International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 11, Issue 02 (February 2015), PP.79-84

A location comparison of three health care centers in Sfax-city

JLASSI Jihene*
ISGI de Sfax Route Mharza,
Km 1.5-B.P954-3018 Sfax., Tunisia

Abstract:- The problem of health facilities location is explored under a mathematical optimization approach. Several models are developed for the location of a generalized health facility system in a manner that the selected criteria are optimized. From the literature we use in our paper the criteria efficiency and availability of the service. The optimal locations satisfying two objectives, one that minimizes health care centers-patient distance and another that captures as many patients as possible within a pre-specified time or distance. The results indicate that the existing locations provide near-optimal geographic access to health care center.

Keywords:- Location, efficiency, availability, patient satisfaction, health care centers.

I. INTRODUCTION

The aim of facility location is to determine spatial position of different types of facilities in order to provide good customer service and to attain a competitive advantage.

Location problems are concerned with the location of (physical or non physical) resources in some given space.

A vast literature has developed out of the broadly based interest in meeting this challenge. Operations research practitioners have developed a number of mathematical programming models to represent a wide range of location problems. Several different objective functions have been formulated to make such models amenable to numerous applications.

The study of location theory formally began in 1929 when Alfred Weber considered how to position a single warehouse so as to minimize the total distance between it and several customers. Location theory gained renewed interest in 1964 with a publication by Hakimi, who sought to locate switching centers in a communications network and police stations in a highway system. In fact, many models have been made to help decision making in this location area. Love *et al* (1988), Francis *et al* (1992), Mirchandani *et al* (1990), Daskin (1995), Drezner *et al* (2002), Nickel *et al* (2005), Church *et al* (2009), Farahani and Hekmatfar (2009), Janis Grabis *et al* (2012) and Dominik Kress *et al* (2012).

The objective of this paper is to develop a facility location model accounting for wide range of factors affecting decision-making to compare location of three health care centers in Sfax city Tunisia.

Locating hospitals is a process that must take into consideration many different stakeholders: patients who need ready access to the facility, doctors who want attractive and easy-to-reach workplaces, taxpayers who want value for their money and politicians who want to demonstrate their ability to deliver a quality product.

There are a significant number of studies concerning the location of health care facilities. Rosenthal *et al* (2005) modeled customer and physicians' locations on a zip code level and modeled accessibility as the number of physicians per capita and the average distance between patients and physicians for rural and urban areas. Using more detail, Love and Lindquist (1995) assessed customer and hospital locations at the census block group level for the State of Illinois.

Griffin *et al* (2008) investigate a variation of the maximal covering location problem whereby the location and services offered at each location are determined. Oliveira and Bevan (2006) consider two location-allocation models for the redistribution of hospital capacity. The first model equalizes capacity utilization across facilities given each facility's predicted utilization. The second model minimizes a weighted distance between the facilities and geographic regions while considering how patient flows and demand change in response to the supply offered by hospitals. Stummer *et al* (2004) determine the location and size of medical departments.

The remainder of the paper is organized as follows. Section 2 discusses healthcare factors influencing facility location. Section 3 develops the model for determining optimal solution. Section 4 reports and discusses the results, and Section 5 contains some concluding remarks and directions for future research.

II. FACTORS INFLUENCING FACILITY LOCATION

Traditional facility location models optimize facility location cost or some kind of coverage criterion. Typical factors influencing facility location are customer demand, facility location costs and distance between facilities and customers (Owen & Daskin, 1998). However, additional factors are often considered in practice. Number of criteria that are relevant in the evaluation of health care facilities and their location will be the

quality of services (a somewhat nebulous concept that needs to be quantified and measured by an appropriate proxy), the accessibility of services, and possibly the fairness of the services. The quality of medical services could be expressed in terms of expected or worst case waiting times for a specific service, the expected success rates of necessary procedures, or others. The accessibility of services is probably easier to measure in terms of distance to a potential patient's home, or the expected coverage of the population at large within a given amount of time. Fairness, another soft concept, could be expressed as the variance of quality and availability of medical services in different regions (Burkey *et al,* 2012).
The two main criteria considered in this work are: The quality of medical service and the service availability.

III. MODEL FORMULATION

As a measure of quality of medical service, we will use the average distance (or time) between any potential patient and his closest hospital.

An important component of location modeling is distance. Most location models attempt to minimize distance, average distance (p-median), or maximum distance (p-center) (Current et al, 2002; Daskin, 1995; Love *et al*, 1988).
Our model is the p-median formulation. This formulation is formulated by Hakimi in the mid-sixties (Hakimi, 1964), has established the foundation for a myriad of location problems in the public and private sector.

The basic problem is to find P locations (in our case p health care centers) that minimize the average distance (or travel time) in a network. Only the nodes of the network need to be considered as location candidates, since there is always at least one optimal solution that consists of locating the facilities on the network nodes.

The p-median model involves the location of p facilities on the network so that total weighted distance is minimized. It is assumed that each demand is served by their closest facility. Given that Hakimi (1965) proved that there is always at least one optimal solution to a p-median problem that consists entirely of nodes of a network, virtually all solution methods have been based on the search for the best solution comprised entirely of nodes.
Consider the following notation:

- i: index of customer locations (potential patients)
- j: index of potential facility locations
- d_{ij} shortest distance from node i to node j, (distance between a customer i and a facility j)
- a_i: demand at node i, (customers at point i)
- y_j= 1 if a facility is sited at site j and demand at j assigns to it as well (yj assume a value of one, if a facility is located at site j)
- 0 otherwise,
- x_{ij}= 1 if demand at i assigns to facility at j (xij express the proportion of customer i's demand that is satisfied from facility j)
- 0 otherwise,
- p the number of facilities that are to be located.

Using the notation deﬁned by ReVelle and Swain (1970), and actualized by (Marianov et al, 2011) (Burkey *et al*, 2012), formulated the p-median problem as an Integer Linear Problem(ILP):

$$Min\ Z = \sum_{i=1}^{n}\sum_{j=1}^{n} a_i d_{ij} X_{ij} \quad (1)$$

$$St\ \sum_{j=1}^{n} X_{ij} = 1 \quad for\ each\ i = 1, 2, \dots, n \quad (2)$$

$$\sum_{j=1}^{n} Y_j = p \quad (3)$$

$$X_{ij} \le Y_j \quad for\ each\ i = 1, 2, \dots, n \quad and \quad j = 1, 2, \dots, n \quad where\ i \ne j \quad (4)$$

$$X_{ij} \ge 0 \quad for\ each\ i = 1, 2, \dots, n \quad and \quad j = 1, 2, \dots, n \quad (5)$$

$$Y_j = 0\ or\ 1 \quad for\ each\ j = 1, 2, \dots, n$$

The objective seeks to minimize the total weighted distance of all demand assignments. Constraints of type 2 ensure that each demand must assign exactly once. The fourth type of constraint maintains that a demand cannot assign to a node unless that node has been selected for a facility. Since the objective minimizes the distances of assignments, constraints of type 2 and 4 in concert with the objective ensure that at optimality, each demand assigns to their closest located facility. The third constraint fixes the number of located facilities to be equal to p. Note that in solving this model, it is only necessary to require the Yj variables to be zero-one.

In the context of this study, the problem locates a given number of p health care centers, so as to minimize the average patient-hospital distance.

The service availability may be measured as the proportion of the population that is located within a prespecified distance D from their nearest facility (Burkey *et al*, 2012).

All authors use travel time rather than distance, as distance is just a proxy for time. We decided to use 30 minutes in this study as a goal. (Bosanac, 1976) (Carr , 2009) (Frezza,1999)

This factor is presented by another model in location theory. The Maximal Covering Location Problem.

A well-known type of location problems, which has been studied since the very beginning of location science, is the covering location problem (CLP). It seeks a solution to cover a set of demands while one or more objectives are to be optimized. There are two distinct categories of CLPs in the literature as maximal covering location problem (MCLP), and set covering location problem (SCLP). Regardless of type of the problem, a population is covered if it can be reached within a pre-defined time/distance by one or more facilities. While a SCLP calls for covering all the demand nodes with the least possible number of facilities, MCLP is associated with covering the maximum possible demand with a known number of facilities. MCLP was first introduced by Church and ReVelle (1974) on networks. Since then, numerous applications and theoretical extensions to the classical model of MCLP have been presented.

In order to formulate the problem, define the set Ni= {j: dij <D} as the set of all departments' hospitals that ware no farther away from patient i than the "service level" distance D. Furthermore, we will use the binary variables Yj defined earlier. In addition, we need coverage variables Xi, which assume a value of one, if all patients at site i are within distance D of any of the hospitals. We can then formulate the maximal covering location problem as:

- S: The distance (or time) standard within which coverage is expected,
- N_i: {j | dij ≤ S} = the nodes j that are within a distance of S to node i,
- X_i: A binary variable which equals one if node i is covered by one or more facilities stationed within S and zero otherwise.

$$Max\ Z = \sum_{i=1}^{n} a_i X_i \qquad (1)$$

$$St \sum_{j=1}^{n} Y_j \geq X_i \quad i = 1, 2, \ldots, n \qquad (2)$$

$$\sum_{j=1}^{n} Y_j = p \qquad (3)$$

$$0 \leq X_i \leq 1 \quad i = 1, 2, \ldots, n \qquad (4)$$

$$Y_j = 1\ or\ 0 \quad j = 1, 2, \ldots, n \qquad (5)$$

IV. EVALUATION OF HEALTH CARE CENTERS LOCATIONS IN SFAX

For the purpose of evaluating actual situations on the criteria delineated in the previous section, we have chosen three health care centers that are comparable in size, population and density. These centers are: Agareb, Mahres and El Hencha. Table 1 presents the basic information (Sfax 2010).

TABLE1. DESCRIPTIVE STATISTICS

Regions	population	Land area	Pop/Km^2
Agareb	38 158	737,07	51,77
Mahres	31 849	445,65	71,46
El Hencha	44 761	529,32	84,56

In this case we take three samples each represents 50 patients.
Tables 2, 3 and 4 indicate that there is a very strong correlation between distance and time.

TABLE2. ACTUAL RESULTS

Centers	Mean distance	Mean time	Pop	Pop<30min	%<30min
Agareb (A)	7,2	14	50	32	64
Mahres (M)	8,3	15	50	30	60
El Hencha (E)	8,4	15,5	50	29	58

TABLE3. OPTIMIZATION RESULTS (P-MEDIAN)

Centers	Mean distance	Mean time	Pop	Pop<30min	%<30minu
A	6,16	13,5	50	37	74
M	7,1	14,8	50	33	66
E	7,15	14,9	50	31	62
Overall mean					

TABLE4. OPTIMIZATION RESULTS (MAX COVER STATE)

Centers	Mean distance	Mean time	Pop	Pop<30min	%<30min
A	8,6	16,1	50	39	78
M	9,2	17,2	50	35	70
E	9,3	17,3	50	33	66
Overall mean					

Tables 2, 3 and 4 clearly show that actual solution and that of the p-median problem are quite similar.
In both tables 5 and 6 "x% more quality of medical service" means x% less time.

TABLE5. IMPACT OF USING P-MEDIAN SOLUTIONS

Centers	Quality of medical service	Service availability
A	7,62% more	10% more
M	5,33% more	6% more
B	6,1% more	4% more
Average	6,35%	6,67% more

Table 5 indicates that on average, the p-median solution is able to improve the actual situation of the quality of medical service and the service availability by about 6%.

TABLE 6.IMPACT OF USING OPTIMAL MAX COVER SOLUTIONS

Centers	Quality of medical service	Service availability
A	1,2 less	14% more
M	2,3% less	10% more
B	1,34 less	8% more
Average	1,63 less	10,67% more

Table 6 presents The max cover solution which significant decreases of 1,6% in quality of medical service and some increase of service availability.

V. CONCLUSION

The location decision describes, given a set of alternatives, the problem of where to locate an organization's facility (Melo *et al*, 2009).

The optimal locations, studied in this paper, satisfying two objectives, one that minimizes health care center -patient distance and another that captures as many patients as possible within a pre-specified time or distance. The purpose of this study was to provide us with a theoretical optimum that can be used as a benchmark to evaluate the existing locations on.

Remarkably, we found that the existing health care centers locations in these regions are very efficient relative to the optimized set of locations. Similarly, the existing locations provide a good level of service availability.

Another avenue for future research could be to add other criteria in the model and to add other health care centers of the region.

REFERENCES

A. Weber, Uber den Standort der Industrien (Alfred Weber's Theory of the Location of Industries), University of Chicago, 1929.

[1]. S.L. Hakimi, Optimum locations of switching centers and the absolute centers and medians of a graph, Operations Research 12 (1964) 450-459.

[2]. Love, R., Morris, J., & Wesolowsky, G. O. (1988). Facility location: Models and methods.

[3]. Amsterdam, The Netherlands: North-Holland.

[4]. Francis, R. L., McGinnis, L. F., & White, J. A. (1992). Facility layout and location: An analytical approach (2nd ed.). Englewood Cliffs, NJ, US: Prentice-Hall.

[5]. Mirchandani, P. B., & Francis, R. L. (Eds.). (1990). Discrete location theory. New York, US: Wiley-Interscience-Interscience.

[6]. Daskin, M. S. (1995). Network and discrete location: Models, algorithms and applications. New York, US: John Wiley and Sons.

[7]. Drezner, Z., & Hamacher, H. W. (Eds.). (2002). Facility location: Applications and theory. Berlin, Germany: Springer-Verlag.

[8]. Nickel, S., & Puerto, J. (2005). Location theory: A unified approach. Berlin, Germany: Springer Verlag.

[9]. Church, R. L., & Murray, A. T. (2009). Business site section, location analysis and GIS. New York: Wiley.

[10]. Farahani, R. Z., & Hekmatfar, M. (Eds.). (2009). Facility location: Concepts, models, algorithms and case studies. Heidelberg, Germany: Physica Verlag.

[11]. Janis Grabis., Charu Chandra., Janis Kampars. (2012). Use of distributed data sources in facility location. Computers & Industrial Engineering 63 (2012) 855–863.

[12]. Dominik Kress., Erwin Pesch. (2012). Sequential competitive location on networks. European Journal of Operational Research 217 (2012) 483–499.

[13]. Rosenthal M, Zaslavsky A, Newhouse J. The geographic distribution of physicians revisited. Health Services Research 2005;40(6 Part 1):1931e52.

[14]. Love D, Lindquist P. The Geographical accessibility of hospitals to the aged: a GIS analysis within Illinois. Health Services Research 1995;29:629e51.

[15]. Griffin, P., Scherrer, C., Swann, J., 2008. Optimization of community health center locations and service offerings with statistical need estimation. IIE Transactions 40 (9), 880–892.

[16]. Oliveira, M., Bevan, G., 2006. Modelling the redistribution of hospital supply to achieve equity taking account of patient's behavior. Health Care Management Science 9 (1), 19–30.

[17]. Stummer, C., Doerner, K., Focke, A., Heidenberger, K., 2004. Determining location and size of medical departments in a hospital network. Health Care Management Science 7 (1), 63–71.

[18]. Owen, S. H., & Daskin, M. S. (1998). Strategic facility location: A review. European Journal of Operational Research, 111(3), 423–447.

[19]. M.L. Burkey, J. Bhadury, H.A. Eiselt. (2012). A location-based comparison of health care services in four U.S. states with efficiency and equity. Socio-Economic Planning Sciences 46 (2012) 157e163.

[20]. Bosanac EM, Parkinson RC, Hall DS. Geographic access to hospital care: a 30-minute travel time standard. Medical Care 1976;14/7:616e24.

[21]. Carr BG, Branas CC, Metlay JP, Sullivan AF, Camargo Jr CA. Access to emergency care in the United States. Annals of Emergency Medicine 2009;54(2):261e9

[22]. Frezza EE, Mezghebe H. Is 30 minutes the golden period to perform emergency room thoratomy (ERT) in penetrating chest injuries? Journal of Cardiovascular Surgery (Torino) 1999;40(1):147e51.

[23]. Current, J., Daskin, M., Schilling, D., 2002. Discrete network location models. In: Drezner, Z., Hamacher, H.W. (Eds.), Facility Location: Applications and Theory, Springer-Verlag, Berlin, pp. 81–118.
[24]. Daskin, M., 1995. Network and Discrete: Location Models, Algorithms, and Applications. John Wiley, New York.
[25]. Love, R.F., Morris, J.G., Wesolowsky, G.O., 1988. Facilities Location: Models & Methods. North Holland, New York.
[26]. Hakimi SL. Optimum distribution of switching centers and some graph related theoretic problems. Operations Research 1965;13:462–75.
[27]. ReVelle CS, Swain R. Central facilities location. Geographical Analysis 1970;2:30–42.
[28]. Marianov V, Serra D. Median problems in networks. In: Eiselt HA, Marianov V, editors. Foundations of location analysis. International series in operations research & management science, vol. 155. Springer-Verlag; 2011. p. 39e59. Chapter 3.
[29]. R. Church, C.S. ReVelle, The maximal covering location problem, Papers of the Regional Science Association 32 (1974) 101–118.
[30]. ReVelle, C., Scholssberg, M. and Williams, J. ‘‘Solving the maximal covering location problem with heuristic concentration’’, Computers & Operations Research, 35(2), pp. 427–435 (2008).
[31]. Melo, M. T., Nickel, S., & Saldanha-da-Gama, F. (2009). Facility location and supply chain management – A review. European Journal of Operational Research, 196(2), 401–412.