Location analysis with given fixed factories' location by using Huff-Model in Inner Anatolia

Ziya G. GOKTOLGA, A. Oguz BAYRAKCIL, A. Murat OZKAN

Department of Economics and Administrative Sciences, Cumhuriyet University, Sivas, TURKEY

ABSTRACT

We study on a location selection project in a focused market to investigate simultaneous launching decisions of four new factories. These new factories compete with already established ones. Competition between the established factories and new launched ones is about to gain customer in each market. Main objective is to maximize profits of the investor. In this study, we tried to select the locations of the new factories by examining the customer potential, market characteristics and distances. We use Huff-Model based on gravity model for solution. Probability of gaining customer share depends on attraction level of selected facility location. The model is constructed for the problem of an investor planning to launch four plants in middle Anatolia to produce automated switch systems. Facility locations are selected among alternatives using huff based algorithm and results are analyzed.

Key Words: Location Analysis, Huff Model, Multiple Layout Problem.

1. Introduction

There are several factors affecting the factories' location, both in case of introducing similar, new generation of a previous product or absolutely new product for focused market. New firms planning to enter the market or previously established firms want to present a single or multiple products which are not provided before. This is the nature of competing business environment. At that point every firm inquires that what will be the main difference between them and other firms in the market. This question is the most critical point for new investor or existing firms.

"Facility location decisions are a critical element in strategic planning for a wide range of private and public firms. The ramifications of sitting facilities are broadly based and long-lasting, impacting numerous operational and logistical decisions. High costs associated with property acquisition and facility construction make facility location or relocation projects long-term investments" Owen and Daskin (1998).

“Studying this Project also explains strategic store openings in a situation in which firms can open multiple stores depending on the financial constraints of the firm. They sequentially determine the number of store openings, including their locations, to maximize their profits” Lida and Matsubayashi (2011).

“Facility location analysis deals with the problem of locating one or several new facilities with regard to existing facilities and clients in order to optimize some economic criterion. Examples of facilities are plants, warehouses, schools, hospitals, administrative buildings, department stores, waste material dumps, ambulance or fire engine depots, etc.” Labbe et al (1995).

“Facility location models deal, for the most part, with the location of plants, warehouses, distribution centers and other industrial facilities. In reality, facilities operate in a competitive environment with an objective of profit or market share maximization” Drezner and Drezner (2004).

“When customers travel to the centers in order to obtain service, competition between firms involves ‘‘capturing’’ or ‘‘attracting’’ as many customers as possible through closeness, shorter waiting times, better service, price and so on. While price and quality of service do not have a direct relation to the location of the service centers, closeness has an obvious relation to it, and waiting times are related to the allocation of customers to facilities” Marianov et al (2008).

In competitive market, ratio of market share depends on the term “Utility”. Utility is the basic and most important attraction term for customers showing the preferences to commodity provided by firms. This term is used in every part of modern life such as in business, service and manufacturing areas. As a reflection of this point most firms in construction sector, choose operational products and services in good quality.

“A more realistic approach was introduced by Huff who suggested that customers divide their patronage among the competing facilities according to a gravity-based Formula” Drezner, et al (2002). To estimate market shares, the gravity based model is used. This model, used primarily by marketers, postulated that the probability that a customer patronizes a retail facility is proportional to the facility's floor area (which can be substituted by any attractiveness measure) and inversely proportional to a power of the distance to it. The market share captured is estimated based on this rule Drezner and Drezner (1998) and Rhim et al. (2003).

In construction sector, utility can be described as quality served by firms and such as products and extra attributes discussed in literature. Other utility factors are technology and safety provided by firms. Safety, for most firms is, main point to attract customer. So, firms try to satisfy upper safety level for customers. They investigate high constructing technology to reach this goal in their products. For example, most firms use nonflammable cables and dye. Regarding to most customers such these safety precautions is worth to think about buying houses or flat.

In this study we have the problem of an investor wants to make an investment for a construction sector product called AES (Automated Electrical Switch). AES is the main item of every construction elements which is used in flats and apartments. AES are used in the new buildings and for second hand replacement in construction sector. Investor points that AES will be used in flats and apartments. So, the investment dedicated to new plants that will produce AES.

This study includes placement of fixed number of factories to fixed number of focused markets. There are also pre-established factories in focused markets which produce same product. Thus, investor's factories (IVF) to be established will also compete to its rivals, but will not compete among them.

"As to scope of the project, there will be some assumptions. Such assumption makes sense only if (1) customers engage in separate trips to the facility, (2) the facility characteristics (such as waiting times) are all the same, and (3) customers are rational (i.e., utility maximizing) planners with utility functions that include only transportation costs, which are assumed to be proportional to customer-facility distances ReVelle.C.S", Eiselt (2005). These assumptions are related to each other, because investor wants to limit and see early project's numerical outcome to make investment decision. In this project, as we mentioned before, we apply an example of traditional models studied before. This model analyzes decision criteria for two competitors in given market. In our model, we analyze multiple factory and market situations and each factory can serve one or more city. We are supposing in each separate market, there will be at most two competitors (IVF and Rivals). By the way, we numerate candidate market regions and we numerate each factory to be established. So, these types of model studied can be found in papers written by Eiselt and Laporte (1996) and Plastria (2001). These studies show that two type of customer behaviors. One of the behaviors is called, patronizing behavior of customer; firms share customer demand according to customer attraction level. This also called deterministic shape of customer demand. Other model is probabilistic customer behavior of demand sharing. So, we will use Huff-Model to analyze location decision in geographic meaning Huff and McCallum (2008). Huff-Model is a tool to formulate and evaluate business geographic decisions such as competitive location selection. This model has an extensive usage in literature. Almost, many scientist, firms and government authorities use this model for location selection. This model is also called "Spatial Interaction" models. Over years, there is a continuous interest to fit known models for customer spatial behavior.

Customers follow buying processes by different settings and situations. Thus, customers are free to travel between facilities who serve them and when they need products. Spatial movement model explains population ratio, customer ratio and competitive factors. So, all these dynamics set a framework of model behavior. To get high value of customer demand firms must attract present customer or potential customer. To achieve this, firms should be aware of customer spatial behavior, and, they should investigate customer buying behavior. This kind of similar problem studied before in papers by Drezner and Drezner (1998). In their study they consider locating a new facility in a competitive environment. They consider a future competitor is expected to enter market and locate facility its best region. So, the best location is founded by depending on market share captured by competitor. Location selection of competitor depends on one's own facility. They use heuristics solutions. Bello et al. (2011) studied single-facility location problem that reflects a firm enters market with single facility in region of plane. They show that demand of customer captured by facility will be proportional to the customers buying buyer. They formulate problem as global optimization problem with objective written as difference of two convex monotonic functions.

2. Material and Methods

Our study was done in middle Anatolia including cities (these cities are factory locations, they also have high population) Ankara, Kirikkale, Kayseri and Konya. We also numerate market regions. Ankara is the capital city of Turkey. Kayseri and Konya is the second and third biggest cities in inner Anatolia (Turkey Statistical Yearbook, 2010). They also have modern Industry Regions and they have important role in Turkey's economy in export.

Huff's main theme is customer demand can be best described in probabilistic term. "Sometimes firms cannot forecast the behavior of every customer in a deterministic fashion, but it is able to show by a probabilistic manner". Benati and Hansen (2002). This procedure should be explained in "utility of customer". That means probability of customer choosing facility equals to utility of given facility divided by total utility of all facility centers Aboolian et al. (2007) and Saiz et al. (2010).

There are some properties of Huff's spatial model such as Huff and McCallum (2008); It is based on customer choose behavior, it can be established on model related with obtained real data, it can be applied to all prediction of local selection for calculation of sale potential for facilities, result calculations lead near approximation outputs for new or existing firms, it leads to describe and search focused market, it determines economic aspect, it estimates market share.

This model will include spatial interaction, multiple factories and inelastic demand properties. Key assumptions are;

1) Each factory locations has also its market
2) Factories do not compete with each other. They compete with pre-establish factories or other new firms.
3) Number of factories will be four. They will be established in cities which has high population in their market region
4) Number of markets is also same number of factories and around their markets.
5) Each market is numerated.
6) Each factory will serve the only in its numerated market region. Some market regions contain only one city or more than one, but, number of cities not more than five.
7) Each IVF enters the market simultaneously.
8) Customer demand is mostly related with getting high utility from factories. Distance and design (quality=new technology) is the point of view of customer.
9) Market expands only if factories increase utility level for customers.
10) Factories can change design characteristics as demand level change.

“Succeeding the location problem, we obtain knowledge framework of location, size and competition situations by getting all realist inputs. The demand associated with a customer will not increase with distance, meaning that the closer the assigned facility is to a given customer, the greater the demand from the customer. In our example, customers may be seen as local populations. The further they have to move in order to purchase the goods, the fewer residents will be willing to buy them. So, we assume that customers will always patronize the closest facilities (Dias and Godinho.P, 2010).

2.1. Formulation of Problem

j: indices of IVF locations j:=(1,2,3,4)

i: indices of customers demand point i:=(1,2,…11)

$\alpha = 1$, $\beta = -2$ According to Reilly’s original equation.

$y_j =$ Location variable

$p =$ Number of factories to be located (P=4)

$Q_i =$ Demand weight at point “i”

$D_{ij} =$ Distance from customer “i” to factory (store) location “j”.

$U_{ij} =$ Utility of customer “i” is gotten from factory (store) “j”.

$K_{ij} =$ Cost of traveling from demand point “i” to factory (store) “j”

$M_j =$ Cost of opening factory at point “j”.

$S_j =$ Population of factory located city. It is an mass attraction variable shown by measure of variable of size of cities.

$SH_i =$ Market share of customer I (it is a probabilistic value driven from Reilly’s Formula)

$pr =$ Price of product produced

$$SH_i = \frac{U_{ij}}{\sum_{k=1}^{j} U_{ik}} = \frac{S_j^{\alpha} D_{ij}^{\beta}}{\sum_{k=1}^{j} s_k^{\alpha} D_{ik}^{\beta}} \tag{1}$$

- If $SH_i = 1$ this means that firm is the only supplier in that region.
- If $SH_i = 0$ this means that firm does not supply anything to that region.

Because "SH_i" is the probabilistic value then it takes value between 0 and 1. This value means that shared portion of customer demand taken by the firm, and remain part is taken by the rival firm. In deterministic way of calculations, results of course depend on customer behavior to attraction level served by firms. So, Huff based probabilistic formula will be described;

2.2. Profit Function

$$\Pi = \sum_{i=1}^{11} pr * Q_i SH_i - M_J(S_j) - \sum_{i=1}^{11}\sum_{j=1}^{4} D_{ij}K_{ij} \tag{2}$$

Profit equation basically explains, total demand multiplied with market share, establishment costs and travel costs are subtracted from this.

When we evaluate profit function if firm1 takes market share and we calculate above profit function for firm1 then remain part will belong to other firms

Firm 1(IVF) profit function

$$\Pi_1 = \sum_{i=1}^{11} pr * Q_i SH_i - M_J(S_j) - \sum_{i=1}^{11}\sum_{j=1}^{4} D_{ij}K_{ij} \tag{3}$$

Firm2 profit function

$$\Pi_2 = \sum_{i=1}^{11} pr * Q_i (1 - SH_i) - \sum_{i=1}^{11}\sum_{j=1}^{4} D_{ij}K_{ij} \tag{4}$$

We assume that rival firms has no establishment cost ($M_J(S_j)$=0). There are also operational costs such as production, employment, safety, worker…etc. We assume that operational costs are evaluated later after detailed market price inspection. In order to run the model and choose among alternatives we suppose an arbitrary selling price for the product.

As we mentioned before investor wants to early numerical outputs. When we equal equation 3 to “0” we can get minimum cost equation. Right hand side of equation shows cost and left hand side shows revenue from market if we apply cost coefficient. Such as;

$$\Pi_1 = 0$$

$$\sum_{i=1}^{11} pr * Q_i SH_i = M_J(S_j) + \sum_{i=1}^{11}\sum_{j=1}^{4} D_{ij} K_{ij} \qquad (5)$$

2.3 Objective Function

$$\text{Max } \sum_{i=1}^{11}\sum_{j=1}^{4}\left[pr * Q_i SH_i - \left[M_j(S_j) + (D_{ij}K_{ij})\right]\right]$$

Subject to

$$SH_i \le y_j$$

$$\sum_{j=1}^{4} y_j = p$$

$$SH_i = 0 \vee 1$$

$$y_j = 0 \vee 1$$

$$p = 4$$

$i = (1........11)$
$j = (1.....4)$ i and j are grater and equal than 0.

3. Numerical Input Data and Results

Middle Anatolia region is the scope of our study. There are 11 cities in the region regarded as market points and the problem is to choose the best four plant location among these cities ensuring the profit maximization (Table-1). We have $\binom{11}{4}$ alternatives to evaluate and work is carried out to find the optimal one.

Table-1

Table-2 shows one of the main elements of numerical results of profit function. Results are for the optimal alternative. This solution also guides to determine main cost elements and revenue elements. This solution shows us probability of customer at demand points to visit factories located. Important note is we use population density of cities to calculate "SH_i" value as mass attraction value. Factories are located in cities with respect to value which has high population densities in Market regions. So customer in factory locations is going to shop from located factory in his city with probability equals 1. According to the best solution, factories have to be located in Ankara, Konya, Kayseri and Kirikkale. This is so what we may expect intuitively because the 3 cities in the optimal solution are the most populous ones and having high customer demand.

Table-2

Optimal solution table for probabilistic values

Demand Points and SH_i Values	Factory Locations			
	Ankara	Konya	Kayseri	Kirikkale
Ankara	1,00	0,00	0,00	0,00
Konya	0,00	1,00	0,00	0,00
Karaman	0,23	0,70	0,07	0,01
Kayseri	0,00	0,00	1,00	0,00
Sivas	0,40	0,10	0,47	0,03
Yozgat	0,67	0,08	0,24	0,01
Kirikkale	0,00	0,00	0,00	1,00
Aksaray	0,53	0,40	0,04	0,03
Nigde	0,53	0,31	0,12	0,04
Nevsehir	0,57	0,28	0,09	0,05
Kirsehir	0,72	0,12	0,06	0,10

Table-3

Data table for number of constructions and population

Cities	Population	Number of Constructions per Quarter		
		2010-1	2010-2	2010-3
Kayseri	1027279	1753	2177	2242
Sivas	417756	713	886	912
Yozgat	271270	463	575	592
Ankara	4513921	16348	15814	13867
Konya	1450682	2330	2309	2726
Karaman	155932	251	248	293
Kirikkale	232990	463	458	596
Aksaray	223727	445	440	573
Nigde	158398	315	311	405
Nevsehir	151689	301	298	388
Kirsehir	154205	306	303	395

Construction and population data was taken from “Turkish Statistical Institute” TUIK (2010)

Table-3 is data of our study showing the population and number of constructions built by quarter in corresponding city regions. As decided the locations of plants to be launched, customers close to the plants composes the market regions (Table-4).

- Region1 includes only the city Ankara
- Region 2 includes the cities Konya and Karaman
- Region 3 includes the cities Kayseri, Sivas and Yozgat
- Region 4 includes the cities Kirikkale, Aksaray, Nigde, Nevsehir and Kirsehir

To find the constructions ratio of individual cities; firstly we sum the overall population including cities in their regions then we divide individual population number to all population in focused region to find population ratio. By using population ratio of each city we find number of construction produced in each city. We assume that construction number is related to number of populations.

Table-4

Profit function elements

Demand Points	FACTORY LOCATİONS							
	Ankara		Konya		Kayseri		Kirikkale	
Ankara	13867	1	0	258	0	320	0	77
Konya	0	258	2726	1	0	304	0	301
Karaman	66	369	204	119	20	317	3	412
Kayseri	0	320	0	304	2241	1	0	247
Sivas	367	442	92	500	425	196	28	365
Yozgat	399	218	45	370	141	175	7	365
Kirikkale	2	77	0	301	0	247	594	1
Aksaray	306	225	228	148	21	414	18	210
Nigde	214	346	127	255	48	349	16	286
Nevsehir	223	277	110	223	34	339	21	204
Kirsehir	285	186	48	258	22	319	40	113
	QiSHi	DijKij	QiSHi	DijKij	QiSHi	DijKij	QiSHi	DijKij
	15729	2719	3579	2737	2952	2981	728	2581
	*Mj(Sj)	--	Mj(Sj)	--	Mj(Sj)	--	Mj(Sj)	--
	136531	--	186372	--	171015	--	68264	--

***** Mj (Sj) is calculated with values are taken from websites and converted in form price of land divided by meter square of land to find price of each individual of land in meter square. We assume all factories have one thousand meter square area. Then we multiply one thousand meter square with price of each individual meter square cost of cities.

Table-4 depicting the calculations based on the profit formula according to optimal alternative.

Firstly, some values in project are taken from government websites; some values are taken from websites which are related for land cost of dedicated market regions for factory locations in meter square. In calculations we used approximate costs of lands. Then, cost of land is divided in total size of land to find square meter price. Land costs are taken for only cities in market regions. Cumulating the relevant costs we use arithmetic average for each city individually. In addition, we assumed each factory will have a size thousand meters square operation area. Cost of transportation is calculated by multiplying the quantity and per kilometers cost and the traveling distance in kilometers from demand points to factories. Cost of per kilometer transportation taken as 1 Turkish lira.

When we look at Table-2, the city Ankara gains more customer share from other factory locations. Ankara has a demand of nearly fifty percent much than the eight cities total demand. That shows the intuition that Ankara is the most important location for market region is correct. So the firm can make extra investment after project beginning. The city Kırıkkale has the lowest share between cities. This means to make an investment for this city can have financial lost for further. So we can eliminate to establish a factory in the Kırıkkale. Customer in the Kırıkkale can travel to the Ankara city. Because of distance from this city to the Ankara is closer than others. If the investor decides to launch only three plants rather than four it may be more economic.

In order to calculate profit function, predicting the price of product is important. There are two way to predict the selling price. One of them is searching the market for similar products and making an estimate depending on those products in the market. Other is calculating the costs by evaluating all operational costs take part in the process. Since every operation and production environment has its own characteristics, estimating the costs is nearly impossible before a plant is launched. We also should calibrate price to satisfy cost-revenue equilibrium. Revenue should be at least equal or more than costs calculated.

We are planning to open four factories as the request of the investor. But we may establish only one or two factories without spend more money. Actually the results show that we should open only 3. But it is obvious that opening less plant will lead to high transportation costs.

4. Conclusion

Location selection problem, having vital economic outcomes, is a widely known business operation. Placement of plants to dedicated regions plays an important role in competitive environment. To survive in such competitive environment, success of a business starts with a proper layout selection. Location is not a static term, but a dynamic criterion in business. Sometimes we should change our location to compete with rival in better way. Compelling factor is the customers' demand behavior and it mostly depends on the proximity to purchase.

In this study we tried to elaborate location selection problem of an investor planning to enter the constructions market by launching four plants in middle Anatolia which are to produce a construction element AES . We construct the problem, regarding the distances, population levels, land values as parameters and formulate a Huff based model to analyze and find the best places to locate new plants.

As a result we find the best alternative that includes three biggest cities of the region, Ankara, Kayseri, Konya and a minor city Kirikkale. We foresee the 3 largest cities been in the solution set because of their customer potential, the model also verified our expectation. Launching fewer plants will be our suggestion to investor, leading to better profit outcome.

Constructed model can be extended by relaxation of the assumptions we made. Allowing customers purchasing from other regions rather than they belong to by including a penalty cost and manipulating customer utility and sensitivity to product quality are some subjects for future prospects.

References

Abolian, R., Berman, O., Krass, D., 2007. Discrete optimization competitive facility location and design problem, European Journal of Operational Research 182, 40-62.

Bello, L., Blanquero, R., Carrizosa, E., 2011. On minimax-regret Huff location models, Computers&Operations Research 38, 90-97.

Benati, S., Hansen, P., 2002. Discrete optimization, the maximum capture problem with random utilities: Problem formulation and algorithms, European Journal of Operational Research 143, 518-530

Dias, J., Godinho, P., 2010. A two-Player competitive discrete location model with simultaneous decisions, European Journal of Operational Research 207, 1419-1432

Drezner, T., Drezner, Z., 1998. Facility location in anticipation of future competition, Location Science 6, 155-173

Drezner, T., Drezner, Z., Salhi.S. 2002. O.R applications, solving the multiple competitive facilities location problem, European Journal of Operational Research 142, 138-151.

Drezner, T., Drezner, Z., 2004. Finding the optimal solution to the huff based competitive location model, College of Business and Economics, California State University-Fullerton, Fullerton, CA 92834, USA, CMS 1: 193–208. DOI: 10.1007/s10287-004-0009-6.

Huff, D., McCallum, M.B., 2008. Calibrating the huff model using ArcGIS business analyst, An ESRI White Paper, September.

Labbe, M., Peeters, D., Thisse, J.F., (1995) Location on Networks., Ball et al., Eds., Handbooks in OR & MS, VoL 8.

Land costs in Ankara, available online at< http://www.ankaraarsa.net/>

Land costs in Kayseri, available online at< http://www.emlak.net/arsa/satilik-arsa/turkiye/kayseri/merkez/merkez.html>

Land costs in Kayseri, available onlineat <http://www.odabasiemlak.com.tr/kat.asp?id=4>

Land costs in Kayseri, available online at<http://www.kayseriemlak.com/>

Land costs in Kayseri, available online at<http://www.satilikarsa.org/category/kayseri-satilik-arsalar>

Land costs in Kayseri, available onlineathttp://www.emlak.net/index.php?action=search&searchart=arsa&typ=34&sira=1&resim=0&il=6&ilce=975&liste=1&sira=1&page=2

Land costs in Konya, available online at< http://sahraemlak.com/index.php?option=com_hotproperty&task=viewfeatured&Itemid=>

Land costs in Konya, available online at<http://www.emlak.net/index.php?action=search&searchart=arsa&typ=34&pricestart=0&priceend=0&qm1=0&qm=0&il=57&ilce=1000&td=0&resim=0&user=0&liste=1&sira=1>

Land costs in Konya, available online at <http://www.yilmazemlakofisi.com/search.php>

Land costs in Kırıkkale, available online at< http://sansal.emlak.net/arsa/4.html>

Land costs in Kırıkkale, available online at< http://www.milliyetemlak.com/satilik/arsa/kirikkale/emlak.html?lgth=2,2,79&t=2>

Land costs in Kırıkkale, available online at< http://www.milliyetemlak.com/satilik/arsa/kirikkale/emlak.html?lgth=2,2,79&t=2&PageNo=2>

Lida, T., Matsubayashi, N., 2011. Innovative applications of o.r, strategic multi-store opening under financial constraint, European Journal of Operational Research 210, 379-389.

Marianov, V., Rı´os, M., Icaza, M.J., 2008. Facility location for market capture when users rank facilities by shorter travel and waiting times, European Journal of Operational Research 191, 32–44.

Owen, H.S., Daskin, S.M., 1998. Invited Review, strategic facility location: A review, European Journal of Operational Research 111, 423-447.

Plastria, F., 2001. Static competitive facility location: An overview of optimization approaches, European Journal of Operational Research 129, 461-470.

ReVelle, C.S., Eiselt, H.A., 2005. Location analysis: A synthesis and survey, European Journal of Operational Research 165 1-19

Rhim, H., Ho, H.T., Karmakar, S.U., 2003. Competitive location and market selection, European Journal of Operational Research 149, 211-228.

Saiz, E.M., Hendrix, M.T.E., Pelegrin, B., 2010. On a Nash Equilibria of a competitive location-design problem, European Journal of Operational Research, Accepted manuscript.

Tuik, 2010. available online at< http://www.tuik.gov.tr/PreTabloArama.do?metod=search>

Turkey Statistical Yearbook, 2010. Turkish Statistical Institute. ISSN 0082-691X