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Optimum Locations for Intercity Bus Terminals with the AHP Approach – Case Study of the City of Esfahan

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***Abstract*—**Interaction between human, location and activity defines space. In the framework of these relations, space is a container for current specifications in relations of the 3 mentioned elements. The change of land utility considered with average performance range, urban regulations, society requirements etc. will provide welfare and comfort for citizens. From an engineering view it is fundamental that choosing a proper location for a specific civil activity requires evaluation of locations from different perspectives. The debate of desirable establishment of municipal service elements in urban regions is one of the most important issues related to urban planning. In this paper, the research type is applicable based on goal, and is descriptive and analytical based on nature. Initially existing terminals in Esfahan are surveyed and then new locations are presented based on evaluated criteria. In order to evaluate terminals based on the considered factors, an AHP model is used at first to estimate weight of different factors and then existing and suggested locations are evaluated using Arc GIS software and AHP model results. The results show that existing bus terminals are located in fairly proper locations. Further results of this study suggest new locations to establish terminals based on urban criteria.

***Keywords*—**Arc GIS, Esfahan city, Optimum locations, Terminals.

I. Introduction

THE selection of an appropriate location for any activity requires precise evaluation from different perspectives. The topic of optimum location for urban infrastructures (service centers and structures) is one of the key subjects in urban design and engineering. One of the most important urban infrastructural elements is intercity bus terminals. Due to their high level of human traveling and specific service traffic their location identification is a challenge for urban planners and designers. Any shortcoming in the location-finding of these terminals can lead to problems in the surrounding urban traffic and urban land uses. An appropriate approach for identifying the location of these terminals results in convenient access, reduced fuel consumption and less pollution (air and noise).

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A. The Case Problem

The placement of any urban element in any certain urban space requires pursuing specific regulations, mechanism and rules in order to seek the efficient (optimum), reliable and sustainable performance of that element. One of the most significant topics in urban planning and engineering is the identification of the most appropriate locations for any urban element. This means that for all urban elements which provide services to the residents, the identification is unique. This identification requires a thorough understanding of different aspects such as;

- The performance of the element and its detailed requirements
- The integration of the element with its surroundings and the effects
- The future of the urban system and it's known perspectives
- Considerations of the sustainable design and performance of the element

The case of this study is on identifying the optimum locations for bus terminals. Afandizadeh et al. considered the traveller access time for locating optimum locations of urban bus terminals [1]. With the growing population and increased demands for traveling, the importance of the location of bus terminal becomes more crucial. Factors such as convenient access, socio-economic parameters, environmental regulations and traffic regulations are the most primary features in determining the optimum location for bus terminals. The aim of this study is identifying the location for bus terminals in the city of Esfahan, Iran under these factors. The problem of identifying the optimum locations looks to find the most optimum zone (for the location) from a set of zones which are better candidates for the terminal regarding the set of previously determined parameters for the terminal. In this case study, the determined parameters are defined respective to the urban circumstances and preferences for the city of Esfahan.

B. The Importance of the Research

The intercity bus public transport lines are one of the important sectors of public transport. Consequently any defect in the operation of buses, causes lower levels of service and less demand for them which in a long run can lead to excessive exploitation of resources. For developing the public modes of transport system (under current circumstances) two branches are investigated, the network infrastructure (formation) and the network operation. The network infrastructure includes the specifications of the terminals for the buses.

C. The Aim of Research

The efficiency of an operating network is an important factor for sustainable development. The aim of any public transport system operator is initially improving the system for the users and secondly gradually enticing more travelers for an efficient and sustainable transport inside the network. Identifying the most reasonable location for bus terminals (defined within the parameters introduced in 2.1.) not only do the current users benefit from the optimum location (optimization problem solved) but also new users would be attracted to a more beneficial system of transport.

D. Problem Details

The two main debatable questions are; is it possible to locate optimum point for bus terminals in a long term planning of an urban metropolis. Until when can the optimum locations remain optimum locations, regarding the future development of the city of Esfahan.

II. The Theory behind the Research

The logic behind this research is upon defining the nature of the problem, the aim, the proposed performance. The solution of the problem is sought via the AHP model.

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by [2]. The AHP is a decision support tool which is able to solve complex decision problems. It utilizes a multi-level hierarchical structure of objectives, criteria, subcriteria, and alternatives [7]. Zebardast and Triantaphyllou have implemented this method for urban and regional planning [6], [7].

The sources of information in this research have been visualization, interviews, data banks and computer networks. The optimum location has been found with the help of Geographic Information Systems and the model AHP. The limitations in time and certain lack of data have been the shortcomings of this research.

A. Terminal's Evaluation Criteria

Terminal as an urban land use can be evaluated in 3 categories [1]:

a- Urban and environmental issues (as an urban land use)
b- Passenger related issues (receiver service)
c- Vehicle related issues (provider service)

Terminal locating studies try to find a location to maximize site desirability for these 3 issues. So if data accuracy of these factors be more complete, locating would be performed more precisely. In general any of these issues could be categorized into many factors. But by considering the condition of the city in which the problem is being investigated, seven most important factors are selected as following in order to locate bus terminal's location:

- Access to main streets
- Access to public transportation services
- Compatibility with surrounding land uses
- Access to urban infrastructures
- Conformity with outreach plans
- Future development possibility
- Environmental effects

1. Esfahan Bus Terminals

One of the necessities of national development is to increase accessibility between residential areas in the country. This connection is dependent on intercity transportation facilities. Intercity terminals are the location of urban and suburban transportation mode change and have a major role in intercity exchanges. Esfahan city has a 6.5 percent of country population and area and is the first city in number of terminals and third in number of passengers. Table I shows area and number of passengers that are daily carried to other cities through these terminals. The location if these terminals are presented in Fig. 1 (The technical regulations for terminal designs, Number 352, Technical deputy of presidency, Iran. 2007) and more details of them are included in, The Governmental Managing and Supervising Body of Esfahan Intercity Terminals (http://www.rmto.ir/) [3] - [4].

TABLE I
Terminals of Esfahan City

Terminal	Area (m^2)	No. of daily passengers
Kaveh	100000	12000
Soffeh	45000	10000
Jey	17000	2500
Zayandehrood	10400	13500

B. Evaluating Existing Terminals

1) Based On Accessibility to Major Streets

Table II shows terminal's rating according to "access to major roads":

TABLE II
Rating Bus Terminals Based On Factor "Access to Major Streets"

Type of access	Point
Access to major roads	10
Access to collecting roads	5
Access to locals roads	0

According to Figs. 2-6, the points displayed in Table III are considered for existing terminals.

TABLE III
Points of Esfahan Bus Terminals Based On Factor "Access to Major Streets

Bus terminal name	Point
Kaveh	10
Soffeh	10
Zayandehrood	10
Jey	10

Since all terminals are located next to the city's main entrance and departing routes, so these terminals take the maximum possible points.

2) Based On Accessibility to Public Transportation

In order to evaluate terminals based on this factor, first the network of rapid and semi rapid transit of the city must be surveyed. Figs. 8 and 9 show existing terminal locations along with rail rapid transit lines and bus rapid transit lines in this

city (Only one metro line and one BRT line is operating in 2014).

Table IV shows terminal's rating according to "access to public transportation".

TABLE IV
RATING BUS TERMINALS BASED ON FACTOR "ACCESS TO PUBLIC TRANSPORTATION"

Type of access	Point
Access to mass rapid transit	10
Access to semi rapid transit	5
Access to local public transit	0

According to Figs. 1-4 and Table IV, points of existing bus terminals based on this factor are specified in Table V.

TABLE V
POINTS OF ESFAHAN BUS TERMINALS BASED ON FACTOR "ACCESS TO PUBLIC TRANSPORTATION

Bus terminal name	Point
Kaveh	10
Soffeh	10
Zayandehrood	0
Jey	0

3) Based On Compatibility with the Surrounding Land Uses

In order to rate terminals based on this factor, Table VI is provided.

TABLE VI
RATING BUS TERMINALS BASED ON FACTOR "COMPATIBILITY WITH SURROUNDING LAND USES"

Type of land use	Point
Residential	0
Parks and other green spaces	10
Public services	0
Industrial	5
Administrative and Commercial	3
Transportation and warehousing	10
Military	5
Farm	10
Arid	10
Other	5

The land uses around four bus terminals of Esfahan city has been determined. These land uses are defined based on maps and data obtained from Esfahan municipality research and development office [3].

According to Table VI, points of existing bus terminals based on this factor are specified in Table VII.

TABLE VII
POINTS OF BUS TERMINALS BASED ON FACTOR "COMPATIBILITY WITH SURROUNDING LAND USES"

Bus terminal name	Point
Kaveh	5
Soffeh	7
Zayandehrood	5
Jey	4

4) Based On Compatibility with Future Development Plans of the Region

In order to rate terminals based on this factor, Table VIII is provided.

TABLE VIII
RATING BUS TERMINALS BASED ON FACTOR "COMPATIBILITY WITH FUTURE PLANS"

Plan period	Point
Compatibility with long-term plans	10
Compatibility with medium-term plans	5
Compatibility with short-term plans	0

According future plans considered for lands around terminal's location and rating specified in Table VIII, points of existing bus terminals based on this factor are specified in Table IX.

TABLE IX
POINTS OF ESFAHAN BUS TERMINALS BASED ON FACTOR "COMPATIBILITY WITH FUTURE PLANS"

Bus terminal name	Point
Kaveh	5
Soffeh	10
Zayandehrood	5
Jey	5

5) Based On Accessibility to Infrastructure Installations

In order to rate terminals based on this factor, Table X is provided.

TABLE X
RATING BUS TERMINALS BASED ON THE FACTOR "COMPATIBILITY WITH FUTURE PLANS"

Infrastructure installations	Point
Drinking water	10
Non-drinking Water	10
Industrial electricity	10
Non-commercial Electricity	10
Urban sewage system	5
Sewage system	10
Urban gas	5
Fuel	10
Telephone	10

As all the existing terminals have access to all infrastructure mentioned, then they all achieve the maximum points.

6) Based On Future Development Possibility

Existence or non-existence of empty lands around terminal locations or lands which are easy to be possessed are one of the advantages of terminal locations. In order to rate terminals based on this factor, Table XI is provided.

TABLE X1
RATING BUS TERMINALS BASED ON FACTOR "FUTURE DEVELOPMENT POSSIBILITY"

Possibility of using surrounding lands	Point
Easy	10
Medium	5
Hard	0

According to the investigation on land uses around Esfahan bus terminals, points of existing bus terminals based on this factor are specified in Table XII.

TABLE XII
POINTS OF ESFAHAN BUS TERMINALS BASED ON FACTOR "FUTURE DEVELOPMENT POSSIBILITY"

Bus terminal name	Point
Kaveh	0
Soffeh	5
Zayandehrood	0
Jey	0

7) Based On Environmental Effects

In order to rate terminals based on this factor, Table XIII is provided.

According to the investigation on environmental effects of Esfahan bus terminals, points of existing bus terminals based on this factor are specified in Table XIV.

TABLE XIII
RATING BUS TERMINALS BASED ON FACTOR "ENVIRONMENTAL EFFECTS"

Environmental investigations	Point
Noise pollution	10
Air pollution	10
Water pollution	10
Terrestrial pollution	10

TABLE XIV
POINTS OF ESFAHAN BUS TERMINALS BASED ON FACTOR "ENVIRONMENTAL EFFECTS"

Bus terminal name	Point
Kaveh	5
Soffeh	10
Zayandehrood	5
Jey	7.5

8) Total Points of Each Terminal

By considering points of each terminal based on different factor, total rating of Esfahan existing bus terminals are specified and is illustrated in Table XV.

TABLE XV
RATING OF ESFAHAN EXISTING INTERCITY BUS TERMINALS BASED ON DIFFERENT FACTORS

Terminal	accessibility to major streets	accessibility to public transportation	compatibility with surrounding land uses	compatibility with future development plans	accessibility to infrastructure installations	future development possibility	environmental effects
Kaveh	10	10	5	10	5	0	5
Soffeh	10	10	7	10	10	5	10
Zayandehrood	10	10	5	10	5	0	5
Jey	10	0	4	10	5	0	7.5

In the later step, weight of different factor is obtained by using Binary comparison approach and then these weights are multiplied by points specified in Table XV. The result is a table that the numbers in the horizontal order shows relative importance of existing bus terminals. In order to do this, a questionnaire was provided which involved 21 comparisons. This questionnaire was answered by 18 transportation and urban development experts and the results were analyzed.

Weight of each factor is calculated by AHP method and using sum of rows. In this approach incompatible matrix is first provided for every questionnaire and then by normalizing these matrixes, mean of every row's sum is obtained.

TABLE XVI
WEIGHT OF DIFFERENT FACTORS FOR EVALUATING TERMINAL LOCATIONS ACCORDING TO AHP METHOD

Factor	Weight
accessibility to major streets	0.1863
accessibility to public transportation	0.20883
compatibility with surrounding land uses	0.1497
compatibility with future plans	0.0809
accessibility to infrastructure installations	0.1053
future development possibility	0.1202
environmental effects	0.1488

By considering weight of each criterion and points of existing terminals, relative importance of each one is specified. The more the points get closer to 10, the better the terminal location is. The results for 4 terminals are provided in Table XVII.

TABLE XVII
TOTAL POINTS OF ESFAHAN EXISTING BUS TERMINALS

Bus terminal name	Point
Kaveh	6.78
Soffeh	8.95
Zayandehrood	6.78
Jey	4.91

As it can be seen among the Esfahan existing intercity bus terminals, Soffeh and Jey terminal have the maximum and minimum points respectively.

C. Suggesting Alternatives for the Esfahan City Terminals

For suggesting alternative locations for the terminals, the factors which have the highest weights should be selected as the major priorities. The major factors are access to local public transportation network and access to major roads. For that aim, the public transport network coverage and the highway network are determined. A distance of 500m around metro lines and 300m around BRT lines and 100m around highways and major arterial roads are considered as the coverage area. This coverage is defined in the Arc GIS map of Esfahan. The map representing the whole coverage area is displayed in Fig. 9. By analyzing the map, the areas which are covered by the two major factors (access to public transport network and access to major arterial roads) can be pictured.

Then by surveying these areas based on the 7 factors defined, the suitable locations to establish new terminals are selected. These locations are presented in Fig. 10.

In Table XVIII the points assigned for each factor for the suggested terminal locations are provided.

TABLE XVIII
RATING OF ESFAHAN'S SUGGESTED INTERCITY BUS TERMINALS BASED ON DIFFERENT FACTORS

Terminal	accessibility to major streets	accessibility to public transportation	compatibility with surrounding land uses	compatibility with future development plans	accessibility to infrastructure installations	future development possibility	environmental effects
A	10	10	7.5	10	5	5	5
B	10	10	5	10	5	10	10
C	10	10	6.66	10	10	10	7.5
D	10	10	5	10	10	0	7.5
E	10	10	4.33	10	5	5	5
F	10	10	0	10	0	0	5

According to Table XV, the weight and the sum of the weights, the final score for each terminal is displayed in Table XIX.

TABLE XIX
FINAL POINTS OF ESFAHAN'S SUGGESTED BUS TERMINALS BASED ON THE SEVEN FACTORS

Bus terminal name	Final points
A	7.754
B	8.525
C	9.128
D	7.678
E	7.28
F	5.504

By considering all the results, the final ratings of the existing and suggested terminal locations are shown in Table XX.

TABLE XX
FINAL POINTS OF ESFAHAN'S SUGGESTED AND EXISTING BUS TERMINALS BASED ON THE SEVEN FACTORS

Bus terminal name	Final points
C	9.128
Soffeh	8.95
B	8.725
D	7.678
A	7.754
E	7.28
Kaveh	6.78
Zayandeh Rood	6.78
F	5.504
Jey	4.913

Since some of the suggested terminal locations are located in the same district and considering them together is not a reasonable act. Therefore the final suggested intercity terminals are in the order below (according to their final score); 1- Terminal C, 2- Terminal Soffeh (existing), 3- Terminal B or Terminal E, 4-Terminal A, 5- Terminal Kaveh (existing)

III. CONCLUSION

In this paper seven factors were defined which are decisive for appropriate locations of intercity terminals. Regarding the factors, with the help of Arc GIS, six new terminal locations were suggested. The final score point of each terminal (existing and suggested) were calculated as the sum of the points for each factor (defined for each terminal). In the conclusion five locations were presented to be the appropriate locations for the intercity bus terminals of the city of Esfahan. The five locations included two of the current bus terminal of Esfahan.

APPENDIX

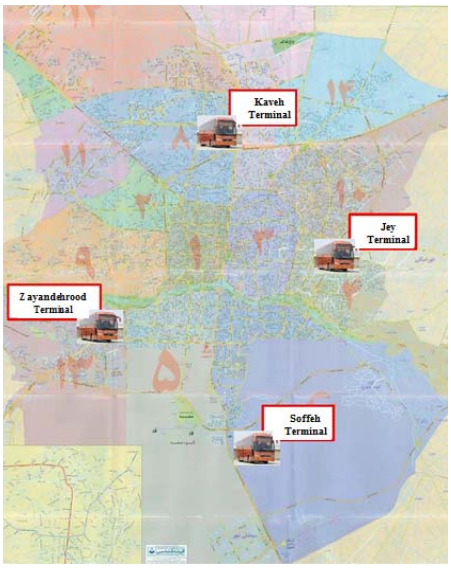

Fig. 1 The locations of the existing terminals in the city of Esfahan

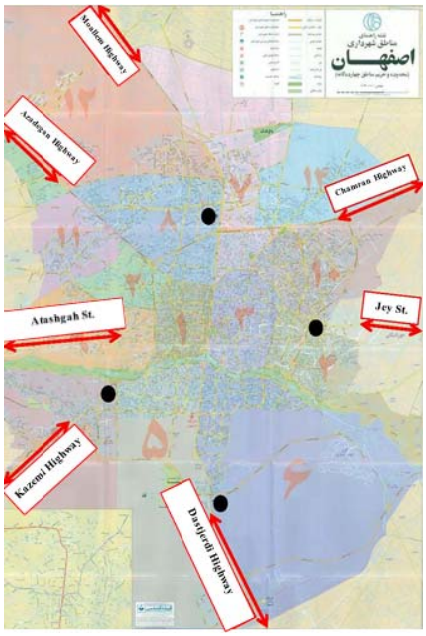

Fig. 2 The entering roads to the city of Esfahan and the relative locations of the existing terminals in the city of Esfahan

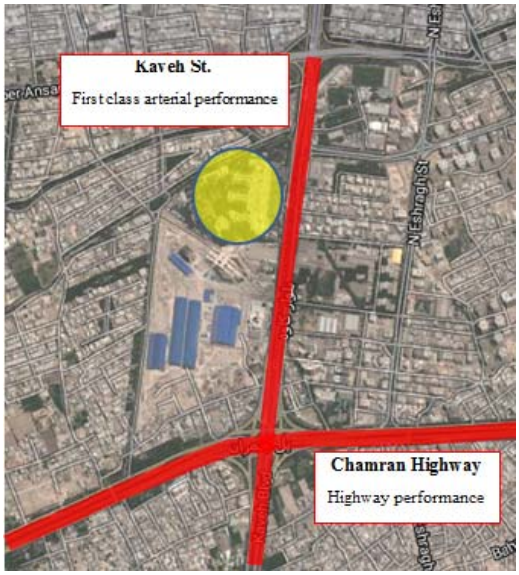

Fig. 3 The roads leading to the Kaveh Terminal and their land use

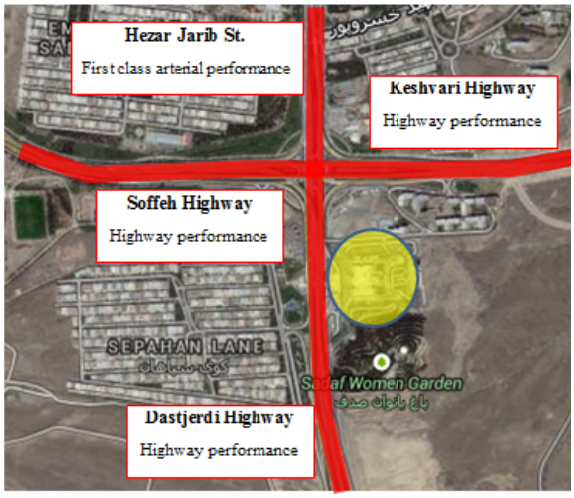

Fig. 4 The roads leading to the Soffeh Terminal and their land use

Fig. 5 The roads leading to the Zayandehrood Terminal and their land use

Fig. 6 The roads leading to the Jey Terminal and their land use

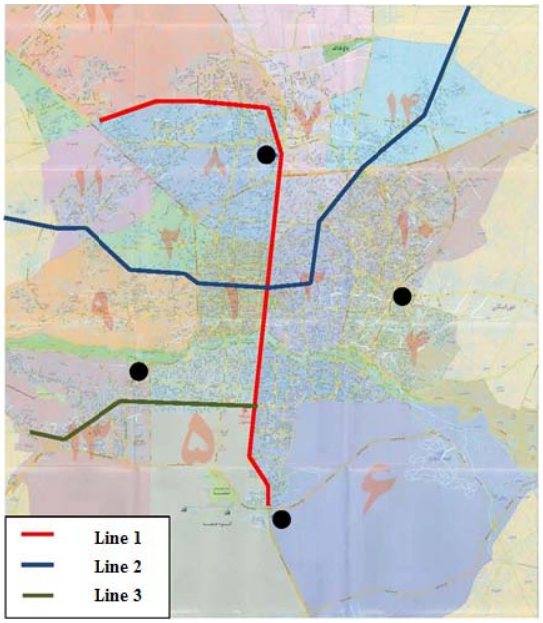

Fig. 7 Esfahan metro lines (constructed, under construction and planned)

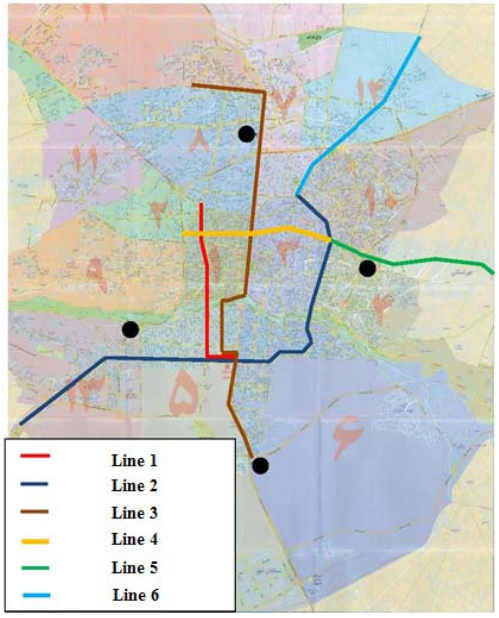

Fig. 8 Esfahan BRT lines (constructed, under construction and planned)

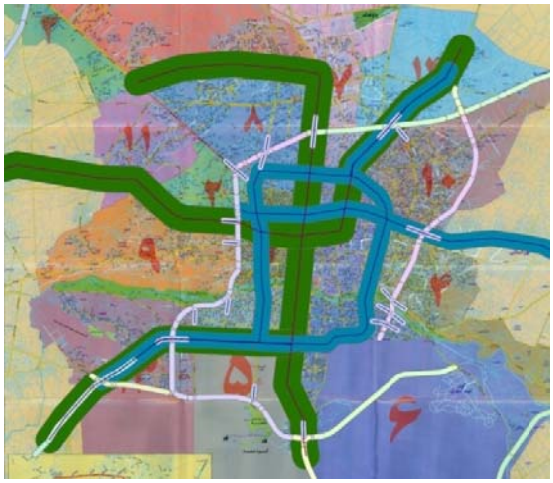

Fig. 9 The coverage area of major arterial roads and highways as defined in the paper for the city of Esfahan

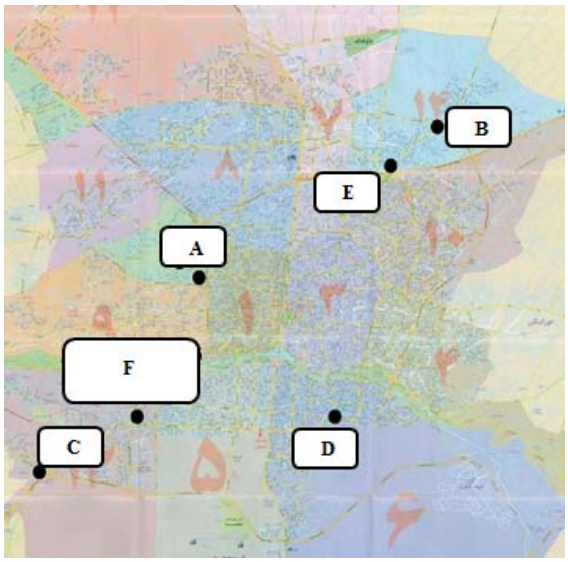

Fig. 10 The suggested locations for the intercity bus terminals of Esfahan city

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