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# Study of Locating Fire Stations using Linear Assignment Method : Case Study Maku City

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*Abstract-* Today, excess density of population in city and it is increasing growth in bulk is led to demand and attention to urban development. Demand for urban development is one of the most important issues against human in future. Therefore, to solve this problem and obstacles, safety system of city should be developed along this to cover whole city. The most important problem about the services of fire stations is the inappropriate distribution of stations and restricted function area of present stations. So, qualities and quantities distribution of stations is investigated scientifically and professionally. Using traditional methods planning fire stations for services mean wasting papers and time, but today, using GIS serves as a tool to create proper and effective database.

*Keywords:* *linear assignment method, location, fire stations, Maku.*

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# Study of Locating Fire Stations using Linear Assignment Method : Case Study Maku City

S. A. Nourozi [α] & A. R. Shariati [σ]

*Abstract-* Today, excess density of population in city and it is increasing growth in bulk is led to demand and attention to urban development. Demand for urban development is one of the most important issues against human in future. Therefore, to solve this problem and obstacles, safety system of city should be developed along this to cover whole city. The most important problem about the services of fire stations is the inappropriate distribution of stations and restricted function area of present stations. So, qualities and quantities distribution of stations is investigated scientifically and professionally. Using traditional methods planning fire stations for services mean wasting papers and time, but today, using GIS serves as a tool to create proper and effective database. In recent decades, several researchers attempt to use Multi Criteria Decision Making (MCDM) in complex and complicated decisions. The results and findings show that area (3) is located in the first rank and it is the most suitable area for establish of Fire stations, area (4) in the last rank and area (2, 5, 1,) in other ranks respectively.

*Keywords: linear assignment method, location, fire stations, Maku.*

## I. Introduction

Pay attention to the public transportation, cycling and Pedestrian oriented development (POD) and car-free streets can increase the quality of urban spaces and create more secure pedestrians with Psychological comfort for human. Old urban fabric with hidden physical, historical, and cultural values has been the best evidence of urban identity and meanwhile, the life and growth of this fabric has prevented the internal erosion of the city and has limited its unlimited expansion. The city communication network plays its lifeline role and it is considered as one of the important fundamental and determinant lines in urban development plans. The importance of networks in urban design is such that they cannot be considered separated from each other, because all of the activities of the inhabitants of a city including commercial, cultural and administrative activities depend on communication networks [7]. On the other hand, the formation of a city fabric is directly related to the city's street network so that each of these fabric types is affected by formation of the streets within the city. Star (radial) annular (circular), raster, and linear fabrics are of this type. What are important from the perspective of transportation and traffic in various fabrics, are the characteristics of movement, access and efficiency of various transportation systems, safety, and costs associated with these systems [2].

Locating, including spatial analysis, which is abundant in the impact of reducing the cost of creating and setting up various activities. That's why one of the most important stages of the project and the Executive transition effects. one of the anxieties of urban planners in urban spaces and service spaces located design appropriate and desirable. the equipment and facilities of the Foundation of urban informal settlements and lack of defects formed they cause problems for citizens. Validity and importance of each city, depending on the services and facilities. As providing this service will be better lives in the more comfortable and the cost of living for citizens will be less. If this is the appropriate location services and is enough of aqtasdi costs and reduce appreciably when residents will be able to settle this matter from another expert and scientific research that should be carried out by the various support organizations and organs. Today, find the appropriate location or locations to create a specific geographic area of activity is an important component of project steps, particularly in the macro level and national Executive is considered. The final locations have all required terms and conditions and the lack of gratification check these terms and conditions prior to the implementation of such projects will be looking for plenty of undesirable results. One of the basic tasks of urban management or in a very clear and significant city, organized a comprehensive service management system. Hence the most important tasks of the city are significant to the topic assigned services. In order to achieve the efficient management and how to assign a user category has always been urban space can be raised to different user until the late Renaissance period and the beginning of the industrial world's population growth and ataqlab to the city and population trend of late urbanization has been the result of solving the problems of the city and planning has been easy for them. with the beginning of the industrial revolution and the migration of villagers to the cities city population cities faster Copyright problems and has been to the cities has increased . The city's population, according to

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United Nations estimates these world of 2.3 billion in 1990 to 4.7 billion in 2020 will increase that 90 percent of the growth in developing countries will happen (UN, 1993, Table A. 2). Unfortunately, a third world country on a low income and who are not entitled to the growth and development of preparation necessary for dealing with the issues arising from the accelerating urban growth are not administrators and dastnderkaran cities in relation to the provision of services to citizens and classified with a serious face and have a problem.

There are many examples of applications of Multi Criteria Decision Making in literature (For instance: The evaluation of service quality[9]; Inter company comparison [10]; The applications inaggregate production planning [11], Facility location selection [12] and large scale nonlinear programming [1]. The modifications proposed in this paper can be implemented in all real world applications of Fuzzy TOPSIS.., Krishnamurthy et.al (1995, 1996) used RS and GIS techniques to find a suitable position for artificial recharge of ground water in India. Also, they investigated the effects of geomorphologic and geological factors on the behavior of ground water and stated that there is a special unevenness in each area for recharge of ground water[13]. parhizkar and Choudhury (1998) used remote sensing capabilities in extracting different layers like land usage, geomorphology, vegetation, and their integration in GIS environment to determine the most suitable area for artificial recharge of ground water[3]. Mahdavi (1997, 16) investigated water management and artificial recharge of ground water in Jourm city and indicated that controlling usage and recharge of water tables by the watershed management is the main management technique[6]

In this study, we tried to locate optimized fire station in Maku city using linear assignment.

## II. Methods and Materials

### a) *Mathematical situation of studied area*

Maku city Being situated in the north part of Western Azarbayezan province, Maku city is bounded by 39°, 00' latitude to 18°, 00' north latitude and 44°, 31' longitude. Globally, Maku is located at 2560 meter height above sea level .distance from city to center of provence is 280km and distance from city to Tehran is 850km.

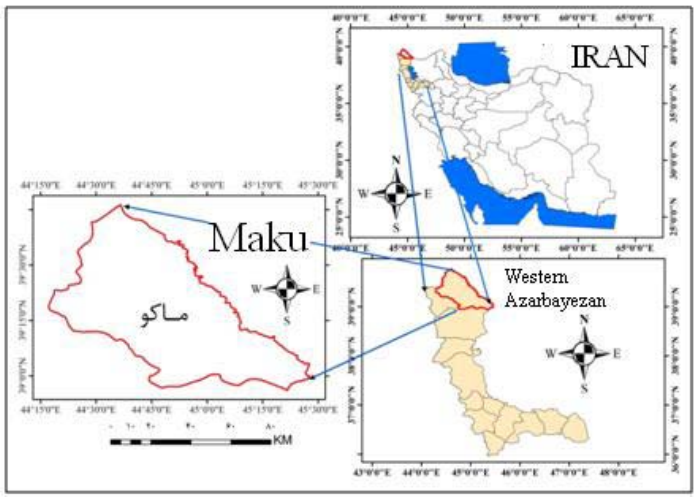



*Figure 1 :* mathematical situation of studied area

## III. Research Methodology

In this study we used following methods to collect data:

1. Library and software method and using locating instructions from scientific papers and studies.
2. Interview with fire fighting expert of Maku city.
3. Field study to evaluate present stations and collecting data which were questionable.

In present study we used linear assignment to locate fire station in Maku city, and with field study and using present maps, numeral data as Shape file and providing distance map, weighting these data using linear assignment has been done and finally using software Arc GIS 9.3 these data incorporated using index overlay method and presented as fit places for locating fire stations in Maku city.

### a) *Theoretical principles of Linear Assignment*

In recent decades, several researchers attempt to use Multi Criteria Decision Making (MCDM) in complex and complicated decisions. These decision methods divide into two parts; MODM = Multi Objective Decision Making ,MADM = Multi Attribute Decision Making. Multi Criteria Models use to select the best

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options. Evaluative Models for MADM classify into two models; Compensatory Model, Non- Compensatory Model. Non-compensatory model includes methods which don`t need to achieve data from DM and lead to objective answer. Exchanging between indictors is permitted in Compensatory model. It means that for example, a weakness in a indicator may be compensated by option of other indicator. Electrical Method is a type of available methods in Compensatory Models. In this method whole options evaluate by non-ranked comparisons. All stages of this method are established based on coordinated and uncoordinated sets and thus this method is known as ''Coordination Analysis''. Banayoun established the Electrical Method and Delft, Nijkamp, Roy and their colleagues developed it. In Electrical method, the concept of domination uses implicitly. In this method, options are compared in pairs, then dominant and weak (dominant and defeated) options determined and weak or defeated options omitted [14]. Linear Assignment is one of the Multi Criteria Decision Making combines qualitative and quantitative indicators, weights criteria based on their importance and helps decision makers to select the best options at the same time. In this method, supposed options are ranked based on their points in each available indicator and then the final rank of the options determined by the Linear Compensatory Process. The situation of these two models show among the other Multi Criteria Decision Making (Figure2).solution process doesn`t need to scale down the quantitative and qualitative indicators.

*a) Applying Linear Assignment Technique for locating Fire stations*

1. Establishing Decision Making matrix

First, decision Making Matrix is established based on quantitative data related to the indicators in each area.

2. Ranking options according to available indicators.

Second, the areas are prioritized based on their ranks in each indicator.

3. Establishing QG Matrix

Third, having access to determined weights of indicators (W), QG Matrix is established. Each element in QG Matrix equals:

$$q/_{it} = \sum_{j=1}^{n} \pi itj \,.\, wj \qquad :(1)$$

If option i were in rank t in indicator j, $\pi itj = 1$ otherwise it would be $\pi itj$.

4. The following assignment problem is solved with variables (0, 1 hit) in order to determine the final priority of options.

$$\max : \sum_{i=1}^{m} \sum_{k=1}^{m} \gamma_{ik} \,.\, h_{i\,k} \qquad : (2)$$

$$s.t \;\; : \sum_{k=1}^{m} h_{ik} = 1 \quad ; \quad i = 1,2,\dots,m$$

$$\sum_{i=1}^{m} h_{ik} = 1 \quad ; \quad k = 1,2,\dots,m \qquad :(3)$$

$$h_{ik} \quad \begin{cases} = 1 \\ = 0 \end{cases}$$

5. Ranking Options

In the final stage, the options are ranked.

## IV. Discuss

In this study, for the correct locating of fire stations, firstly, effective criteria were determined and classified.

Stage one: preparing position data layers:

In this stage, the 1:2000 map of detailed plan in Maku city which was provided in 1385 by housing and urban development organization, , was entered into GIS software and converted to Shape File.

Stage two: digitizing position data layers

Digitizing effective layers in locating fire stations are performed in 3 ways:

1. Spot complications: hydrants, Mosques, oil and gas stations.
2. Polygonal complications: residential centers, educational centers, medical centers, administrative centers, industrial and workshop centers, storage centers and ….
3. Linear complications: passage network, strap business centers.

Stage three: providing distance map

In this stage, the distance map was created using spatial analyst for each criterion of position data.

Stage four: reclassifying maps on the basis of suitable areas and rating

In this stage, each map was classified into some classes according to the importance of each class, values between 1(the worst value) to 5 (the best value) was allocated to them.

"Fire stations should be near residential, business and administrative complications, main streets, storage centers, industrial centers, hydrants, gas station, and dense population places, and should be far from educational, medical and religious centers, and then reclassification will be done on the basis of suitable places into 5 classes."

Stage five: analysis of data in linear assignment.

The results of Linear Assignment method to locating Fire stations are showed in tables (1-7) and figures (2-5).



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*Table 1 :* Data Collection Matrix

| Regions | available | trade | industrial | habitate | area | educational | official | Religiously | transportation |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 15889 | 6150 | 438418 | 1221221 | 23610 | 31800 | 3296 | 290000 |
| 2 | 5 | 37600 | 1800 | 297315 | 962319 | 47976 | 43708 | 6255 | 284116 |
| 3 | 13 | 20340 | 3890 | 565835 | 1475081 | 47974 | 4900 | 3919 | 489218 |
| 4 | 23 | 6227 | 950 | 345449 | 762035 | 19865 | 9470 | 1577 | 197811 |
| 5 | 26 | 2951 | 126 | 414707 | 804172 | 257214 | 21432 | 1854 | 207650 |

*Table 2 :* Options Ranked Matrix based on indicators

| Rated | available | trade | industrial | habitate | area | educational | official | Religiously | transportation |
|---|---|---|---|---|---|---|---|---|---|
| first | 5 | 2 | 1 | 3 | 3 | 5 | 2 | 2 | 3 |
| Second | 4 | 3 | 3 | 1 | 1 | 2 | 1 | 3 | 1 |
| third | 3 | 1 | 2 | 5 | 2 | 3 | 5 | 1 | 2 |
| Fourth | 1 | 4 | 4 | 4 | 5 | 1 | 4 | 5 | 5 |
| Fifth | 2 | 5 | 5 | 2 | 4 | 4 | 3 | 4 | 4 |

*Table 3 :* Ranks Number Matrix of Options

| Regions | first | Second | third | Fourth | Fifth |
|---|---|---|---|---|---|
| 1 | 1 | 4 | 2 | 2 | 0 |
| 2 | 3 | 1 | 3 | 0 | 2 |
| 3 | 3 | 3 | 2 | 0 | 1 |
| 4 | 0 | 1 | 0 | 4 | 4 |
| 5 | 2 | 0 | 2 | 3 | 2 |

*Table 4 :* Paired Comparison Matrix of different criteria (S)

| | available | trade | industrial | habitate | area | educational | official | Religiously | transportation | Wij |
|---|---|---|---|---|---|---|---|---|---|---|
| available | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0.307 |
| trade | 0.5 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 0.218 |
| industrial | 0.33 | 0.5 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0.154 |
| habitate | 0.25 | 0.33 | 0.5 | 1 | 2 | 3 | 4 | 5 | 6 | 0.108 |
| area | 0.2 | 0.25 | 0.33 | 0.5 | 1 | 2 | 3 | 4 | 5 | 0.076 |
| educational | 0.17 | 0.2 | 0.25 | 0.3 | 0.5 | 1 | 2 | 3 | 4 | 0.053 |
| official e | 0.14 | 0.17 | 0.2 | 0.2 | 0.3 | 0.5 | 1 | 2 | 3 | 0.037 |
| Religiously | 0.13 | 0.14 | 0.17 | 0.2 | 0.2 | 0.33 | 0.5 | 1 | 2 | 0.025 |
| transportation | 0.11 | 0.13 | 0.14 | 0.1 | 0.2 | 0.25 | 0.33 | 0.5 | 1 | 0.019 |
| Inconsistency rate: 0/0242 (due to being less than 0/1 compatibility matrix indices are acceptable) | | | | | | | | | | |

*Table 5 :* Weight Matrix of rank number of options

| Regions | first | Second | third | Fourth | Fifth |
|---|---|---|---|---|---|
| 1 | 0.1542 | 0.2413 | 0.2441 | 0.3603 | 0 |
| 2 | 0.2812 | 0.0533 | 0.2496 | 0 | 0.4158 |
| 3 | 0.2042 | 0.3983 | 0.3603 | 0 | 0.0371 |
| 4 | 0 | 0.307 | 0 | 0.5183 | 0.1746 |
| 5 | 0.3603 | 0 | 0.1459 | 0.1213 | 0.3724 |



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*Table 6 :* Options Rating Table

| Points / Regions | | | | | |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 1 | 0 |
| 2 | 0 | 1 | 0 | 0 | 0 |
| 3 | 1 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 1 |
| 5 | 0 | 0 | 1 | 0 | 0 |

*Table 7 :* Options Ranking

| Regions | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Rated | Fourth | Second | First | Fifth | Third |

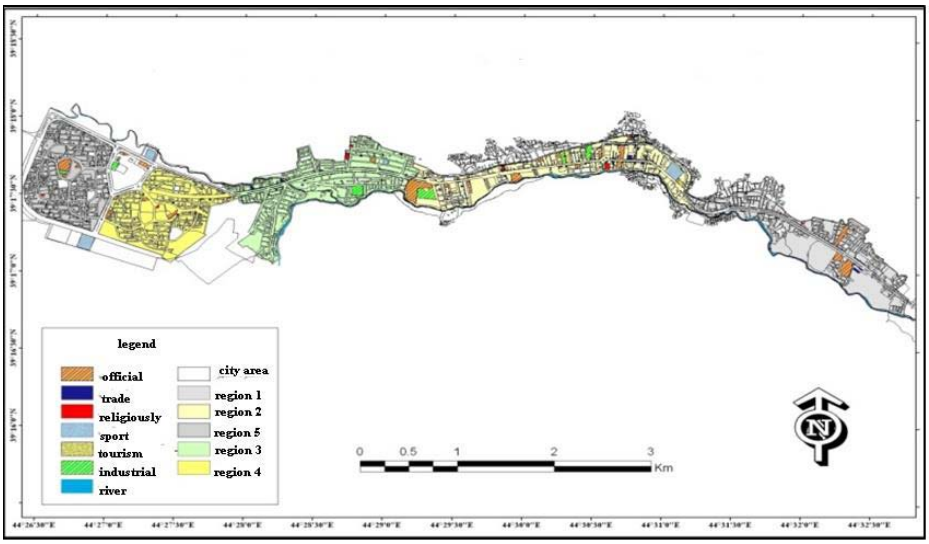



*Figure 2 :* Applicational map of Religously and official applicational map

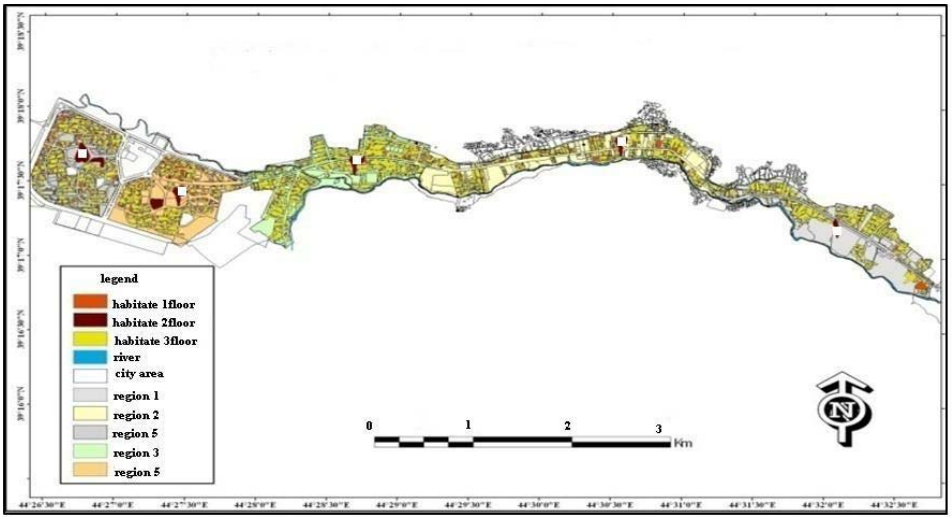



*Figure 3 :* Habitate applicational map



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*Figure 4 :* The map of roads of Maku city

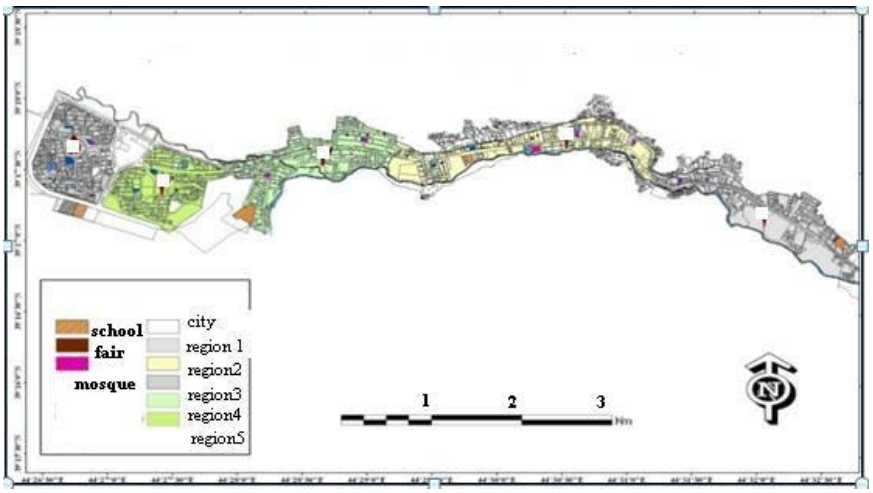



*Figure 5 :* Applicational map of educational and industrial

## V. Conclusion

It could be stated that using GIS and linear assignment for analyzing position data and choosing optimized location, has unique performance, so it is suggested that fire fighting organizations use these software applications to create database. It is suggested that fire fighting organization and safety services, create reasonable relationship with urban service centers to enhance their performance, and equip these centers to safety tools before the incident. It is suggested that fire fighting organization and safety services, promote in teaching citizens about how to use fire extinction tools. The three existing stations in Maku city are suitable regarding the population of the city and that one station per 30000 persons is necessary, but because of the vastness of city, these three stations can't service optimally to whole city. It is suggested that 2 additional medium stations to be located in city area, , and because Maku city has one central station and three secondary (small) stations, and this city doesn't have medium station.

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