2008, pp. 598-606.

23 Çebi, F., & Otay, İ., Multi-criteria and multi-stage facility location selection under interval type-2 fuzzy environment: a case study for a cement factory. International Journal of Computational Intelligence Systems, 8(2), 2015, 330-344.; Yong, D. "Plant location selection based on fuzzy TOPSIS." The International Journal of Advanced Manufacturing Technology, 28(7-8), 2006, pp. 839-844.; Önüt, S., and Soner, S. "Transshipment site selection using the AHP and TOPSIS approaches under fuzzy environment." Waste Management, 28(9), 2008, pp. 1552-1559.; Destiny Ugo, P. A "Multi-Criteria Decision Making for Location Selection in the Niger Delta Using Fuzzy TOPSIS Approach." International Journal of Management and Business Research, 5(3), 2015, pp. 215-224.; Asadzadeh, A., Sikder, S. K., Mahmoudi, F., and Kötter, T. "Assessing Site Selection of New Towns Using TOPSIS Method under Entropy Logic: A Case study: New Towns of Tehran Metropolitan Region" (TMR). Environmental Management and Sustainable Development, 3(1), 2014, pp. 123-137.

24 UYSAL, H. T., and Yavuz, K. "Selection of Logistics Centre Location via ELECTRE Method: A Case Study in Turkey." International Journal of Business and Social Science, 5(9), 2014, pp. 1-2; Gundogdu, C.E., "Selection of facility location under environmental damage priority and using ELECTRE method." Journal of Environmental Biology, 32(2), 2011, pp. 221-226.; Hatami-Marbini, A., Tavana, M., Moradi, M., and Kangi, F. "A fuzzy group Electre method for safety and health assessment in hazardous waste recycling facilities." Safety science, 51(1), 2013, pp. 414-426.

process[25]. Dağ and Önder[26], El-Santawy, Güzel and Erdal, Tavakkoli and Mousavi puts forward some examples of using VIKOR technique for facility location selection[27]. Önder and Yıldırım proposed a logistic village ranking model considering both Analytic Hierarchy Process (AHP) and VIKOR methods[28]. Yıldırım and Önder proposed a freight village analysis model considering both AHP and PROMETHEE method[29]. AHP by itself is a very common multi-criteria decision making technique used by many researchers to determine the location of new facility[30]. Some researches and research topics in which AHP is used for location selection is given in the Table 1. There have been found no mere solution for the criteria set or subset because every sector requires its own specific need for their facilities.

25 Athawale, V. M., and Chakraborty, S. "Facility location selection using PROMETHEE II method." Proceedings of the 2010 international conference on industrial engineering and operations management, (2010, January), pp. 9-10.

26 Dağ, S., and Önder, E. "Decision-Making for Facility Location Using Vikor Method." Journal of International Scientific Publications: Economy and Business, 7, 2013, pp. 308-330

27 El-Santawy, M. F., Ahmed, A. N., and Metwaly, M. A. E. B. "Ranking Facility Locations Using VIKOR." Computing and Information Systems, 16(2), 2012, pp. 201-222; Güzel, D., and Erdal, H. "A Comparative Assesment of Facility Location Problem via fuzzy TOPSIS and fuzzy VIKOR: A Case Study on Security Services." International Journal of Business and Social Research, 5(5), 2015, pp. 49-61.; Tavakkoli-Moghaddam, R., Heydar, M., and Mousavi, S. M. "An integrated AHP-VIKOR methodology for plant location selection." International Journal of Engineering-Transactions B: Applications, 24(2), 2011, p. 127.

28 Önder E., Yıldırım B.F., "Vikor Method For Ranking Logistic Villages In Turkey", Journal of Management and Economic Research, vol.23, 2014, pp. 293-314.

29 Yıldırım B.F., Önder E., "Evaluating Potential Freight Villages In Istanbul Using Multi Criteria Decision Making Techniques", Journal of Logistics Management, vol.3, no.1, 2014, pp. 1-10.

30 Yang, J., and Lee, H. "An AHP decision model for facility location selection." Facilities, 15(9/10), 1997, pp. 241-254.; Tzeng, G. H., Teng, M. H., Chen, J. J., and Opricovic, S. "Multicriteria selection for a restaurant location in Taipei." International Journal of Hospitality Management, 21(2), 2002, pp. 171-187.; Burdurlu, E., and Ejder, E. "Location choice for furniture industry firms by using Analytic Hierarchy Process (AHP) method." Gazi University Journal of Science, 16(2), 2003, pp. 369-373.; Badri, M. A. "Combining the analytic hierarchy process and goal programming for global facility location-allocation problem." International Journal of Production Economics, 62(3), 1999, pp. 237-248.; Wu, C. R., Lin, C. T., and Chen, H. C. "Optimal selection of location for Taiwanese hospitals to ensure a competitive advantage by using the analytic hierarchy process and sensitivity analysis." Building and Environment, 42(3), 2007, pp. 1431-1444.; Dağdeviren, M., Yavuz, S., and Kılınç, N. "Weapon selection using the AHP and TOPSIS methods under fuzzy environment." Expert Systems with Applications, 36(4), 2009, pp. 8143-8151.

***Table 1[31]:** Some researches using AHP for location selection*

Industries	Authors and References
Manufacturing	Yurimoto and Masui (1995)[31], Melachrinoudis and Min (1999)[32], Bitici et al. (2001)[33], Tahriri et al. (2008)[34], Verma and Paeteriya (2013)[35], Amiri (2010)[36], Ballı, S., & Korukoğlu, S. (2009).[37]
Marketing	Yang and Lee (1997)[38], Erbıyık et al. (2012)[39], Ngai (2003)[40]
Logistics	Alberto (2000)[41], Buyukozan et al. (2008)[42], Şener et.al. (2011)[43], Temur, G. T., Kaya, T., & Kahraman, C. (2014)[44].
Engineering	Ramanathan and Ganesh (1995)[45], Partovi (2006)[46], Chan and Kumar (2007)[47], Yu and Tsai (2008)[48]

31 **Adapted from**: Koç, E., and Burhan, H. A. "An Application of Analytic Hierarchy Process (AHP) in a Real World Problem of Store Location Selection." Advances in Management and Applied Economics, 5(1), 2015, p41.

31 Yurimoto, S., and Masui, T. "Design of a decision support system for overseas plant location in the EC." International Journal of Production Economics, 41(1), 1995, pp. 411-418.

32 Melachrinoudis, E., and Min, H. "The dynamic relocation and phase-out of a hybrid, two-echelon plant/warehousing facility: A multiple objective approach." European Journal of Operational Research, 123(1), 2000, pp. 1-15.

33 Bititci, U. S., Suwignjo, P., and Carrie, A. S. "Strategy management through quantitative modelling of performance measurement systems." International Journal of production economics, 69(1), 2001, pp. 15-22.

34 Tahriri, F., Osman, M. R., Ali, A., Yusuff, R. M., and Esfandiary, A. "AHP approach for supplier evaluation and selection in a steel manufacturing company." Journal of Industrial Engineering and Management, 1(2), 2008, pp. 54-76.

35 Verma, D. S., and Pateriya, A. "Supplier selection through analytical hierarchy process: A case study in small scale manufacturing organization." International Journal of Engineering Trends and Technology, 4(5), 2013, pp. 1428-1433.

36 Amiri, M. P. "Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods." Expert Systems with Applications, 37(9), 2010, pp. 6218-6224.

37 Ballı, S., & Korukoğlu, S. Operating system selection using fuzzy AHP and TOPSIS methods. Mathematical and Computational Applications, 14(2), 2009, 119-130.

38 Yang, J., and Lee, H. "An AHP decision model for facility location selection." Facilities, 15(9/10), 1997, pp. 241-254.

39 H. Erbıyık, S. Özcan and K. Karaboğa, "Retail store location selection problem with multiple analytical hierarchy process of decision making an application in Turkey", 8th International Strategic Management Conference, Procedia - Social and Behavioral Sciences, 58, 2012, pp. 1405-1414

40 Ngai, E. W. T. "Selection of web sites for online advertising using the AHP." Information and Management, 40(4), 2003, pp. 233-242.

41 Alberto, P. "The logistics of industrial location decisions: An application of the analytic hierarchy process methodology." International Journal of Logistics, 3(3), 2000, pp. 273-289.

42 Büyüközkan, G., Feyzioğlu, O., and Nebol, E. "Selection of the strategic alliance partner in logistics value chain." International Journal of Production Economics, 113(1), 2008, pp. 148-158.

43 Şener, Ş., Sener, E., and Karagüzel, R. "Solid waste disposal site selection with GIS and AHP methodology: a case study in Senirkent–Uluborlu (Isparta) Basin, Turkey." Environmental monitoring and assessment, 173(1-4), 2011, pp. 533-554.

44 Temur, G. T., Kaya, T., & Kahraman, C. (2014). Facility location selection in reverse logistics using a type-2 fuzzy decision aid method. In Supply Chain Management Under Fuzziness (pp. 591-606). Springer Berlin Heidelberg.

45 Ramanathan, R., and Ganesh, L. S. "Using AHP for resource allocation problems." European Journal of Operational Research, 80(2), 1995, pp. 410-417.

46 Partovi, F. Y., and Corredoira, R. A. "Quality function deployment for the good of soccer." European journal of operational research, 137(3), 2002, pp. 642-656.

47 Chan, F. T., and Kumar, N. "Global supplier development considering risk factors using fuzzy extended AHP-based approach." Omega, 35(4), 2007, pp. 417-431.

48 Yu, J. R., and Tsai, C. C. "A decision framework for supplier rating and purchase allocation: A case in the semiconductor industry." Computers and Industrial Engineering, 55(3), 2008, pp. 634-646.

Commercial Tools	Cebi and Zeren (2008)[49], Schoenherr et al. (2008)[50]
Services (Hospital, Hotel, Observation Centre, Landfill)	Vahidnia et.al. (2009)[51], Chou et.al. (2008)[52], Aras et.al. (2004)[53], Wang et.al. (2009)[54]

323334353637

FACILITY LOCATION PROBLEM AND SELECTED CRITERIA

Our research focuses on the selection of the facility location for a leading plastics company which produces a broad range (670 different) of plastic products including household, baby, garden, cleaning, and pool products. Irak Plastik is the biggest plastics company in Turkey and has both national and international customers, exports to about 90 different countries all around the world[55]. The company operates with its 3 different plants and has recently decided to move its Istanbul plant to another location in 2016-2017 because of its relatively high operating costs. The top managers have determined 4 different location options for the new plant and requested from us to evaluate and create a decision model based on co-decided criteria. In this respect top management and the researchers have determined several criteria, which are summarized in Table 2, consistent with the needs for the production and operations also with compliance to the academic theory for location selection.

After the evaluation of the theory and several discussions on the subject, the criteria for factor weighting had been prepared. To calculate the factor weights and thus to determine the location for the new plant AHP technique was adopted. The Analytic Hierarchy Process is a procedure

49 Cebi, F., and Zeren, Z. "A decision support model for location selection: Bank branch case." Management of Engineering and Technology, 2008. PICMET 2008. Portland International Conference (2008, July). pp. 1069-1074.

50 Schoenherr, T., Tummala, V. R., and Harrison, T. P. "Assessing supply chain risks with the analytic hierarchy process: Providing decision support for the offshoring decision by a US manufacturing company." Journal of Purchasing and Supply Management, 14(2), 2008, pp. 100-111.

51 Vahidnia, M. H., Alesheikh, A. A., and Alimohammadi, A. "Hospital site selection using fuzzy AHP and its derivatives." Journal of environmental management, 90(10), 2009, pp. 3048-3056.

52 Chou, T. Y., Hsu, C. L., and Chen, M. C. "A fuzzy multi-criteria decision model for international tourist hotels location selection." International journal of hospitality management, 27(2), 2008, pp. 293-301.

53 Aras, H., Erdoğmuş, Ş., and Koç, E. "Multi-criteria selection for a wind observation station location using analytic hierarchy process." Renewable Energy, 29(8), 2004, pp. 1383-1392.

54 Wang, G., Qin, L., Li, G., and Chen, L. "Landfill site selection using spatial information technologies and AHP: a case study in Beijing, China." Journal of environmental management, 90(8), 2009, pp. 2414-2421.

55 http://www.irakplast.com/

designed to quantify managerial judgments of the relative importance of each of several conflicting criteria used in the decision making process[56].

Table 2: *Hierarchical Structure of Facility Location*

Aim	Criteria	Code	Sub Criteria
SELECTION OF FACILITY LOCATION	A_Physical Facilities	A1	Proximity to urban areas
		A2	Availability of industrial drainage system
		A3	Proximity to public transport
		A4	Opportunities for possible site expansion
		A5	Availability of parking
		A6	Availability of medical care
		A7	Proximity to fire response equipment
	B_Infrastructure for Production	B1	Proximity to energy sources
		B2	Proximity to water sources
		B3	Proximity to fuel sources/stations
		B4	Proximity to natural gas resources
		B5	Potential for hazardous material handling
		B6	Proximity to raw material supplies/sources
	C_Logistic Facilities	C1	Density of traffic around the facility
		C2	Proximity to third party warehouses/depots
		C3	Proximity to highway system
		C4	Proximity to railroad system
		C5	Proximity to harbours
		C6	Proximity to airports
		C7	Ease of material storage
	D_Cost	D1	Total transportation costs
		D2	Raw material costs
		D3	Total site cost (rent, utilities etc.)
		D4	Initial investment cost
		D5	Cost of maintenance
	E_Strategic Facilities	E1	Environmental regulations
		E2	Proximity to customers
		E3	Proximity to suppliers
		E4	Proximity to free trade zones
		E5	Proximity to the target market
		E6	Proximity to competitors
	F_Proximity to Production Factors	F1	Proximity to existing site development
		F2	Opportunity for governmental investment subsidy
		F3	Proximity to subsidiary industry
		F4	Proximity to minor producers
		F5	Proximity to organised industry
		F6	Proximity to unskilled labor
		F7	Proximity to skilled labor

56 Bhutia, P. W., and Phipon, R. "Appication of ahp and topsis method for supplier selection problem." IOSR Journal of Engineering (IOSRJEN), (2), 2012, pp. 43-50.

PROPOSED METHODOLOGY

In this study Analytic Hierarchy Process and TOPSIS methodologies are used for ranking facility location problem for a plastic goods manufacturing company in Turkey. The weights of the criteria are calculated in the first part of the methodology by using AHP. Because AHP is very successful tool for converting qualitative judgments into quantitative ones. Literature review, experts' opinions and previous studies give the direction of criteria list of facility location problem. Criteria weights (the output of AHP) are used as input of TOPSIS for the ranking of facility locations. General manager, marketing manager, sales manager, logistics manager, export manager, finance manager and production manager expressed importance levels of criteria using pairwise comparison survey which was prepared in Excel. The surveys were done between the dates 10-20 November 2015 by experts in their offices.

Analytical Hierarchy Process

AHP is one of the well-known multi-criteria decision making (MCDM) technique developed by Thomas Saaty. AHP methodology has following steps: [57] [58] [59] [60] [39] [40] [41] [42]

Step 1. Identify the problem and define the criteria.

Step 2. Construct the hierarchy of the decision problem based on the aim of the decision.

Step 3. Structure comparison matrix by using experts' judgments

Step 4. Find local or global weights and priorities

Step 5. Calculate consistency index (CI) and consistency ratio (CR)

Step 6. Check if CR value is less than 0.10 (comparisons is appropriate) or not.

57 Saaty, T.L., "How To Make Decision: The Analytic Hierarchy Process," European Journal of Operational Research, North Holland, 48, 1990, pp. 9-26.

58 Saaty, T. L., "Decision Making With The Analytic Hierarchy Process." Int. J. Services Sciences, 1 (1), 2008, pp. 83.

59 Saaty, T. L., Vargas Luis L., "Models, Methods, Conceptsand Applications of The Analytic Hierarchy Process." International Series in Operations Research and Management Science, (Kluwer Academic Publishers, 2001).

60 Lee, S., Kim, W., Kim, Y.M., Oh, K.J., "Using AHP to determine intangible priority factors for technology transfer adoption." Expert Systems with Applications, 39, 2012, pp. 6388-6395.

The formulas and details of these steps above can be found in Dağ and Önder's paper[61] and Önder, Taş and Hepşen's paper[62].

Using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to rank the alternatives

TOPSIS technique was developed by Yoon (1980)[63] and Hwang and Yoon (1981)[64], for solving MCDM problems and for ranking alternatives based on closeness to the ideal solution. TOPSIS technique does not need pairwise comparisons. The steps of TOPSIS technique are as follows[65]:

Step 1. Define a decision matrix for the ranking.

Step 2. Normalize the decision matrix

Step 3. Calculate the weighted normalized decision matrix

Step 4. Determine the positive ideal solution (PIS) and negative ideal solution (NIS)

Step 5. Identify the distances (Euclidean) of each alternative from the PIS and NIS

Step 6 Calculate the relative closeness of the i^{th} alternative to ideal solution

Step 7. Rank of alternatives by using RC_i values in descending order (Higher is better).

The formulas and details of TOPSIS steps above can be found in Önder, Taş and Hepşen's paper[66].

61 Dağ, S., and Önder, E. "Decision-Making for Facility Location Using Vikor Method." Journal of International Scientific Publications: Economy and Business, 7, 2013, pp. 308-330

62 Önder E., Taş N., Hepşen A., "Performance Evaluation Of Turkish Banks Using Analytical Hierarchy Process And Topsis Methods", Journal of International Scientific Publications: Economy & Business, vol.7, pp.470-503, 2013

63 Yoon, K. "Systems selection by multiple attributes decision making" (PhD Dissertation, 1980)., Kansas State University, Manhattan, Kansas

64 Hwang, C.L., and Yoon, K. "Multiple attribute decision making: Method and application." (New York: Spring-verlag, 1981).

65 Tsaur, R.C., 2011. "Decision risk analysis for an interval TOPSIS method." Applied Mathematics and Computation 218, 2011, pp. 4295–4304

48 Önder E., Taş N., Hepşen A., "Performance Evaluation Of Turkish Banks Using Analytical Hierarchy Process And Topsis Methods", Journal of International Scientific Publications: Economy & Business, vol.7, pp.470-503, 2013

FACILITY LOCATION SELECTION PROBLEM (CASE PROBLEM)

In our facility location selection problem there are 6 criteria, 38 sub-criteria and 4 candidate location namely Balıkesir Bandırma Organized Industrial Zone, Bilecik Bozüyük, Bilecik Osmaneli and Sakarya Karasu. Interviews for filling pairwise comparison surveys were done with the general manager, marketing manager, sales manager, logistics manager, export manager, finance manager and production manager in order to determine criteria weights. All criteria in the selection of facility location are determined by literature review and experts in this Plastic Goods Manufacturing Company. 6 criteria with 38 important sub-criteria to be used for facility location selection are identified. These 6 main criteria are as follows: "Physical Facilities" (A), "Infrastructure for Production" (B), "Logistic Facilities" (C), "Cost" (D), "Strategic Facilities" (E) and "Proximity to Production Factors" (F). Decision hierarchy is shown in Table 2. The aim of the decision (the selection of the optimal facility location), the criteria, sub-criteria and alternatives structure the four levels in the decision hierarchy.

Figure 1. *Location alternatives of the problem*

(Source: https://maps.google.com)

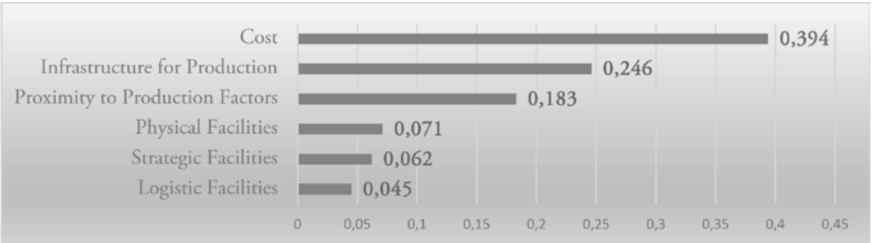
After identifying the hierarchy of problem, the weights of the criteria are calculated by using AHP method. In this step, the experts formed individual pairwise comparison matrix by using the Saaty's 1-9 scale.

Table 5. *The pairwise comparison matrix for main criteria*

Code	A	B	C	D	E	F
A	1.00	0.52	1.08	0.28	0.45	0.31
B	1.92	1.00	6.53	0.89	6.30	1.32
C	0.92	0.15	1.00	0.11	1.00	0.19
D	3.60	1.13	8.70	1.00	8.40	5.57
E	2.20	0.16	1.00	0.12	1.00	0.19
F	3.21	0.76	5.18	0.18	5.28	1.00

Geometric means of experts' judgments' values are calculated to structure the pairwise comparison matrix for group decision making (Table 5). The main criteria weights calculated by using the pairwise comparison matrix (Table 5), are shown in Figure 2.

Figure 2. *Main criteria weights (The output of AHP)*



The main criteria weight and AHP parameters are presented in Table 6.

Table 6. *Results of main criteria obtained by AHP*

Criteria	Weights	λ_{max}, CI, RI	CR
Physical Facilities	0.07135		
Infrastructure for Production	0.24594	λ_{max} = 6.60	
Logistic Facilities	0.04452	CI =0.12	CR = 0.097
Cost	0.39401	RI = 1.24	
Strategic Facilities	0.06156		
Proximity to Production Factors	0.18261		

"Cost" (0.39401), "Infrastructure for Production" (0.24594) and "Proximity to Production Factors" (0.18261) are determined as the three most important main criteria in the facility location selection process by using AHP. "Physical Facilities" (0.07135), "Strategic Facilities" (0.06156) and "Logistic Facilities" (0.04452) are determined as the three least important criteria in the facility location selection process by using AHP. Consistency ratios of the experts' pairwise comparison matrixes are calculated as 0.097 and is less than 0.1. So the weights are shown to be consistent and they are used in the selection process. The most important criterion is "Cost" (0.39401) and the least important criterion is "Logistic Facilities" (0.04452). Table 7 shows the global weights obtained by AHP.

Importance level of some criteria relatively less than others such as "Density of traffic around the facility" (0.00094), but these criteria can also be included the calculations and evaluations although their effects are small.

Table 7. *Global weights obtained by AHP*

Rank	Code	Criteria	Sub Criteria	Global Weights
1	D4	Cost	Initial investment cost	0.17650
2	D2	Cost	Raw material costs	0.13914
3	F2	Proximity to Production Factors	Opportunity for governmental investment subsidy	0.08512
4	B5	Infrastructure for Production	Potential for hazardous material handling	0.08227
5	B2	Infrastructure for Production	Proximity to water sources	0.07341
6	B1	Infrastructure for Production	Proximity to energy sources	0.04905
7	D3	Cost	Total site cost (rent, utilities etc.)	0.04306
8	F3	Proximity to Production Factors	Proximity to subsidiary industry	0.03343
9	F6	Proximity to Production Factors	Proximity to unskilled labor	0.02700
10	D1	Cost	Total transportation costs	0.02140
11	B6	Infrastructure for Production	Proximity to raw material supplies/sources	0.02109
12	F5	Proximity to Production Factors	Proximity to organised industry	0.01912
13	E2	Strategic Facilities	Proximity to customers	0.01896
14	A2	Physical Facilities	Availability of industrial drainage system	0.01888
15	E5	Strategic Facilities	Proximity to the target market	0.01823
16	A7	Physical Facilities	Proximity to fire response equipment	0.01814
17	A6	Physical Facilities	Availability of medical care	0.01771
18	D5	Cost	Cost of maintenance	0.01391
19	B4	Infrastructure for Production	Proximity to natural gas resources	0.01371
20	C5	Logistic Facilities	Proximity to harbours	0.01339
21	E4	Strategic Facilities	Proximity to free trade zones	0.01075
22	C7	Logistic Facilities	Ease of material storage	0.01004
23	E3	Strategic Facilities	Proximity to suppliers	0.00992
24	A4	Physical Facilities	Opportunities for possible site expansion	0.00860
25	C2	Logistic Facilities	Proximity to third party warehouses/depots	0.00844
26	C3	Logistic Facilities	Proximity to highway system	0.00807
27	F4	Proximity to Production Factors	Proximity to minor producers	0.00709
28	B3	Infrastructure for Production	Proximity to fuel sources/stations	0.00641
29	F1	Proximity to Production Factors	Proximity to existing site development	0.00611
30	F7	Proximity to Production Factors	Proximity to skilled labor	0.00474
31	A3	Physical Facilities	Proximity to public transport	0.00338
32	A1	Physical Facilities	Proximity to urban areas	0.00309
33	C6	Logistic Facilities	Proximity to airports	0.00230
34	E6	Strategic Facilities	Proximity to competitors	0.00185
35	E1	Strategic Facilities	Environmental regulations	0.00185
36	A5	Physical Facilities	Availability of parking	0.00155
37	C4	Logistic Facilities	Proximity to railroad system	0.00135
38	C1	Logistic Facilities	Density of traffic around the facility	0.00094

Then, the global weights of the criteria, calculated by AHP and shown in Table 7, can be used as input of TOPSIS (Table 8).

Table 8. *Input values of the TOPSIS analysis*

w	Code	Criteria	BALIKESİR BANDIRMA	BİLECİK BOZÜYÜK	BİLECİK OSMANELİ	SAKARYA KARASU
0.003091	A1	Proximity to urban areas	*7.5*	*6.0*	*7.5*	*7.5*
0.018877	A2	Availability of industrial drainage system	*6.0*	*5.0*	*5.5*	*4.5*
0.003375	A3	Proximity to public transport	*6.5*	*5.5*	*6.0*	*6.5*
0.008602	A4	Opportunities for possible site expansion	*8.5*	*7.5*	*7.5*	*8.0*
0.001552	A5	Availability of parking	*9.5*	*9.0*	*9.0*	*9.5*
0.017713	A6	Availability of medical care	*7.0*	*6.5*	*6.5*	*7.5*
0.018144	A7	Proximity to fire response equipment	*8.5*	*7.5*	*7.5*	*7.5*
0.049047	B1	Proximity to energy sources	*8.5*	*8.5*	*8.5*	*8.0*
0.073413	B2	Proximity to water sources	*9.0*	*6.5*	*6.5*	*8.0*
0.006408	B3	Proximity to fuel sources/stations	*7.0*	*8.0*	*8.0*	*6.5*
0.013711	B4	Proximity to natural gas resources	*8.0*	*8.0*	*8.0*	*6.5*
0.082274	B5	Potential for hazardous material handling	*5.5*	*4.5*	*4.0*	*5.0*
0.021091	B6	Proximity to raw material supplies/ sources	*8.0*	*7.0*	*7.0*	*6.5*
0.000941	C1	Density of traffic around the facility	*8.0*	*7.5*	*7.5*	*6.5*
0.008437	C2	Proximity to third party warehouses/ depots	*7.5*	*5.5*	*5.5*	*6.5*
0.00807	C3	Proximity to highway system	*10.0*	*6.0*	*6.0*	*7.5*
0.001349	C4	Proximity to railroad system	*6.0*	*6.5*	*6.5*	*6.0*
0.013386	C5	Proximity to harbours	*9.0*	*4.0*	*4.0*	*9.0*
0.002303	C6	Proximity to airports	*5.5*	*5.0*	*5.0*	*4.5*
0.010036	C7	Ease of material storage	*8.5*	*7.0*	*7.0*	*7.5*
0.021397	D1	Total transportation costs	*10.0*	*6.0*	*6.0*	*6.5*
0.139144	D2	Raw material costs	*6.5*	*5.0*	*5.5*	*5.0*
0.043058	D3	Total site cost (rent, utilities etc.)	*10.0*	*6.5*	*6.5*	*6.5*
0.176497	D4	Initial investment cost	*9.0*	*7.0*	*7.0*	*7.0*
0.013912	D5	Cost of maintenance	*7.0*	*5.5*	*6.0*	*6.5*
0.001852	E1	Environmental regulations	*6.5*	*6.0*	*6.0*	*6.0*
0.018964	E2	Proximity to customers	*10.0*	*8.0*	*8.0*	*7.0*
0.009917	E3	Proximity to suppliers	*8.0*	*6.0*	*6.5*	*8.0*
0.010745	E4	Proximity to free trade zones	*9.5*	*7.0*	*7.0*	*9.0*
0.018229	E5	Proximity to the target market	*10.0*	*8.0*	*8.0*	*7.0*
0.001853	E6	Proximity to competitors	*4.5*	*3.5*	*4.0*	*6.5*
0.00611	F1	Proximity to existing site development	*8.0*	*7.5*	*7.5*	*8.5*
0.08512	F2	Opportunity for governmental investment subsidy	*9.5*	*6.0*	*7.0*	*4.5*
0.033428	F3	Proximity to subsidiary industry	*5.5*	*4.0*	*4.0*	*3.5*
0.007094	F4	Proximity to minor producers	*5.5*	*4.0*	*4.0*	*6.0*
0.019117	F5	Proximity to organised industry	*9.5*	*7.5*	*7.5*	*5.5*
0.027001	F6	Proximity to unskilled labor	*8.0*	*8.0*	*8.0*	*8.0*
0.004739	F7	Proximity to skilled labor	*8.5*	*6.0*	*6.0*	*8.0*

Finally, TOPSIS method is applied to rank the facility locations. The weighted normalized decision matrix can be seen from Table 9.

Table 9. *Weighted evaluation for the facility locations*

Code	BALIKESİR BANDIRMA	BİLECİK BOZÜYÜK	BİLECİK OSMANELİ	SAKARYA KARASU	Min or Max	A*	A-
A1	0.00162	0.00130	0.00162	0.00162	+	0.00162	0.00130
A2	0.01073	0.00894	0.00983	0.00804	+	0.01073	0.00804
A3	0.00179	0.00151	0.00165	0.00179	+	0.00179	0.00151
A4	0.00464	0.00409	0.00409	0.00436	+	0.00464	0.00409
A5	0.00080	0.00075	0.00075	0.00080	+	0.00080	0.00075
A6	0.00900	0.00836	0.00836	0.00964	+	0.00964	0.00836
A7	0.00993	0.00877	0.00877	0.00877	+	0.00993	0.00877
B1	0.02488	0.02488	0.02488	0.02342	+	0.02488	0.02342
B2	0.04361	0.03150	0.03150	0.03877	+	0.04361	0.03150
B3	0.00303	0.00346	0.00346	0.00281	+	0.00346	0.00281
B4	0.00717	0.00717	0.00717	0.00582	+	0.00717	0.00582
B5	0.04731	0.03870	0.03440	0.04301	+	0.04731	0.03440
B6	0.01181	0.01033	0.01033	0.00959	+	0.01181	0.00959
C1	0.00051	0.00048	0.00048	0.00041	+	0.00051	0.00041
C2	0.00502	0.00368	0.00368	0.00435	+	0.00502	0.00368
C3	0.00534	0.00320	0.00320	0.00401	+	0.00534	0.00320
C4	0.00065	0.00070	0.00070	0.00065	+	0.00070	0.00065
C5	0.00865	0.00384	0.00384	0.00865	+	0.00865	0.00384
C6	0.00126	0.00115	0.00115	0.00103	+	0.00126	0.00103
C7	0.00567	0.00467	0.00467	0.00500	+	0.00567	0.00467
D1	0.01462	0.00877	0.00877	0.00950	+	0.01462	0.00877
D2	0.08172	0.06286	0.06914	0.06286	+	0.08172	0.06286
D3	0.02859	0.01859	0.01859	0.01859	+	0.02859	0.01859
D4	0.10520	0.08182	0.08182	0.08182	+	0.10520	0.08182
D5	0.00776	0.00610	0.00665	0.00721	+	0.00776	0.00610
E1	0.00098	0.00091	0.00091	0.00091	+	0.00098	0.00091
E2	0.01139	0.00912	0.00912	0.00798	+	0.01139	0.00798
E3	0.00552	0.00414	0.00449	0.00552	+	0.00552	0.00414
E4	0.00622	0.00458	0.00458	0.00589	+	0.00622	0.00458
E5	0.01095	0.00876	0.00876	0.00767	+	0.01095	0.00767
E6	0.00088	0.00068	0.00078	0.00126	+	0.00126	0.00068
F1	0.00310	0.00291	0.00291	0.00329	+	0.00329	0.00291
F2	0.05783	0.03653	0.04261	0.02739	+	0.05783	0.02739
F3	0.02130	0.01549	0.01549	0.01356	+	0.02130	0.01356
F4	0.00394	0.00286	0.00286	0.00429	+	0.00429	0.00286
F5	0.01190	0.00939	0.00939	0.00689	+	0.01190	0.00689
F6	0.01350	0.01350	0.01350	0.01350	+	0.01350	0.01350
F7	0.00279	0.00197	0.00197	0.00263	+	0.00279	0.00197

By using TOPSIS method, the ranking of facility locations are calculated. Table 10 shows the evaluation results and final ranking of facility locations

Table 10. *TOPSIS results*

	BALIKESİR BANDIRMA	BİLECİK BOZÜYÜK	BİLECİK OSMANELİ	SAKARYA KARASU
Si*	***0.00096***	***0.04256***	***0.03845***	***0.04610***
Si-	***0.04942***	***0.01096***	***0.01710***	***0.01270***
Ci*	***0.98096***	***0.20480***	***0.30779***	***0.21601***
Rank	**1**	**4**	**2**	**3**

CONCLUSION

In our study two MCDM techniques namely AHP and TOPSIS are used for solving one of the important strategic decision making problem (facility location selection). The methodology has two steps. We used AHP as the first step for its strongest side which is converting subjective judgments into quantitative (objective) form. TOPSIS method is the second step of the methodology. AHP weights are used as input weights of TOPSIS method. Proposed method shows the most and least suitable facility locations based on the managers' group decision making. Results show that Balıkesir Bandırma is the best alternative with 0.98096 C_i value and Bilecik Bozüyük is the least suitable facility location.

Strategic use of such analyses for facility location selection has become an important focus both for practitioners and academicians. Many of these researches however solely focus on the artificial cases and storytelling practices. Hence, being a real application for a company to select its facility location, this research proves factual evidence. Moreover, after the investment decision made by the company, the property prices in the aforementioned location has started to rise rapidly; not only because did the company invest to the location, but also because managers in this sector has acknowledged the results of such research.

Strategic decision making is a delicate subject, and recent developments in information technology allows managers to use more complex simulations and eventually reach a better or at least more purified decisions. Facility location selection among all decisions is the one that is hardest or impossible to return from; since it is this fragile, besides the managers' common sense, experience, instinct e.g. rational and computerized techniques had to be used. This research aims to put forward the importance of such applications with the help of a real life and industry-wise important example from Turkey.

RERERENCES

Adam E., Ebert R. Production and Operation Management,Concepts,Models and Behaviour, 2nd Edition, (1982 Prentice-Hall), p.201

Alberto, P. "The logistics of industrial location decisions: An application of the analytic hierarchy process methodology." International Journal of Logistics, 3(3), 2000, pp. 273-289.

Amiri, M. P. "Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods." Expert Systems with Applications, 37(9), 2010, pp. 6218-6224.

Aras, H., Erdoğmuş, Ş., and Koç, E. "Multi-criteria selection for a wind observation station location using analytic hierarchy process." Renewable Energy, 29(8), 2004, pp. 1383-1392.

Asadzadeh, A., Sikder, S. K., Mahmoudi, F., and Kötter, T. "Assessing Site Selection of New Towns Using TOPSIS Method under Entropy Logic: A Case study: New Towns of Tehran Metropolitan Region" (TMR). Environmental Management and Sustainable Development, 3(1), 2014, pp. 123-137.

Athawale, V. M., and Chakraborty, S. "Facility location selection using PROMETHEE II method." Proceedings of the 2010 international conference on industrial engineering and operations management, (2010, January), pp. 9-10.

Badri, M. A. "Combining the analytic hierarchy process and goal programming for global facility location-allocation problem." International Journal of Production Economics, 62(3), 1999, pp. 237-248.

Ballı, S., Korukoğlu, S. Operating system selection using fuzzy AHP and TOPSIS methods. Mathematical and Computational Applications, 14(2), 2009, 119-130.

Ballı, S., Korukoğlu, S., Development of a fuzzy decision support framework for complex multi-attribute decision problems: A case study for the selection of skilful basketball players. Expert Systems, 31(1), 2014, 56-69.

Baumol, W. J., and Wolfe, P. "A warehouse-location problem." Operations Research, 6(2), 1958, pp. 252-263.

Behzadian, M., Otaghsara, S.K., Yazdani, M., Ignatius, J., "A state-of the-art survey of TOPSIS applications." Expert Systems with Applications 39, 2012, pp. 13051–13069

Bhutia, P. W., and Phipon, R. "Appication of ahp and topsis method for supplier selection problem." IOSR Journal of Engineering (IOSRJEN), (2), 2012, pp. 43-50.

Bititci, U. S., Suwignjo, P., and Carrie, A. S. "Strategy management through quantitative modelling of performance measurement systems." International Journal of production economics, 69(1), 2001, pp. 15-22.

Bowen, W. M. "A Thurstonian comparison of the analytic hierarchy process and probabilistic multidimensional scaling through application to the nuclear waste site selection decision." Socio-Economic Planning Sciences, 29(2), 1995, pp. 151-163.

Brandeau, M. L., and Chiu, S. S. "An overview of representative problems in location research." Management science, 35(6), 1989, pp. 645-674.

Brown, P. A., and Gibson, D. F. "A quantified model for facility site selection-application to a multiplant location problem." AIIE transactions, 4(1), 1972, pp. 1-10.

Burdurlu, E., and Ejder, E. "Location choice for furniture industry firms by using Analytic Hierarchy Process (AHP) method." Gazi University Journal of Science, 16(2), 2003, pp. 369-373.

Büyüközkan, G., Feyzioğlu, O., and Nebol, E. "Selection of the strategic alliance partner in logistics value chain." International Journal of Production Economics, 113(1), 2008, pp. 148-158.

Campbell, James F. "Integer programming formulations of discrete hub location problems." European Journal of Operational Research 72(2), 1994, pp. 387-405.

Cebi, F., and Zeren, Z. "A decision support model for location selection: Bank branch case." Management of Engineering and Technology, 2008. PICMET 2008. Portland International Conference (2008, July). pp. 1069-1074.

Cebi, F., Otay, İ., Multi-criteria and multi-stage facility location selection under interval type-2 fuzzy environment: a case study for a cement factory. International Journal of Computational Intelligence Systems, 8(2), 2015, 330-344

Chan, F. T., and Kumar, N. "Global supplier development considering risk factors using fuzzy extended AHP-based approach." Omega, 35(4), 2007, pp. 417-431.

Chen, S. J.,and Hwang, C. L. "Fuzzy multiple attribute decision making: Methods and applications." (Berlin: Springer- Verlag, 1992).

Chen, C. T. A fuzzy approach to select the location of the distribution center. Fuzzy sets and systems, 118(1), 2001, pp. 65-73.

Chou, T. Y., Hsu, C. L., and Chen, M. C. "A fuzzy multi-criteria decision model for international tourist hotels location selection." International journal of hospitality management, 27(2), 2008, pp. 293-301.

Current, J., Min, H., and Schilling, D. "Multiobjective analysis of facility location decisions." European Journal of Operational Research, 49(3), 1990, pp. 295-307.

Dağ, S., and Önder, E. "Decision-Making for Facility Location Using Vikor Method." Journal of International Scientific Publications: Economy and Business, 7, 2013, pp. 308-330

Dağdeviren, M., Yavuz, S., and Kılınç, N. "Weapon selection using the AHP and TOPSIS methods under fuzzy environment." Expert Systems with Applications, 36(4), 2009, pp. 8143-8151.

Destiny Ugo, P. A "Multi-Criteria Decision Making for Location Selection in the Niger Delta Using Fuzzy TOPSIS Approach." International Journal of Management and Business Research, 5(3), 2015, pp. 215-224.

Drezner, Z. (Ed.). "Facility location: a survey of applications and methods." (1995 Springer.)

Drezner, Z., and Wesolowsky, G. O. "Network design: selection and design of links and facility location." Transportation Research Part A: Policy and Practice, 37(3), 2003, pp. 241-256.

El-Santawy, M. F., Ahmed, A. N., and Metwaly, M. A. E. B. "Ranking Facility Locations Using VIKOR." Computing and Information Systems, 16(2), 2012, pp. 201-222

Eleren, A. "Kuruluş yeri seçiminin analitik hiyerarşi süreci yöntemi ile belirlenmesi; deri sektörü örneği." Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 20(2), pp. 2006.

Erkut, E., and Neuman, S. "Analytical models for locating undesirable facilities." European Journal of Operational Research, 40(3), 1989, pp. 275-291.

Erlenkotter, D. Comment on 'Optimal timing, sequencing, and sizing of multiple reservoir surface water supply facilities' by L. Becker and W. W-G. Yeh. Water Resources Research, 11(2), (1975). pp. 380-381.

Ertuğrul, İ., and Karakaşoğlu, N. "Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection." The International Journal of Advanced Manufacturing Technology, 39(7-8), 2008, pp. 783-795.

Farahani, R. Z., SteadieSeifi, M., and Asgari, N. "Multiple criteria facility location problems: A survey. Applied Mathematical Modelling", 34(7), 2010, pp. 1689-1709.

Francis, R. L., McGinnis, L. F., and White, J. A. "Facility layout and location: an analytical approach." (Pearson College Division, 1992)

Geoffrion, A., and Bride, R. M. "Lagrangean relaxation applied to capacitated facility location problems". AIIE transactions, 10(1), 1978, pp. 40-47.

Gundogdu, C.E., "Selection of facility location under environmental damage priority and using ELECTRE method." Journal of Environmental Biology, 32(2), 2011, pp. 221-226.

Güzel, D., and Erdal, H. "A Comparative Assesment of Facility Location Problem via fuzzy TOPSIS and fuzzy VIKOR: A Case Study on Security Services." International Journal of Business and Social Research, 5(5), 2015, pp. 49-61.

H. Erbıyık, S. Özcan and K. Karaboğa, "Retail store location selection problem with multiple analytical hierarchy process of decision making an application in Turkey", 8th International Strategic Management Conference, Procedia - Social and Behavioral Sciences, 58, 2012, pp. 1405-1414.

Hamacher, H. W., and Drezner, Z. "Facility location: applications and theory." (Springer Science and Business Media, 2002).

Hamacher, H. W., and Drezner, Z. "Facility location: applications and theory." (Springer Science and Business Media, 2002).

Hatami-Marbini, A., Tavana, M., Moradi, M., and Kangi, F. "A fuzzy group Electre method for safety and health assessment in hazardous waste recycling facilities." Safety science, 51(1), 2013, pp. 414-426.

http://www.irakplast.com/

Hwang, C.L., and Yoon, K. "Multiple attribute decision making: Method and application." (New York: Spring-verlag, 1981).

Kaboli, A., Aryanezhad, M., Shahanaghi, K., and Niroomand, I. "A New Method for Plant Location Selection Problem: A Fuzzy-AHP Approach", Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, Montréal, Canada, 7-10 October 2007, pp.582-586.

Ko, Jesuk. "Solving a distribution facility location problem using an analytic hierarchy process approach." ISAHP Proceedings Honolulu Hawaii, 2005, pp. 1991-1996

Koç, E., and Burhan, H. A. "An Application of Analytic Hierarchy Process (AHP) in a Real World Problem of Store Location Selection." Advances in Management and Applied Economics, 5(1), 2015, p41.

Kostas N.DERViTSiOTiS; "Operations Management", (2005 McGraw-Hill Book Co,New York), p.382

Kuehn, A. A., and Hamburger, M. J. "A heuristic program for locating warehouses." Management science, 9(4), 1963, pp. 643-666.

Lai, Y.J., Liu, T.Y., Hwang, C.L. "TOPSIS for MODM." European Journal of Operational Research, 76, 1994, pp. 486-500

Lee, S., Kim, W., Kim, Y.M., Oh, K.J., "Using AHP to determine intangible priority factors for technology transfer adoption." Expert Systems with Applications, 39, 2012, pp. 6388-6395.

Liang, G. S., and Wang, M. J. J. "A fuzzy multi-criteria decision-making method for facility site selection." The International Journal of Production Research, 29(11), 1991, pp. 2313-2330.

Liberatore, M.J., Nydick, R.L., "Group Decision Making in Higher Education Using the Analytic Hierarchy Process", Research in Higher Education, 38(5), October 1997, pp 593-614

MacCarthy, B. L., and Atthirawong, W. "Factors affecting location decisions in international operations-a Delphi study." International Journal of Operations and Production Management, 23(7), 2003, 794-818.

Melachrinoudis, E., and Min, H. "The dynamic relocation and phase-out of a hybrid, two-echelon plant/warehousing facility: A multiple objective approach." European Journal of Operational Research, 123(1), 2000, pp. 1-15.

Ngai, E. W. T. "Selection of web sites for online advertising using the AHP." Information and Management, 40(4), 2003, pp. 233-242.

Önder E., Taş N., Hepşen A., "Performance Evaluation Of Turkish Banks Using Analytical Hierarchy Process And Topsis Methods", Journal of International Scientific Publications: Economy & Business, vol.7, pp.470-503, 2013

Önder E., Yıldırım B.F., "Vikor Method For Ranking Logistic Villages In Turkey", Journal of Management and Economic Research, vol.23, 2014, pp. 293-314.

Önüt, S., and Soner, S. "Transshipment site selection using the AHP and TOPSIS approaches under fuzzy environment." Waste Management, 28(9), 2008, pp. 1552-1559.

Partovi, F. Y., and Corredoira, R. A. "Quality function deployment for the good of soccer." European journal of operational research, 137(3), 2002, pp. 642-656.

Rao R. V. "Decision Making in the Manufacturing Environment, Facility Location Selection", (SpringerLink, 2007), pp. 305

Ramanathan, R., and Ganesh, L. S. "Using AHP for resource allocation problems." European Journal of Operational Research, 80(2), 1995, pp. 410-417.

Rao, R. V. "Facility Location Selection. Decision Making in the Manufacturing Environment: Using Graph Theory and Fuzzy Multiple Attribute Decision Making Methods", 2007, pp. 305-314.

Rosenthal, R. E., White, J. A., and Young, D. Stochastic dynamic location analysis. Management Science, 24(6), (1978). pp. 645-653.

Saaty, T. L. "The analytic network process: decision making with dependence and feedback; the organization and prioritization of complexity." (Rws publications,1996.)

Saaty, T. L., "Decision Making With The Analytic Hierarchy Process." Int. J. Services Sciences, 1 (1), 2008, pp. 83.

Saaty, T. L., Vargas Luis L., "Models, Methods, Conceptsand Applications of The Analytic Hierarchy Process." International Series in Operations Research and Management Science, (Kluwer Academic Publishers, 2001).

Saaty, T.L., "How To Make Decision: The Analytic Hierarchy Process," European Journal of Operational Research, North Holland, 48, 1990, pp. 9-26.

Saaty, T.L., "The analytic hierarchy process." (1980 McGraw-Hill New York).

Schoenherr, T., Tummala, V. R., and Harrison, T. P. "Assessing supply chain risks with the analytic hierarchy process: Providing decision support for the offshoring decision by a US manufacturing company." Journal of Purchasing and Supply Management, 14(2), 2008, pp. 100-111.

Şener, Ş., Sener, E., and Karagüzel, R. "Solid waste disposal site selection with GIS and AHP methodology: a case study in Senirkent–Uluborlu (Isparta) Basin, Turkey." Environmental monitoring and assessment, 173(1-4), 2011, pp. 533-554.

Tabari, M., Kaboli, A., Aryanezhad, M., Shahanaghi, K., and Siadat, A. "A New Method for Location Selection: A Hybrid Analysis", Applied Mathematics and Computation, 206 (2), 2008, pp. 598-606.

Tahriri, F., Osman, M. R., Ali, A., Yusuff, R. M., and Esfandiary, A. "AHP approach for supplier evaluation and selection in a steel manufacturing company." Journal of Industrial Engineering and Management, 1(2), 2008, pp. 54-76.

Tavakkoli-Moghaddam, R., Heydar, M., and Mousavi, S. M. "An integrated AHP-VIKOR methodology for plant location selection." International Journal of Engineering-Transactions B: Applications, 24(2), 2011, p. 127.

Tekin M., "Üretim Yönetimi", Cilt 1, (2005 Nadir Kitap), pp. 48-49.

Temur, G. T., Kaya, T., & Kahraman, C. (2014). Facility location selection in reverse logistics using a type-2 fuzzy decision aid method. In Supply Chain Management Under Fuzziness (pp. 591-606). Springer Berlin Heidelberg.

Tsaur, R.C., 2011. "Decision risk analysis for an interval TOPSIS method." Applied Mathematics and Computation 218, 2011, pp. 4295–4304

Tzeng, G. H., Teng, M. H., Chen, J. J., and Opricovic, S. "Multicriteria selection for a restaurant location in Taipei." International Journal of Hospitality Management, 21(2), 2002, pp. 171-187.

UYSAL, H. T., and Yavuz, K. "Selection of Logistics Centre Location via ELECTRE Method: A Case Study in Turkey." International Journal of Business and Social Science, 5(9), 2014, pp. 1-2

Vahidnia, M. H., Alesheikh, A. A., and Alimohammadi, A. "Hospital site selection using fuzzy AHP and its derivatives." Journal of environmental management, 90(10), 2009, pp. 3048-3056.

Verma, D. S., and Pateriya, A. "Supplier selection through analytical hierarchy process: A case study in small scale manufacturing organization." International Journal of Engineering Trends and Technology, 4(5), 2013, pp. 1428-1433.

Wang, G., Qin, L., Li, G., and Chen, L. "Landfill site selection using spatial information technologies and AHP: a case study in Beijing, China." Journal of environmental management, 90(8), 2009, pp. 2414-2421.

Wang, H., Xie, M., and Goh, T. N. "A comparative study of the prioritization matrix method and the analytic hierarchy process technique in quality function deployment." Total Quality Management, 9(6), 1998, pp. 421-430.

Wesolowsky, G. O. Probabilistic weights in the one-dimensional facility location problem. Management Science, 24(2), 1977, pp. 224-229.

Wu, C. R., Lin, C. T., and Chen, H. C. "Optimal selection of location for Taiwanese hospitals to ensure a competitive advantage by using the analytic hierarchy process and sensitivity analysis." Building and Environment, 42(3), 2007, pp. 1431-1444.

Yang, J., and Lee, H. "An AHP decision model for facility location selection. Facilities", 15(9/10), 1997, pp. 241-254.

Yıldırım B.F., Önder E., "Evaluating Potential Freight Villages In Istanbul Using Multi Criteria Decision Making Techniques", Journal of Logistics Management, vol.3, no.1, 2014, pp. 1-10.

Yong, D. "Plant location selection based on fuzzy TOPSIS." The International Journal of Advanced Manufacturing Technology, 28(7-8), 2006, pp. 839-844.

Yoo, K.E, Choi, Y.C., "Analytic Hierarchy Process Approach For Identifying Relative Importance Of Factors To Improve Passenger Security Checks At Airports", Journal of Air Transport Management 12, 2006, 135–142

Yoon, K. "Systems selection by multiple attributes decision making" (PhD Dissertation, 1980). , Kansas State University, Manhattan

Yu, J. R., and Tsai, C. C. "A decision framework for supplier rating and purchase allocation: A case in the semiconductor industry." Computers and Industrial Engineering, 55(3), 2008, pp. 634-646.

Yurimoto, S., and Masui, T. "Design of a decision support system for overseas plant location in the EC." International Journal of Production Economics, 41(1), 1995, pp. 411-418.

APPENDIX

Table 11. *The pairwise comparison matrix for sub-criteria of "Physical Facilities"*

Code	A1	A2	A3	A4	A5	A6	A7
A1	1.00	0.18	0.74	0.19	3.97	0.15	0.15
A2	5.45	1.00	7.57	3.89	7.96	1.45	0.93
A3	1.35	0.13	1.00	0.17	5.13	0.14	0.14
A4	5.24	0.26	5.79	1.00	6.53	0.24	0.31
A5	0.25	0.13	0.19	0.15	1.00	0.12	0.12
A6	6.74	0.69	7.35	4.16	8.14	1.00	1.00
A7	6.86	1.08	7.35	3.22	8.14	1.00	1.00

Table 12. *The pairwise comparison matrix for sub-criteria of "Infrastructure for Production"*

Code	B1	B2	B3	B4	B5	B6
B1	1.00	1.10	7.79	2.86	0.30	3.70
B2	0.91	1.00	7.81	7.54	1.32	5.04
B3	0.13	0.13	1.00	0.26	0.14	0.16
B4	0.35	0.13	3.81	1.00	0.15	0.44
B5	3.35	0.76	7.40	6.83	1.00	5.53
B6	0.27	0.20	6.08	2.25	0.18	1.00

Table 13. *The pairwise comparison matrix for sub-criteria of "Logistic Facilities"*

Code	C1	C2	C3	C4	C5	C6	C7
C1	1.00	0.12	0.11	0.40	0.11	0.34	0.12
C2	8.56	1.00	0.98	7.25	0.59	7.21	0.64
C3	8.70	1.02	1.00	7.96	0.74	4.08	0.49
C4	2.52	0.14	0.13	1.00	0.12	0.24	0.15
C5	8.85	1.71	1.35	8.12	1.00	7.54	2.86
C6	2.94	0.14	0.25	4.24	0.13	1.00	0.14
C7	8.14	1.57	2.03	6.72	0.35	7.37	1.00

Table 14. *The pairwise comparison matrix for sub-criteria of "Cost"*

Code	D1	D2	D3	D4	D5
D1	1.00	0.12	0.38	0.13	2.35
D2	8.12	1.00	7.25	0.51	7.98
D3	2.62	0.14	1.00	0.16	5.67
D4	7.94	1.96	6.42	1.00	7.88
D5	0.43	0.13	0.18	0.13	1.00

Table 15. *The pairwise comparison matrix for sub-criteria of "Strategic Facilities"*

Code	E1	E2	E3	E4	E5	E6
E1	1.00	0.14	0.20	0.13	0.13	1.00
E2	7.00	1.00	1.00	7.00	1.00	7.00
E3	5.00	1.00	1.00	1.00	0.20	7.00
E4	8.00	0.14	1.00	1.00	1.00	7.00
E5	8.00	1.00	5.00	1.00	1.00	7.00
E6	1.00	0.14	0.14	0.14	0.14	1.00

Table 16. *The pairwise comparison matrix for sub-criteria of "Proximity to Production Factors"*

Code	F1	F2	F3	F4	F5	F6	F7
F1	1.00	0.12	0.14	0.74	0.23	0.23	1.57
F2	8.08	1.00	6.28	7.79	6.94	6.76	8.12
F3	7.34	0.16	1.00	7.61	2.97	0.99	7.52
F4	1.36	0.13	0.13	1.00	0.18	0.16	2.37
F5	4.33	0.14	0.34	5.58	1.00	0.52	4.52
F6	4.35	0.15	1.01	6.32	1.93	1.00	7.15
F7	0.64	0.12	0.13	0.42	0.22	0.14	1.00