Geography and human relationships, supplement1, winter2019

Investigation of spatial distribution and optimal site selection of fire station in Iran- A case study of Tehran Township using GIS (AHP model)

Lotfali Kozegar Kaleji

Assistant Prof., in Geography & Urban Planning, Shahid Beheshti University, Tehran, Iran

Submit date: 12/09/2019 *Accept date:27/09/2019*

Abstract:

Firefighting station are one of the elements of public security in the city.to make them have the supposed role in public security; we should look at different urban facilities in detail and lend the city structure as a whole. Appropriate site selection of firefighting stations is one of the most important obligations of the city planners, which should be carefully planned and implemented. Better site selection is meant to avoid waste of resources in one hand and better capability of the stations on the other hand. In this research, best sites for the construction of new stations and moving of those stations with improper location in Tehran city has been studied. First, conceptual model of the study was defined, then, spatial layers and other information about site selection of the stations collected.in the next session Analytical Hierarchy process used to assign weights to spatial layers. This process was done based on the expert's views and pair wise compactionmethod. After collection of expert views and in order to avoid wrong views, judgment compatibility amounts were calculated. After accepting of CR values, these weights used in future analyses. Network analysis, one of GIS spatial functions, used to find best routes from fire stations to affected area and service area of each station. Based on the analyses of this section and field checks, gave good attitude in terms of stations functionality. Regarding to the locations of existing stations, new stations proposed using a moving widow on the potential sites map.

Key Words: *GIS, firefighting stations, site selection, AHP model, network analysis.*

1- Introduction

Today, one of the most important factors and major considerations in designing and planning and the civic management, is to protect and keep the urban basic structure safe against dangers resulting from disasters and events including earthquake, fire after earthquake with the characteristics of the city of Tehran, extensive fire at the critical level, manmade events etc. What is obvious is that if the safety of the city is not addressed in a complete and all-inclusive form, it not only fails to meet the general safety requirements but also will incur heavier costs on the citizens for completion of measures and activities in future and undoubtedly, the immunization of Tehran mega city, shall not be carried out automatically and without having any plan, and having a constant and stable planning in this area seems inevitable. Optimal location of fire stations is influenced by different criteria and measures, the study of which within traditional framework and using paper plans are very difficult. In the recent years, GIS has created undeniable developments in such areas as geographical studies and organization and management of spatial data. Due to such features as the ability to receive and exchange date from different resources, data organization, timely receiving and displaying of data, combination of various data and the possibility of rendering multi-purpose services, this technology has opened new horizons for the researchers, so that since years ago, the technology has been implemented in numerous areas and its importance is increasing on a daily basis. Since the modern GIS technology systematically integrates all effective measures and layers on the city system, while analyzing the problems challenging current situation of the function of fire stations, it is able to provide the basis for their future functions through optimally locating them. Therefore, in this research, based on principles and measures GIS design, the effort is made to use spatial decision support systems (SDDS), especially analytic hierarchy process (AHP) and combine it with Geographical Information System (GIS) features for the regions that are located outside the operational limits of the existing stations, new stations are located and proposed, so that the new proposed stations and the existing stations in the city are able to cover the whole city based on the standard for arrival of the fire engines to the fire point, being 3 minutes in the world and 5 minutes in Iran.

2- Review of literature

GIS have been defined as automated systems for the capture, storage, retrieval, analysis and display of spatial data (Clarke, 1995). Today, using the models and software in urban planning became prevailed with respect to the complex dimension of the urban issues and the role of many different indicators in this field. Geographical Information Systems is one of the powerful tools to response the request of such study. In 1987 it was reported that "up to 20% of local government expenditures are spent on public fire protection" (Mirchandani, 1987). Li and Yeh (2005) used Genetics Algorithm in GIS environment for selection of multi-purpose sites. Based on the resulted obtained from this research, the ability of genetics algorithm played an important role in solving the optimization of highly complicated issues in a constant space Kontoset al. (2005) used AHP in conjunction with GIS in order to find suitable sites for landfill for an island in Greece using 10 suitability criteria taking into account both environmental and social variables and individual site

constraints GIS contributes to the speed with which emergency responders are able to locate, respond size up, and deploy to an emergency (ESRI, 2006), while studying the site selection methods and patterns like the theory of central site selection, numerical taxonomy model, Larry model and random models, were able to provide the ability of GIS compared to other models for locating the fire stations in the city of Tabriz (Parhizgar, 1997).

Shahabian (1997), used GIS to address the spatial site selection of fire stations in the northwest of Tehran.

Farhadi (2000), using such criteria as access radius, condensation and relation with different land use by the use of multi-weighing in combination of the layers, located the schools in Dist. 6 of Tehran. Abbas Poor (2001), using radius method, Tisian polygons and network analysis located the fire stations while studying the distribution of fire accidents in the city of Karaj. Montazeri (2003), located the urban services centers, with an emphasis on the fire stations in the city of Sari. Mahdipour (2006), in a research called "locating en route service-welfare complexes of the Ministry of Road and Transportation in Tabriz-Bazargan Transit Corridor" used geographical information systems and genetic algorithm model to locate the said facilities.

3- Statement of the problem and its significance

The review of the studies and analyses done with regard to fire events and the way of performance of fire stations can be an indicative of this fact that there are some major limitations and failures in identifying the position of fire stations and the desirable operations of stations. We can classify these problems and failures as follows:

- *Lack of adaptation between the location and covering radius of stations with potential centers of fire.*
- *Lack of proportion between the numbers of stations with the number of covered population.*
- *Lack of proportion between geographic distribution of the stations and urban requirements and structure.*
- *Lack of proportion between geographic distribution of the stations and time coverage standards.*
- *Insufficient number of stations with regard to the criteria of population and the area of cities.*

Taking the importance of this issue and the existing problems into account, this study will try to reduce these problems by implementing new methods and considering some applied criteria.

3-1- Objective

- *To study the distribution and location of existing fire stations in Tehran.*
- *To determine the optimal locations for establishing fire stations in Tehran*

3-2- Hypotheses

Referring to the primary objectives of the study, the main research hypotheses raised here are as follows:

- *Location of fire stations and urban services are not optimal in Tehran city at present.*

- *GIS (AHP model) is a desirable system for locating urban services in Tehran city with regard to interference of different variable in urban planning in their systematic performance.*

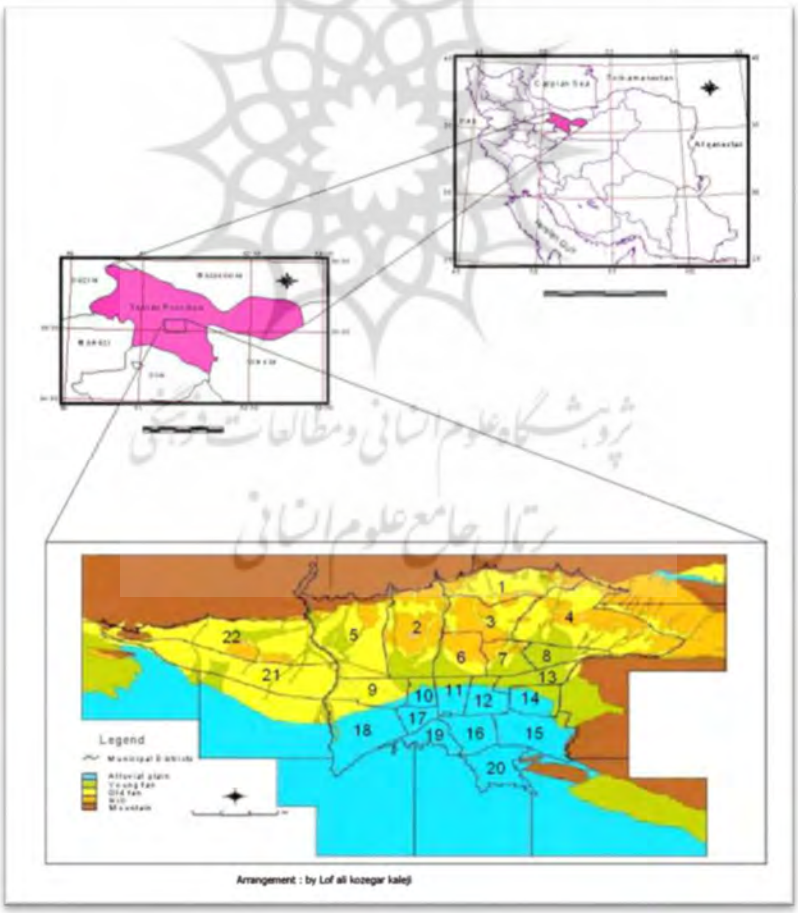
4- *Material and Methodology*

4-1- Study area

Tehran is the capital and largest city of Iran, and the administrative center of Tehran Province, is located between the latitudes 35°31′ and 35° 50′ N. and longitudes 40° and 51° E. Tehran is a sprawling city at the foot of the Alborz mountain range (the highest point in the Middle East (1,191 m, 3,900 ft)) with an immense network of highways unparalleled in Western Asia. Tehran is the largest city in the Middle East and is the most populated city in South Western Asia with a population of 7,404,515 and approximately 15 million in Greater Tehran .

Tehran city from view of geographically in 51 degrees and 8 minutes until 51 degrees and 37 minutes east longitude and 35 degrees and 34 minutes until 35 degrees and 50 minutes north latitude.

Figure 1: study area



4-2- Methodology and Data collection method

In order to prepare data and do subsequent actions, the following software has been used:

- *Autodesk Map software for editing and converting DWG format plan*
- *ArcView3.2 to change the data format of dwg to Shp*
- *ArcGIS 9.3 for doing location analysis, creating topology and providing the network of city transportation, performing network analysis and combining and integrating effective layers in the process of positioning*
- *IDRISI 15 software for weighting effective hierarchical criteria in positioning fire stations*
- *A large amount of data was collected for the purpose of achieving objectives, among which some has been referred to in the following. It should be noted that the coordinate system of all collected data, if necessary, has been converted to the reference coordinate of this research, i.e. UTM with WGS84 level and north 39 zones.*
- *1:10000 map of Tehran city, in which the user had been identified as the main base of positioning analysis and providing urban network, was used. As far as format is concerned, the dwg format was implemented; however, it was necessary to clarify and change format in order to enter the GIS environment.*
- *Getting information about the amount of traffic in the streets of Tehran during peak hours in order to determine the route of facility vehicles is of high degree of significance. This layer of information was provided by Organization of Tehran's Traffic Studies. Its original format was DWG format but it changed to shp format for entering GIS environment.*
- *Getting information about the speed of pavements and streets in Tehran in peak hours of traffic: Knowledge about the amount of the speed of streets in order to determine the functional radius of the fire stations and the essential time for giving facility or relief is of paramount importance. This layer of data was also provided by Organization of Tehran's Traffic Studies and it was changed to shp from DWG for the purpose of entering GIS environment.*
- *Data layer of pavements and transportation network in Tehran, which was extracted from 1:2000 maps of city and produced by Studies Center of Tehran Municipality.*
- *land use layer provided by GIS Centre of Tehran Municipality*
- *Information about population density in different parts of Tehran in order to prepare the map of population density, which was provided by Statistical Center of Tehran.*
- *Information related to the price of urban land: In order to evaluate the value of property and its impact as a factor in positioning stations, the information related to the price of properties and urban lands was implemented regionally.*

In the next step, after determining the study area and the effective factors in site selection, the locating operations with the use of different combination models like index overlay, weight of evidence are carried out, taking into account the conceptual design of site selection.at the end, after evaluation of the results, appropriate models and sites are selected.

In this present study an effort has been made to use the spatial decision support systems (SDDS), especially analytic hierarchy process (AHP) and combined with Geographical Information System (GIS); for the regions that are located outside the operational limits of the existing stations, new optimum locations have been proposed.

4-3- The history of firefighting and its current situation in Tehran

As the current study is focused on efficient location of firefighting stations in Tehran and according to the importance of security and safety obstacles of the cities, we will discuss on Iran and the world firefighting records and also, the history of giant firehappenings.

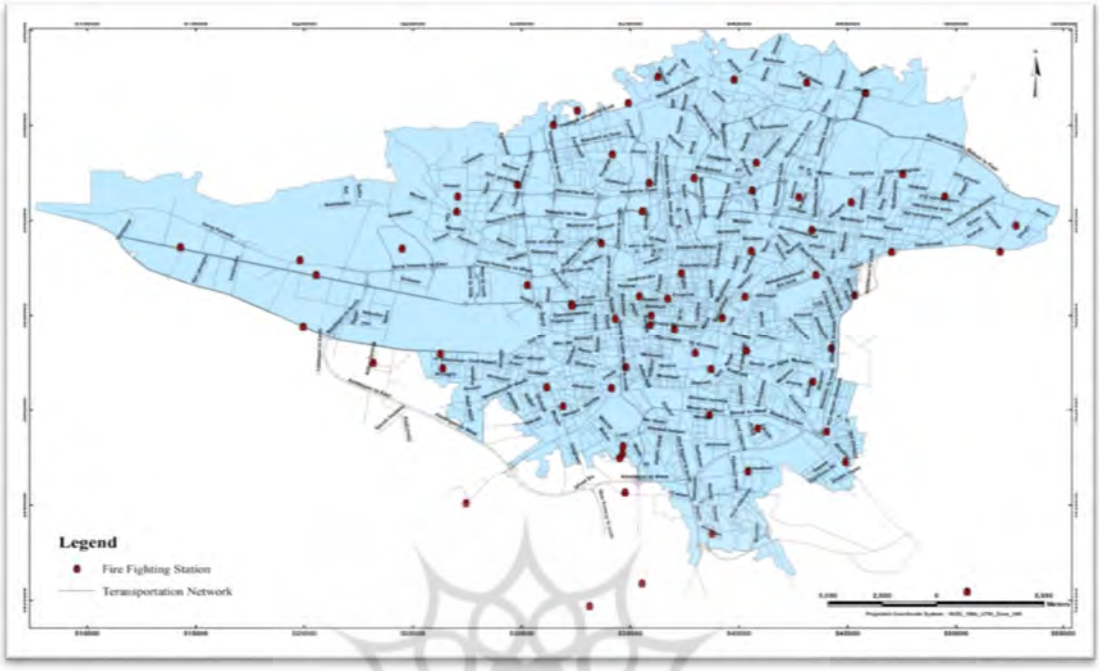
The history of fire fighting in the world dates back to the time when man was able to discover fire. Therefore, without referring to any historical documents, we can speculate that man has been exposed to the hazards of fire when he discovered it. Of course, there are a lot of documents available to confirm this claim. In addition to the awful and terrifying fires which have occurred in Iran, the people from other countries have also experienced the heavy damages arising from intentional or accidental fires. There have been a few articles about the appearance and evolvement of firefighting methods which most of them are in relation with the method of firefighting execution and progress in Tehran. The subject has some statistical and informational differences related to the history and evolvement of firefighting problems faced. However, according to the articles and the information of some books and publications resulted from the questionnaires of the homeland firefighting, we will discuss the revealing and changes of firefighting in Iran in following periods framework.

- *Firefighting in Iran from the beginning to 1921*
- *Firefighting in Iran from 1921 to 1961*
- *Firefighting in Iran from 1961to 1978*
- *Firefighting in Iran after 1978*

5- Existing firefighting station in Tehran

With the expansion of the activities of Tehran municipality in recent years and the necessity of expanding secure spaces and deepening and generalizing safety culture in all part of Tehran, some fundamental plans such as the education of citizens and the creation of appropriate structures and buildings which should be secured and resisted against earthquake and be in accordance with international standards have been high on the agenda. Currently the Great Tehran includes 79 fire stations which are doing their activities in five districts in all parts of Tehran. However, this number of stations cannot satisfy the needs of a city like Tehran. Therefore, the expansion of the network stations as well as the assistance, rescue and education of citizens are still followed. Nowadays, the number of citizens who have been trained for dealing with fire and other disasters has increased from 800 thousands in 1379 to several million people in recent years. The scattering and geographical distribution of the existing fire stations in Tehran has been shown in the following figure.

Figure 2: Distribution of the existing fire stations in Tehran



6- The evaluation or weighting of criteria and regulations by AHP method

Among weighting or evaluation methods, the Analytic Hierarchy Process (AHP) was used for weighting variables in this study. It should also pointed out that, despite the existence of some of the necessary standards in connection with the weighting criteria, some amounts have been reduced based on the comment of some experts in order to make this research more functional. The AHP method is more useful because it emphasizes user as base and considers the knowledge of experts, in comparison to other weighting methods, which were explained in the previous chapter. In order to reduce prejudiced and personal errors of experts in weighting analytic hierarchy process, the amount of their compatibility has been computed in the IDRISI software. Then, the obtained weights were used for analysis after they were recognized as compatible. The following tables indicate the pair comparison of effective factors in the process of positioning fire stations, along with the amounts of adjustment rate. It should be noted that the paired comparison of effective factors and criteria in the process of positioning fire stations have been conducted at two levels. At the first level, paired comparison of some criteria including the level of accessing pavements for the existing stations, land use, land price, and population density has been made while at the second level, a paired comparison of the sub-criteria of each factor has been investigated.

6-1- Paired comparison of effective criteria in positioning fire stations (Level one)

Indicates the paired comparison of effective criteria in positioning fire stations at level one. As it is evident from this table, the importance of each of these criteria has been compared in a pair and matrix framework. Four criteria have been arranged in a framework of first line and first column. At the diameter of this matrix, the criteria have been compared with themselves, which is considered as a reason behind giving them number one. In paired comparison, one half of matrix is the reverse of another half. In this study, the criteria in numerical range of 1/9 to 9 are compared in a paired manner. The more the number given to the criterion is close to 1 indicates the importance of that criterion in the analysis. Based on this, in Table6-1, the determining factors at first level of positioning fire stations were compared two by two. For example, in comparing land price and land use, the value or importance of the land in the analysis equals to 0/125 of the value of land use. In other words, land use is 8 times more important out them land values. The amount of the compatibility ratio (CR) of these paired comparisons was obtained in the environment of IDRISI software, which equals to 0/0345. It should be noted that the CR which is smaller or equal to 0/1 is acceptable in hierarchical analysis.

6-2- Paired comparison of effective sub-criteria in positioning fire stations (Level two)

Paired comparison of land use sub-criteria

The paired comparison of eight users have been done including the users of residential, commercial, schools, hospitals and community health centers, gas stations and fuel stations, passenger terminals, subway stations. The value of 1/2 was given to the commercial user in comparison to residential user. That is, the value of the residential user is two times more than the business user from the positioning of fire station point of view. Gas stations, fuel and storage stations, which have a higher risk probability with regard to their essence, in comparison to residential areas, have given number two. In other words, the importance of gas stations and fuel storage places is two times more than the residential areas. Therefore, fire stations should be placed near gas stations and fuel storage places.

The paired comparison of the sub-criterion of closeness and access level to pavements

The sub-criteria of closeness and access level to pavement and street network have been evaluated at second level in Table 1. The basis for evaluating and weighting is the Analytic Hierarchy Process (AHP).

Table1: The paired comparison of the sub-criterion of closeness to pavement network

	Less than 2 minutes	***Between 2-3 minutes***	***Between 3-4 minutes***	***Between 4-5 minutes***	***More than 5 minutes***
Less than 2 minutes	*1*	*2*	*4*	*6*	*8*
Between 2-3 minutes	*0.5*	*1*	*2*	*4*	*6*
Between 3-4 minutes	*0.25*	*0.5*	*1*	*2*	*4*
Between 4-5 minutes	*0.1667*	*0.25*	*0.5*	*1*	*2*
More than 5 minutes	*0.125*	*0.1667*	*0.25*	*0.5*	*1*

The amount of compatibility ratio (CR), obtained from these paired comparisons, equals to 0/0103, which is acceptable.

Paired comparison of density population sub-criterion

One of the important criteria in positioning the fire station is population density data. As it is clear from table 6-4, like other criteria, a matrix was prepares for this criterion based on the importance of its sub-criteria to each other. The following five criteria have been considered for population density including: 0 to 200 persons in hectares (ha), 200 to 500 persons in ha, 500 to 1000 persons in ha, 1000 and 2000 persons per hectare and more than 2000 persons per hectare. In the table of paired comparison of population density sub-criterion, the importance of the density of 200 to 500 persons per hectare is two times more than the importance of the density of 0 to 200 persons per ha and the importance of the density of 2000 persons is defined six times more than the density of 0 to 200. The amount of compatibility ratio (CR), obtained from these paired comparisons, equals to 0/0111, which is acceptable.

Paired comparison of land price sub-criterion

Another criterion which has been considered in this research is land price. Based on this, those places having less land price have more value for establishing fire stations. For example, according to table 6-5, the land which is cheap has half degree of importance, in comparison to the cheapest land. In other words, the value of the cheapest land has been considered two times more than the land with cheap price. The same method has been considered for other elements of matrix. As another example, the cheapest price is 8 times more important than the most expensive land in positioning fire stations. The CR amount for this matrix equals to 0/0268, which is acceptable.

Weighting the effective criteria in positioning fire stations (within group and outside group)

After the evaluation and paired comparison of the criteria and sub-criteria in positioning fire stations, within-group and outside-group weighting was done by AHP method. Table 5-6 shows the obtained results of this weighting. It should be mentioned that within and outside-group weighting of effective criteria has been computed by AHP method while the weighting of land use sub-criterion is based on internal weights of experts. Therefore, the weights between different users have been computed by AHP method.

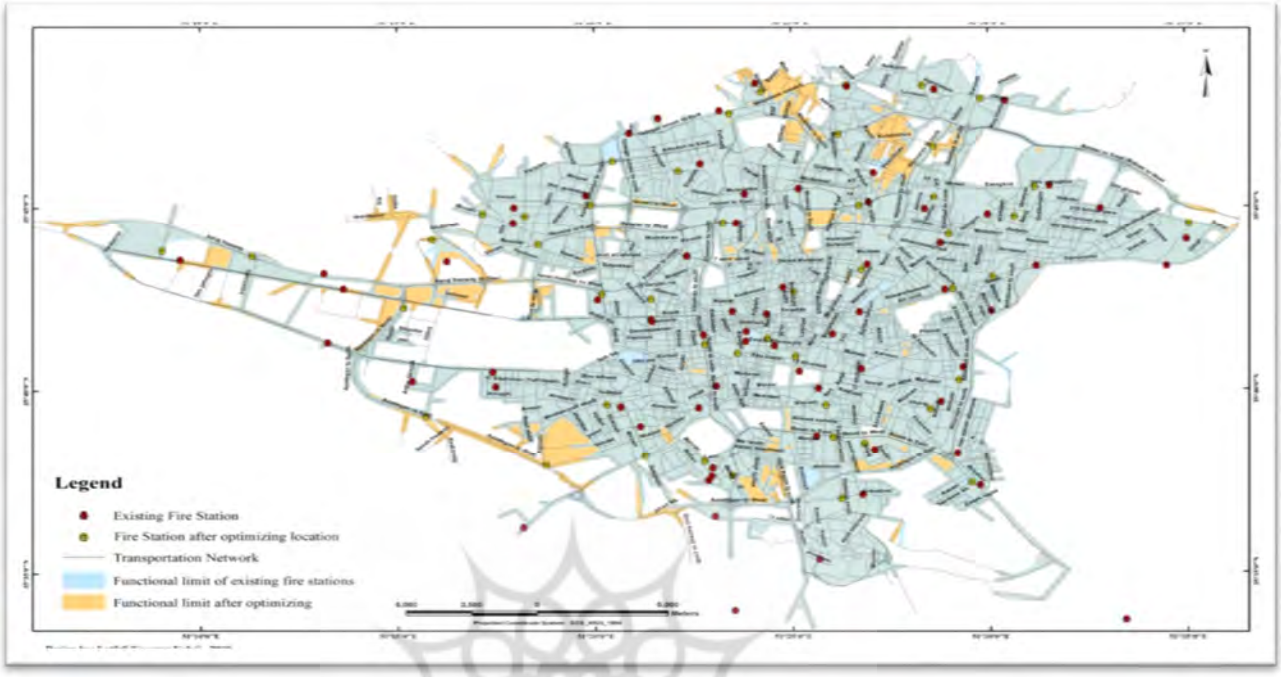
Providing the map resulting from weighting criteria and their within-group combination

After weighting the effective criteria in positioning fire stations, the map was provided for each of these criteria and the weighting of different regions of the city was determined based on the kind of criterion. In the following, the details about each of these maps are explained:

Figure 3: Functional limit of fire stations in Tehran city before optimizing location within 5 minutes

Figure 4: Functional limit of fire stations in Tehran city after optimizing location within 5 minutes

Figure 5: Comparative map of functional limit of fire station in Tehran city within 5 minutes



7- *Conclusion*

The results of this research are as follow:

Before optimal positioning

1. The area of facility service regions of fire stations in Tehran without removing the common area between them= 373768268 m/sq.

2. The total area of facility service regions of fire stations in Tehran after removing the common area between them= 365176952 m/sq.

3. The total area of the regions of Tehran city= 568507240 m/sq.

4. The percentage of facility service regions of fire station in Tehran= 64/23%

After optimal positioning

1. The number of stations was reduced from 74 to 68 due to the large number of common areas between facility service limit.

2. The area of facility service regions of fire stations in Tehran without removing the common area between them= 948281535 m/sq.

3. The total area of facility service regions of fire stations in Tehran after removing the common area between them= 387040948 m/sq.

4. The percentage of facility service regions of fire station in Tehran= 68/08%

As it is observed, the percentage of the range of facility services has increased after moving and optimal positioning of the existing stations in spite of a reduction in the number of fire stations.

- *Regarding the application of the AHP techniques, the advantage of this methodology integrated in GIS as relatively common tools for a number of researches like the one reported here is worth mentioning, where there are several factors and variables influencing in the occurrence of a given fact, phenomenon or objective and there are several viewpoints in the decision-making process. Furthermore, these allow us to handle the assessment in a quantitative way, providing us greater real-world approximation validity and less subjectivity in the analysis and selection of criteria.*
- *Another important reason for using AHP is that they make it possible to assess all criteria simultaneously, with no need to carry out several map-overlaying operations, modifying value attributes using a constant value and making a final map reclassification resulting from the combination of all criteria layers.*
- *The numbers of fire station are inadequate as more than 8000000 people live in the study area. Now, the area needs optimal site for fire stations to have sufficient coverage and quick response to the fire events.*
- *Fire stations have a right to cross one-way streets but, according to field studies, due to narrow width of the streets in Tehran city, making use of one-way streets against the route of fire station's duration is not possible in some routes.*
- *The maps of 1:10000 and 1:20000, which were used for urban network had some problems and needed revision, resulting in lengthening the process of doing research.*
- *The weighting method of AHP has shown to include high potentialities because of its base user and its control of expert assessments with CR index and its lack of sheer dependency on theoretic laws. Therefore, it can be implemented for similar circumstances.*
- *CR amounts, the paired comparisons which were determined as base user, were less than one percent for all factors in the first time. Therefore, there is no need to perform matrix again.*
- *With respect to urban users, five major users have been incompatible in relation to the location of fire stations. Among them, the factor of health care user has played the highest role and inter-city terminal as the lowest role in positioning fire stations.*
- *In addition, those users which are compatible with the location of fire stations ranked 8, among them the user of gas or petrol station and the place of fuel provision had the highest impact and airport as the lowest.*
- *Among the existing factor at the level of Analytic Hierarchy Process, the closeness to streets has the highest impact on positioning stations. The above results seem logical by regarding the role of urban transportation network in providing facility.*
- *The following are the obtained results of the network analysis of fire stations in Tehran city based on the time of 5 minutes before and after optimal positioning.*

8- ***Suggestions***

- *Factors such as traffic lights, speed bumps, secondary passages and other effective factors should be taken into consideration in controlling traffic*
- *Application of other effective factors in locating fire stations such as the material of those things which are used for building, urban structure, etc. should be regarded.*

- *Other methods of weighting and integrating data such as Phasic model and neural- phasic models should be applied for integrating and modeling in order to reduce weighting error in AHP model*
- *The use of Artificial Neural networks can be effective in real time simulation of urban transportation network which facilitate the amount of time for providing facility for the incidents related to fire stations. Making use of this method is suggested for future studies.*
- *The application of genetic algorithm is an appropriate method for solving the problems related to the determination of the route of facility cars. Therefore, the use of this kind of algorithm is suggested for determining the route of firefighting cars in which the time factor is of a high degree of importance.*
- *The use of Cellular Automata method for the purpose of evaluating and studying carefully the direction of future development of the city can provide GIS with locating fire stations for purpose of using it in a longer time.*
- *Various factors can play a role in positioning fire stations but the analysis of all these aspects is not possible by traditional methods. On the other hand, lack of attention to these factors in positioning leads to the wasting of a significant share of materialistic resources, the loss of a large amount of environmental resources and creating a heavy damage to people and urban management. Therefore, the use of information technology, particularly Geographical Information System for analyzing a large volume of data seems necessary.*
- *Use of hierarchical analysis process (AHP) and Geographic Information System (GIS) has an effective role in positioning fire station (and generally in selecting the optimal location of a site). This kind of efficiency is related to the possibility for comparison and evaluation of different places and selection of optimal site with respect to the related criteria.*
- *Use of information technology and Geographical Information System for managing a city is achieved when the required spatial and descriptive data exist with the necessary accuracy. Also, it is necessary to create a spatial database for managing a city in 21st century, where all the maps, statistics and other descriptive information can be stored in an integrated way and all the managers of the city should be provided with this kind of database in order to make correct decisions.*

REFERENCES

- *Abdollah-Khan-Gorji,B. (2006). UrbanFormTransformations:TheExperience ofTehranBeforeandAfterthe1979IslamicRevolution. Unpublished doctoral thesis.*
- *Abed, J. &Kaysi, I. (2003). Identifying urban boundaries: application of remote sensing and geographic information system technologies. Canadian Journal of Civil Engineering, 30, 992-999.*
- *Abrahamian,E. (1980).StructuralcausesoftheIranianrevolution.Middle EastReport,87,21–6.*
- *Adeli, M. (2006). Locating Gorgan city fire fighting stations with use of geographical information systemUnpublished master's dissertation. Faculty of Earth Sciences , ShahidBeheshti University, Tehran.*

- *Adelkhah,F. (2000).BeingModerninIran,translatedbyJonathanDerrick.ColumbiaUniversityPress,New York.*
- *Adian,B. (1985 July).InterviewbyZiaSedghi,Bethesda,MD.TapeRecording No.1.,IranianOralHistoryCollection,HarvardUniversity.*
- *Bahmanpour, H. (2004). Analysis the impacts of urbadevelopment on urban spaces of Tehran city and suggesting management strategies. Unpublished doctoral dissertation. Azad University, Tehran, Iran.*
- *BahramSalmani, K. (1992). Collection of urban planning methods and issues (Environment) (1st edition), Iranian Architecture and Urban Planning Research and Studies Centre.*
- *Bahrambeygui,H. (1977). Tehran:Anurbananalysis.SahabBooksInstitute, Tehran.*
- *Bailey, T. C. &Gatrell, A. C. (1995). Interactive spatial data analysis, Addison Wesley Longman, Harlow, Essex.*
- *Baja, S., Chapman, D. M. &Dragovich, D. (2007). Spatial based compromise programming for multiple criteria decision making in land use planning. Environ. Model. Assess, 12, 171-184.*
- *Barlow. I. M. (1991) Metropolitan government. Rutledge.*
- *Brenner, N. (2003). Metropolitan institutional reform and the rescaling of state space in center car land publishing Inc. New York.*
- *Behrooz, S &Karampour, K. A Research on Adaptation of Historic Urban Landscapes ; The Case of The Historical City of Tehran. Tehran Historical City Office*
- *Canter, D. V., & Gregory, A. (1994). Identifying the residential location of rapists. Journal of the Forensic Science Society, 34, 169-175.*
- *Canter, D. V., & Larkin, P. (1993). The environmental range of serial rapists. Journal of Environmental Psychology, 13, 63-69.*
- *Canter, D. V., & Snook, B. (1999, December). Modelling the home location of serial offenders. Paper presented at the meeting of the CrimeMappingResearchCenter, Orlando, FL.*
- *Caprio, A., C. Conover, et al. (1997). Fire Management and GIS: A Framework for Identifying and Prioritizing Fire Planning Needs. Fire in California Ecosystems: Integrating Ecology, Prevention and Management, San Diego, CA.*
- *Center for Studies and Planning in Tehran (1995). Evolution in the management of Tehran.*
- *Center for the Study and Planning of Tehran (1997). Recognition and status housing in the city of Tehran, Tehran Municipality.*
- *Center for the Study and Planning of Tehran (1999). Recognizing the status and scattering centers in Tehran, Tehran Municipality.*
- *Center for the Study and Planning of Tehran (2002). The role of police management in local government, Tehran Municipality.*
- *Center for Urban Studies and Architecture (2000). Collection of urban design in Tehran and around.*
- *Chang, C. R. (1999). Understanding fire regimes. Unpublished doctoral dissertation. DukeUniversity, Durham*
- *Chen, C.F. (2006). Applying the analytical hierarchy process (AHP) approach to convention site selection. J. Travel Res., 45, 167-174.*

- *Cho, G. (1995). A self teaching student's manual for Geographic Information System (Module 3: GIS: An Introduction). Canberra: University of Canberra and CAUT.*
- *Clarke, K.C. (1995). Analytical and Computer Cartography (2nd edition)., UpperSaddleRiver, Prentice Hall, Nigeria, ISBN 0130334812.*
- *ESRI (2006). GIS Technology and Applications for the Fire Service. An ESRI WHITE PAPER, Redlands CA. March. Accessed November 12, 2006 at http://www.esri.com/library/whitepapers/pdfs/fire-service-gis-applications.pdf*
- *Ghazi AsgariNaeini, A. (2004). Presentation of a suitable method for locating public car parks with use of GIS, Unpublished master's thesis, Faculty of Earth Sciences , ShahidBeheshtiUniversity.*
- *Ghodsi Pour, H. (2002). Analytical Hierarchy Process. Amir Kabir University of Technology (Iran Polytechnics).*
- *Habib, F. (1993). Application of GIS in urban planning. Urban Planning, Architectural and Scientific Magazine.*
- *Habibi, M. (2005). Atlas of Tehran Metropolis, city planning and processing company. Tehran, Iran.*
- *Latifi, G.H. (2003). Sustainable urban development and cultural development. Journal of Social Sciences.*
- *Mansour, J. (2004). City and Municipality Rules and Regulations. Didar Publications, Tehran*
- *Ohta, K., Kobashi, G, Takano, S, Kagaya, S & Yamada, H. (2007). Analysis of the geographical accessibility of neurosurgical emergency hospitals in sapporo city using GIS and AHP. Int. J. Geogr. Inform. Sci., 21, 687-698.*
- *Olfat, H., Daneshpour, S.A, and Rajabifard, A. (2008). The Role of LSDI in Integrated Urban Management, Case study: Tehran 8th divisionMunicipality, Urban Integrated Management Conference, 4th November 2008, The University of Tehran, Tehran, Iran.*
- *Rashidi, Ali. ''De-Privitization Process of the Iranian Economy After the Revolution of 1979.'' In The Economy of Islamic Iran: Between State and Market. edited by Thierry Coville. Tehran: InstitutFranc¸ais de Recherche en Iran, 1994.*
- *Research and planning center of Tehran city. (2004). The environmental studies of Tehran comprehensive plan. RPC, Tehran, Iran.*
- *Rich, T., & Shively, M. (2004). A methodology for evaluating geographic profiling software. Cambridge, MA: Abt Associates.*
- *Robins Es, An Investigation into the Efficacy of the Consistency Ratio with Matrix Order – Limits of the AHP, Report no. ARL97-ER-D01,*
- *Saaty T.L. (1994) Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process. RWS Publications: Pittsburgh.*
- *Saaty TL (1980) The Analytic Hierarchy Process. McGraw-Hill, New York.*
- *Saaty TL (1990) An exposition of the AHP in reply to the paper "Remarks on the analytic hierarchy process". Management Science 36(3).*
- *Saaty TL, Vargas LG (1984) the legitimacy of rank reversal. Omega 12(5): 513-516.*
- *Saaty TL, Vargas LG (1991) Prediction, Projection and Forecasting, Kluwer, Boston, MA.*
- *Saaty TL, Vargas LG (2001) Models, Methods, Concepts and Applications of the Analytic Hierarchy Process. Kluwer, Dordrecht.*

- *Saaty, T.L., 1980. The Analytic Hierarchy Process: Planning Setting Priorities, Resource Allocation. 7th Edn., McGraw-Hill International Book Co., New York, USA., ISBN: 0070543712.*
- *Saaty T.L. (1980) The Analytic Hierarchy Process. New York, McGraw Hill.*
- *Saaty, T.L., 1980. The Analytic Hierarchy Process: Planning Setting Priorities, Resource Allocation. 7th Edn., McGraw-Hill International Book Co., New York, USA., ISBN: 0070543712.*
- *Tehran Province Management and Planning Organisation (B) (2004), Regional Accounts of Province Production Accounts, Statistics and Information deputyship.*
- *Tehran city air quality control Company (2003). The statistics of Tehran city air quality indices. AQCC, Tehran, Iran.*
- *Tehran Municipality. (1992a). Report on NavabAeconstructionOroject. Atek Consulting Firm. Tehran.*
- *Tehran Municipality. (1992b). Report on Navab Reconstruction. Bavand Consulting Firm. Tehran.*
- *Tehran Municipality. (1996). Report on Navab Project. Deputy of Engineering Affairs. Tehran.*
- *Tehran Municipality. (1997). Report on the evaluation of people's satisfaction in Navab project. Deputy of Social and Cultural Affairs. Tehran.*
- *Tehran Safety Services and Fire Fighting Organization, Fire Fighters Magazine, first year, number 2, 1990.*
- *Tehran Safety Services and Fire Fighting Organization, safety services and fire fighting organizations of European countries (1st edition). Anvar publication, Tehran Bayat, M. (1996).*
- *Zanjani, H. (1999). Tehran's population and its future. Tehran University.*
- *Zanjani, H. (1992). Population and city dwelling in Iran, first volume, second edition, Iranian Architectural and Urban Planning Research and Studies Centre.*
- *Zanjani, H. (1991). Collection of issues and methods of urban planning (population), (2nd edition), Iranian Architectural and Urban Planning Research and Studies Centre.*
- *Zanjani, H. (1992). Population and expansion (4th edition). Iranian Architectural and Urban Planning Research and Studies Centre.*