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A MULTI-CRITERIA FACTOR EVALUATION MODEL FOR GAS STATION SITE SELECTION

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ABSTRACT

Location selection is one of the most important aspects of business success. In fuel industry, gas station site selection problem involves several quantitative and qualitative factors such as the number of other stations in the area, traffic directions, social composition of surrounding residential area, and curb appeal of the station structure.

The purpose of this study is to present a comprehensive hierarchy of factors for selecting the best gas station site. In the study, Analytic Hierarchy Process (AHP) methodology was also used to calculate the relative importance of criteria and the sub-criteria in accordance with the aggregate opinions of experts. AHP is a commonly used mathematical tool especially where subjectivity may affect on overall result of the decision making process. The study demonstrated that the access to station from both directions, road barricades in direction of station, to be located on a local or state road, and the speed limit on the front road have been the major factors for the gas station site selection.

Field of Research: *Management Science, Site Selection, Multi-Criteria Decision Making, AHP*

1.0 INTRODUCTION

Survival and profitability of a business is greatly related to optimal selection of the business location. In general, the location of a business can be defined as the place where business operations were carried out. For industries, business locations are the plants or the stores. A poorly selected location will lead to inefficient use of resources thereby the business would destined for failure. Site selection problem involves several quantitative and qualitative factors. Some quantitative factors can be described as transportation costs, labor, capital investment and operating costs. On the other hand, qualitative factors are rather more difficult to define and they include climate, quality and cost of living, public services, closeness to facilities, religious organizations, and property values.

Cost related factors affect the location decision in many industries. However, the relative importance of different costs, depends by the industry according to the subject of the business and to the technology. For instance, in the chemical and energy industries that require large investments, the cost of production and distribution surpass the labor costs. On the contrary, in labor-intensive industries such as textile sector, the business is burdened with large labor costs. Therefore it would be logical to prefer locations where the workforce could be easily obtained and where labor costs predicted to stay minimum for a foreseeable future. In fact, the process of the best location selection usually involves

evaluation criteria that analyze and minimize the sum of tangible costs and long-term intangible costs of the business. Therefore in the site selection problem, factors affecting on long-term profitability are mainly considered. In other words, the principal approach of site selection analysis is to avoid pitfalls that may cause financial loss in the future.

The purpose of this study is to determine and prioritize criteria affecting gas station location selection in Turkey. Analytic Hierarchy Process (AHP) was utilized as a powerful multi-criteria decision making tool. AHP is a commonly used technical tool especially where subjectivity may affect on overall result of the decision making process. The paper demonstrated that the hierarchical structure of the AHP methodology can successfully measure relative importance of the evaluation criteria and sub-criteria in accordance with the aggregate opinions of experts.

2.0 THE BACKGROUND OF THE METHODOLOGY AND THE RELATED LITERATURE

The AHP, developed by Thomas Saaty, helps decision makers to deal with complex decision problems by constructing the problem into various hierarchies as a goal, criteria, sub-criteria and decision alternatives (Saaty, 1990, 2001a, 2001b, Saaty and Vargas, 2001). AHP method performs pairwise comparisons to measure relative importance of the elements in each level of the hierarchy and evaluates the alternatives in the lowest level of the hierarchy in order to make the best decision among multiple alternatives. AHP is a powerful multi-criteria decision making method especially when subjectivity exists and it is very suitable to solve problems where the evaluation criteria can be organized in a hierarchical way into sub-criteria. It provides decision makers with a way to transform subjective judgments into objective measures. It has a process that transforms a complicated problem into a hierarchical structure (Zahedi, 1986). AHP methodology has been used in a wide variety of areas such as economics, management, finance, auditing, marketing, politics, architecture, health, logistics, ecology, farming, sport, law, and military. In their study, Sipahi and Timor (2010) presented a comprehensive literature review of the application of the AHP methodology in many areas. In AHP method, a certain degree of consistency is necessary to get valid results. The AHP measures the overall consistency of judgments by means of a “consistency ratio”. The value of consistency ratio should be 10% or less (Saaty and Vargas, 2001). A consistency ratio (CR) less than 10% indicates a satisfactory degree of consistency. Experts perform pairwise comparisons individually; for obtaining the aggregate comparison matrix computing geometric means of individual judgments is common approach in AHP methodology.

In the last decade, AHP has been often used in site selection or location problems in various industries. Table 1 summarizes recent remarkable site selection and location studies that AHP methodology was utilized

Table 2: Literature of AHP Studies in Location Selection

Journal/Publication Name	Year	Author(s)	Methodology Used	Problem Definition
Journal of Environmental Man.	2010	Beltran P.A., Ferrando J.P.P, Garcia F.G.	AHP, ANP	Selection of the best location for the construction of a municipal solid waste plant
Waste Management	2010	Ekmekcioglu M., Kaya T., Kahraman C.	Fuzzy AHP, Fuzzy TOPSIS	Site selection for municipal solid waste
Expert Systems with Applications	2010	Onut S., Efendigil T., Kara S.S.	Fuzzy AHP, Fuzzy TOPSIS	Shopping center site selection
Acta Geographica Slovenica	2009	Lotfi S., Habibi K., Koohsari M.J.	GIS, AHP	Cemetry site selection
Quality and Quantity	2009	Lee K.L, Huang W.C., Teng Y.J.	SWOT, AHP	Evaluating the competitive position of location for global logistics hub
J. of Environmental Man.	2008	Prasanta K.D., Ramcharan E.K.	AHP	Site selection for limestone quarry expansion
Supply Chain Mngt: An Int. J.	2008	Liu L.B., Berger P., Zeng A., Gerstenfeld A.	AHP	Offshore outsourcing location selection
Renewable and Sustainable Energy Reviews	2008	Carrion J.A. et al.	AHP, GIS	site selection for grid-connected photovoltaic power plants
Int. Journal of Strategic Property Management	2007	Kauko T.	AHP	Evaluating residential location quality profile in the inner city of Budapest
Proceedings of 22nd Int. Conf. on Solid Waste Technology and Man.	2007	Padmaja V., Asadi S.S., Reddy M.A.	AHP	Selection of suitable sites for waste disposal
Environmental Geology	2007	Banar M., Kose B.M., Ozkan A., Acar I.P.	ANP, AHP	Choosing a municipal landfill site
Business Strategy and the Environment	2007	Srdjevic Z., Kolarov V. and Srdjevic B.	AHP	location selection for pumping stations in the Galovica drainage area of Serbia
Environment & Planning B: Planning & Design	2006	Johnson M.P.	Integer Programming, AHP	Location selection for community corrections centers
Journal of Housing and Built Environment	2006	Kauko T.	AHP	Preference evaluation of the attractiveness of residential locations through the eyes of customers
Omega	2006	Partovi F. Y.	QFD, AHP, ANP	Analysing facility location characteristics in a manufacturing company
Construction Innovation	2005	Cheng E .W.L., Li H., Yu L.	AHP, ANP	Shopping mall location selection
Biomass and Bioenergy	2005	Jianguo M., Norman R.S., Gloria S. D., Lembo A.J.	AHP, GIS	Land-suitability assessment of potential energy systems featuring an anaerobic digesters coupled with an energy generator
The Business Review, Cambridge	2005	Timor M., Sipahi S.	AHP	Fast food restaurant site selection
Waste Management	2005	Kontos T.D., Komilis D.P., Halvadakis C.P.	SAW, GIS, AHP	Assessing landfill suitability for a municipal solid waste
Socio-Economic Planning Sciences	2003	Takamura Y., Tone K.	AHP, DEA	Site evaluation study for relocating Japanese government agencies
Environmental Impact Assessment Review	2002	Prasanta K.D.	AHP	Cross-country petroleum pipeline route selection

3.0 PROBLEM DEFINITION AND METHOD

Gas station site selection problem should be considered a complex multi-attribute decision problem. Besides the hardness of determining and avoiding factors that may cause financial failure in the future, local and national laws and regulations tightly control and limit the location of gas stations and construction specifications. Therefore it has becoming more difficult and also important to make correct decisions by carefully examining quantitative and qualitative factors and quantifying intangible criteria. Moreover, today's gas stations are far from being simple stop to fill a gas tank. Many of them have repair facilities, shopping stores, fast food restaurants, and some even have showers and rest areas. Factors such as the number of other stations in the area, traffic directions, social composition of surrounding residential area, and curb appeal of the station structure are some of the important factors in the success of the business.

First, factors were determined by getting experimental opinions of experts and by a literature search. Second, the most recurring criteria were listed and they were transformed into a hierarchical form in accordance with expert opinions.

1) Factors based on near-by traffic conditions:

1.1. One-way traffic to station: This may limit the access to the gas station; potentially fewer cars would stop for gas.

1.2. Speed limit on the front road: Higher speed roads have a negative effect on the number of the cars for refueling. Difficulty of switching lane, reducing speed for entree and possibility of accidents are main concerns subject to this segment.

1.3. Multiple lanes on the road approaching to station: Multiple lanes mean more traffic and more business. Multiple lane roads have turning lanes making entrance to stations easier.

1.4. Closeness to traffic lights: Traffic lights slow or stop the traffic periodically, thus making easier for drivers to enter into station.

1.5. Access to station from both directions: Return lanes and signals usually provide more vehicles to enter to the station.

1.6. Turning lanes through direction of station: Only very careful drivers plan to switch lanes well ahead of time. The prohibitive lights or lane switching prohibition would reduce the number of vehicles entering.

1.7. Road barricades in direction of station: Concrete road barriers would reduce incoming traffic thus creating a decrease in density.

1.8. Is the station located on a local or (inter) state road: Usually more small vehicles travel on the local roads while larger ones are on the state or interstate roads. Larger vehicles require more amount of gas thus leaving more cash to gas stations.

2) Environmental factors:

2.1. Factors related with neighborhood:

2.1.1 Number of the residential buildings in a 2 km radius: Drivers prefer to shop at the nearest stations to avoid extra driving for saving money and time.

2.1.2 Approximate number of the vehicles residents own: In the cities where a fast and effective public transportation available many people might prefer not to own cars. (For instance in Chicago, the ratio of car allowance per 1000 people is dramatically lower than St. Louis has.

2.1.3 Existence of open land for future developments: Promising regional planning provides longer investment and thereby the overall cost per year would be expected to drop.

2.1.4. Other near-by services and industries affecting on the traffic: Hospitals, schools, commercials and public service buildings would bring more business and masses to the region.

2.1.5. The number of vehicles in the city close-by: Predicting total number of registered vehicles in the area would help to estimate the volume of expected business and gather a useful plan for near future.

2.1.6. Annual quantity of gasoline consumed by the residents of a close-by town: Knowledgebase on market size and the number of competitors would inform us expected profit.

2.2. Other competitors in the area:

2.2.1. Number of gas stations in the area: The business coming from the surrounding towns would be shared by the number stations in the area, but most probably not equally.

2.2.2. The services provided by competitors in the area: This factor can be described as the composition of the services available.

2.2.3. Total number of all gasoline stations in close-by town: Especially the existence of any shortage of gasoline stations in the area would be an opportunity for opening a new gas station.

3) Socio-economic factors:

3.1. Economical portrait of residents living close-by towns: Admittedly, high social economical status and the high number of sport and luxurious cars would bring more profit to the station.

3.2. Average annual income level of the residents: High-income people most likely prefer larger and more expensive cars. Lower income people may use second hand cars and trucks that consume less gasoline.

3.3. The growth potential of the province: The growth potential of the area is a considerable factor. If the average age of citizens is younger, more children would be expected, thus population will increase. Moreover, hospitals, research centers, and manufacturing industry can bring more jobs and would attract more people moving into the target area.

3.4. Average age group of inhabitants: Younger and older people differ in their driving habits and choice of the cars they prefer to drive.

4) Factors based on physical attributes of the land

4.1. Total area of the land owned: Services and parking area require a large land. Future developments and additions should be taking account.

4.2. Visibility of the station location from approaching roads: Drivers need proper signs and visibility of the station to prepare to stop.

The overall hierarchical structure of the problem is presented in Figure 1.

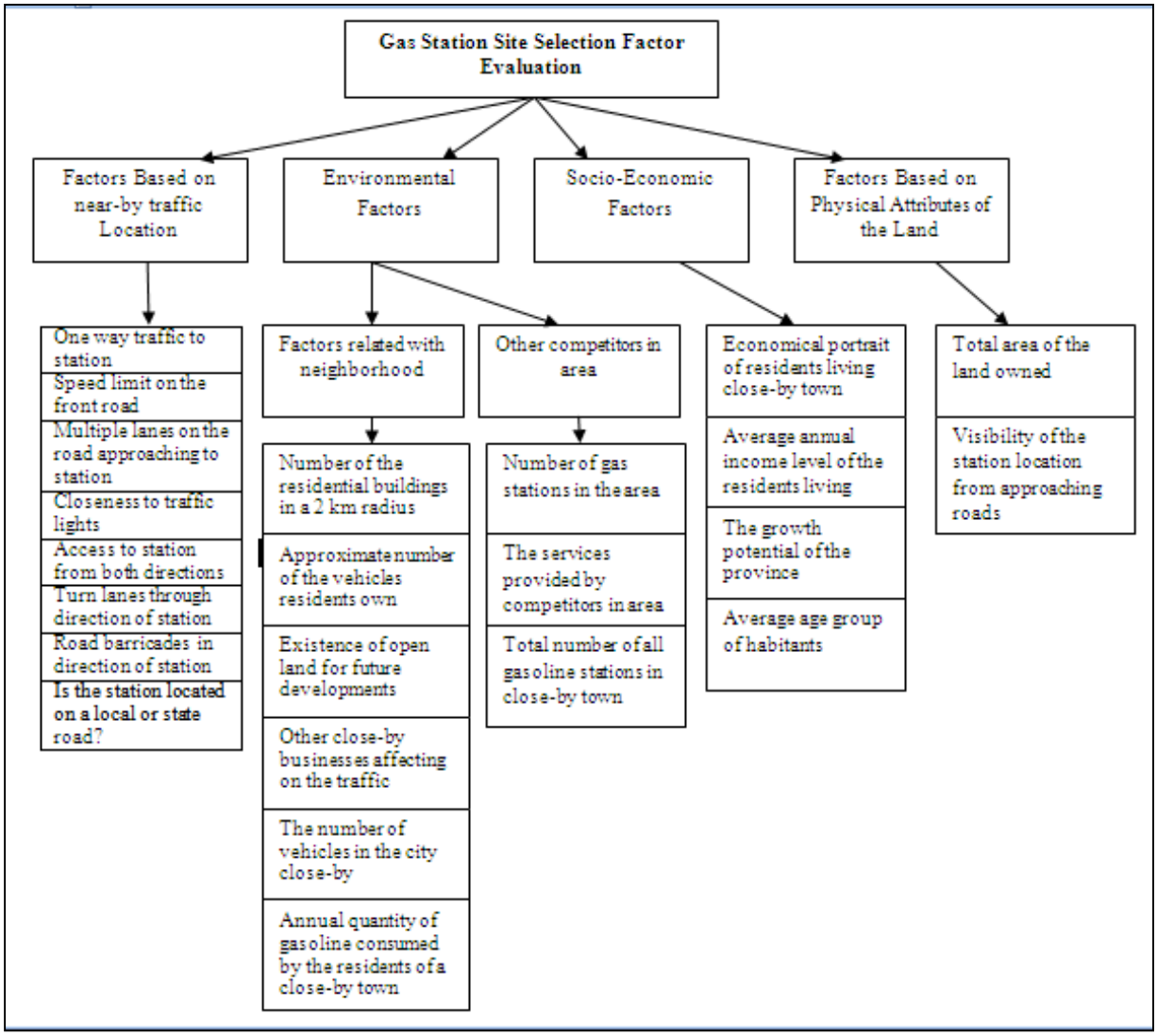

Figure 1: The hierarchical structure of gas station site selection problem

After constructing hierarchy, an AHP survey questionnaire was designed in order to determine relative importance of the evaluation criteria and sub-criteria. In the questionnaire, pairwise comparisons were performed on the basis of nine scale of AHP. Questionnaires were filled by an expert focus group formed by 12 experts. Experts were chosen among people who are finance, sales or marketing managers, have

significant experience in the fuel industry and previously involved in gas station site selection decision process. The aggregate comparison matrix was obtained by taking geometric means of expert judgments. It was noticed that consistency ratio (CR) of the aggregate pairwise comparison matrices were less than 10%, indicating satisfactory consistency.

4.0 FINDING & DISCUSSION

In the Table 3, the second column represents the relative weights of the criteria and sub-criteria.

Table 3: Criteria weights for site selection criteria and sub-criteria

CRITERIA	WEIGHTS
Factors Based on Traffic Near to Location	**0.5607**
One way traffic to station	0.0765
Speed limit on the front road	0.0909
Multiple lanes on the road approaching to station	0.0653
Closeness to traffic lights	0.0772
Access to station from both directions	0.2868
Turn lanes in direction of station	0.0825
Road barricades in direction of station	0.1759
Is the station located on a local or state road?	0.1449
Environmental Factors	**0.2046**
Factors related with neighbourhood	***0.3904***
Number of the residential buildings in a 2 km radius	0.0839
Approximate number of the vehicles residents own	0.1742
Existence of open land for future developments	0.1999
Other close-by businesses affecting on the traffic	0.2715
The number of vehicles in the city close-by	0.1249
Annual quantity of gasoline consumed by the residents of a close-by town	0.1455
Other competitors in area	***0.6096***
Number of gas stations in the area	0.6466
The services provided by competitors in area	0.2445
Total number of all gasoline stations in close-by town	0.1089
Socio-Economical Factors	**0.1203**
Economical portrait of residents living close-by town	0.2760
Average annual income level of the residents living	0.4074
The growth potential of the province	0.0864
Average age group of habitants	0.2302
Factors Based on Physical Attributes of the Land	**0.1144**
Total area of the land owned	0.1659
Visibility of the station location from approaching roads	0.8341

Having a closer look on the results shown in Table 3, it can be seen that traffic related factors have a key role on the selection decision. Environmental factors take second major point, followed by socio-economical factors. Least share is taken by physical attributes of the land.

Factors based on traffic near to location have eight sub-criteria and the weights are said to be leveraged between three factors. The highest weight (0.2868) belongs to "access to station from both directions". Bidirectional entrance will help more drivers reach to gas station and drivers will not have to make a "U turn". Road barricades factor is the second important factor with a weight of 0.1759, it means that any obstacle can cause some driver by-pass the station. To be located on a local or state road also found important with a weight of 0.1449. State roads are most likely have a higher density whereas more cars travel. The least important sub-criterion with a weight of 0.0653 is multiple lanes on the road, that is not considered so much important compared to the other criteria.

When environmental factors are scrutinized, it can be noticed that "other competitors in area" dominates the importance when compared with "factors related with neighbourhood". As the market is shared by rivals, it has a deep impact on the amount of drivers selecting the gas station.

Factors related with neighborhood consist of six sub-criteria. It can be observed that close-by businesses affecting on the traffic has an important role with a score of 0.2715. Open lands for future developments allow us think that the popularity of our target region might increase. Moreover, current number of vehicles naturally finds an important place with a weight of 0.1742. The annual quantity of gasoline consumed by the residents of a close-by town and also the number of vehicles in a near-by city has an important impact.

Moving through for socio-economic factors, we have four weights : Economical portrait of residents living close-by town , average annual income level of the residents living, the growth potential of the province and average age group of habitants. Income level directly affects the living style of citizens whereas gas stations will have more profit. This criterion has the first place with a weight score of 0.4074. Economical portrait of neighbor town and average age group of habitants also considered important. However, the potential growth fails to find a strong point in this section with a score of 0.0864.

5.0 CONCLUSION

In this study, criteria and their relative weights for gas station site selection were determined by the use of a multi-criteria decision making methodology. Several methodologies for location or location selection have been used widely especially for the establishment of factories or production centers. In this problem, firstly, all criteria that are important to determine the location of the station were identified as a result of an comprehensive study. Gas stations should not be considered a basic retail center. Their small stores are adequate to meet many needs, their restaurants serves several food and beverages, and they have services for repair and maintenance facility for vehicles. Therefore they are essential for consumers for purchasing fuel products as well as for several services.

The gas station site selection is a multi-criteria complex problem. It includes criteria such as surrounding traffic, environmental factors, visibility, and criteria related to competitors. The main reason why AHP methodology was used in this study is its capability to evaluate objective as well as subjective and conflicting criteria. In addition, AHP is mathematically easy to implement. In this study, AHP

methodology simplified the structure of problem and evaluated many objective and subjective factors by utilizing expert opinions.

Gas industry has been currently experiencing very intense competition. Alternative places for a gas station are usually limited by some laws and regulations. So managers are more obliged to choose the best place between limited alternatives. Making the best choice from the options makes it even more important in this situation. AHP method can help decision makers and managers to make the appropriate decision where qualitative and quantitative conflicting factors make the decision problem more complex.

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