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An Efficient Approach for Public Transportation Optimization Using Fuzzy Multiple Criteria Decision Making and Mathematical Modeling

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Abstract

One of the main challenges of transportation networks is to directing vehicles to their destination with the aim of reducing costs such as travel time, fuel consumption and more efficient use of existing network capacities. In fact, traffic guidance is sought after the appropriate distribution of traffic flows on all routes within the transportation network. In this paper, Hierarchical methods of the Fuzzy Analytical Hierarchy Process Model (FAHP) along with EXPERT CHOICE software are used to optimize public transport lines in which Arc GIS software is used to display transportation maps. An applied mathematical model is then developed to determine the optimal routing decisions. The study area in this study is zone 4 of Tehran. Finally, the case study for area 1 of zone 4 is described and explained by providing a mathematical model of public vehicles routing through entering the total weight of the paths obtained by the FAHP method.

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1. Introduction

Along with the sustainable growth and development and fundamental changes in economic, social and cultural affairs, the role of roads network as one of the most important and essential sectors in development becomes more visible, which in turn provides the land of growth and prosperity besides fertilizing the potential resources and talents of the territory and can also be effective in increasing urbanization. In this regard, increasing the urbanization has turned the human and commodity movement into a problem whose complexity is constantly increasing. Human and commodity movement and transportation is an important activity in any society which has a major impact on life patterns and social interactions. Passengers and commodity transportation are divided into sub-groups, in which intra-urban transportation is divided into two parts: public and private transportation.

According to the prosperity and dynamics of each city, intra-urban transportation is considered as a major part of macro schemes of Urban Planning in the short and long horizons. If transportation industry is strengthened and rebuild, it will create new economic activities, jobs, investment and production (Liu et al., 2012).

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One of the main challenges of transportation networks is to directing vehicles to their destination with the aim of reducing costs such as travel time, fuel consumption and more efficient use of existing network capacities. In fact, traffic guidance is sought after the appropriate distribution of traffic flows on all routes within the transportation network (Levinson, 2003; Chowdhury and Sadek, 2003). In this regard, the shortage and deficiency in the land transportation system, especially urban transportation is one of the obstacles to the growth and development of any country. One of the most effective solutions to this problem is the development and strengthening of urban public transport systems.

Spatial information systems in the field of optimal management of transportation facilities have many capabilities. Spatial network analysis such as shortest path calculation, resource displacement and allocation, access level calculation, and so forth are the most ones. So, urban Transportation Planning is one of the key issues in developed and even developing countries. This importance comes from the fact that, this problem deals with the three key factors: cost, time and the security of citizens. On the other hand, the importance of this problem for governments is due to the fact that transport planning, especially public transportation, is directly related to the level of citizens' satisfaction, and this is why governments are seeking to do it as well as possible.

In this regard, one of the important management solutions for urban development is the quantitative and qualitative development of the public transport fleet and its optimization (Current et al. 1985; Current and Schilling, 1994). Proper operation and service of the public transport fleet not only is effective for reducing traffic and environmental pollution but also leads to sustainable urban development (Daisa, 2004). A comprehensive public transportation system can improve intra-urban movement besides the quality of urban life by attracting citizens' trust and spending less cost and time. To this end, it is necessary to design a public transportation network and find its optimal routes. GIS in public transportation has been surveyed by Khitha, and Govil (2003).

They are several beneficial research done in the scope of urban transportation including planning, development, and management and so on (Simon, 2002; Vukan, 2005; White, 2016). The optimal selection of public transportation lines in quantitative and qualitative terms has a significant role in execution, exploitation and maintenance costs (Chen et al. 2011). So it is desirable to do thorough and comprehensive studies in the early stages. Naturally, if public transportation routing is optimally studied in any way, its consequences will affect all steps of construction and setup. Therefore, in this paper, we try to optimize public transportation lines using hierarchical methods. In the following, we will look at some works done in this field.

Veluscek et al. (2015) explored the composite goal methods for transportation network optimization. It is pointed that multi-objective transportation network optimization has gained significant attention recently. Using multi-objective transportation network optimization leads to a more accurate and realistic solution than situations where only one objective is considered. The aim of this work is to identify the most promising multi-objective optimization method for solving real-world transportation network optimization problems. Nguyen et al. (2015) investigated the complexity of transportation projects using Fuzzy Analytical Hierarchy Process. They pointed out that transportation projects are increasingly complex. A systematic approach to measuring and assessing the complexity of transportation projects is essential. In particular, 36 complexity factors are identified for transport construction. This work investigates the Inferring of six components of the complexity of the project: namely political and social, environmental, organizational, infrastructure, technology components, and also domain complexity using factor Analysis. In fuzzy analytical hierarchy process, FUZZY AHP is used to determine the weight of components and complexity parameters of the project. The political complexity was the decisive component of the complexity of transportation construction. Complexity Level (CL) is proposed to measure the complexity of the project. The proposed approach is used by a heavy construction company in a case study including three transportation projects. As a quantitative measure, CL has enabled managers to better predict potential problems of complex transportation projects. As a general result, scarce resources should be assigned efficiently among transportation projects within a company.

Qiang et al (2008), in a research conducted in Beijing, used GIS (Geographic Information System) to calculate the public transportation system's performance for the Olympics.

Klimberg et al. (2008) developed and tested a method for modeling locating problems which uses data envelopment analysis (DEA) technique and a performance criterion for finding the optimal location and comparing the performance of different locations. They stated that considering DEA performance criterion with other objectives and locating models leads to a very efficient and powerful method for solving multi-objective locating problems.

Önüt and Soner (2008) proposed a fuzzy multi-criteria decision making model for selecting an optimal location for transportation equipment. They stated that various multi-criteria techniques have been proposed for locating problems that use only deterministic values to rank the options and they are less able to consider the qualitative and subjective aspects of decision makers in this type of problem. In fact, they proposed a fuzzy multi-criteria decision-making method using AHP and TOPSIS techniques which considers Subjective preferences and qualitative criteria of decision makers using verbal variables.

After reviewing literature, research innovations are presented in the form of research objectives. Therefore, in this research, we seek to achieve the following goals:

- Optimizing public transportation lines using hierarchical methods
- Increasing public transportation efficiency by providing an efficient and appropriate model
- Reducing execution, exploitation and maintenance costs of public transportation lines through public transportation optimization

2. Methodology

This research is a descriptive-analytical research and belongs to practical research category in terms of the research objective. Accordingly, library method and field studies are used to collect data. Data needed in this work including statistics and information, articles, books, theses, maps and satellite images, and digital files are collected through documentary methods, library resources, searching on cyberspace and internet and seeing the geographical area of the region and from Deputy of Coordination and planning, Deputy of Transportation and Traffic of Tehran Municipality, Tehran Traffic Control Company and Geographic Information System (GIS) unit of Tehran Municipality.

The minimum length of the route and the highest coverage of population demand are the main objectives in determining the public transportation route (Matisziw et al. 2006). These two goals are summarized into the structural improvement and service level access improvement. A route must have some characteristics and factors in order to be a proper route for public vehicles transportation. The number of these effective factors increases and decreases depending on the circumstances (Belzer and Autler, 2002).

Gupta et al. (2018) presented an integrated AHP-DEA multi-objective optimization model for sustainable transportation in the mining industry. They discussed a case study to demonstrate the applicability of the proposed optimization model and solution method.

The effect of each factor is evaluated based on the opinion of the traffic experts, and a weight is assigned to each of them based on the importance of that factor. Some factors considered in this research are street capacity (Road Service Level), average speed, land use, pavement status, line width, type of street (boulevard or non-boulevard), low density areas, ARC length.

Before integrating relevant factors and maps, the relative importance of each effective factor is determined and an appropriate weight is assigned to each of them. The integration of informative factors regardless of their importance in routing cannot m include their actual value in the final integration and therefore units with different values fall in one parameter, while each of these parameters has a particular importance. Weighting is based on expert knowledge.

Finally, for data analysis, effective criteria in public vehicle locating are prioritized by Hierarchical Analytical Process (AHP) Weighting and after overlapping layers using GIS and their final analysis relative to the research goal, the final layout of the public transportation vehicle is obtained. We have used ArcGIS and GAMS for data analysis.

2.1. Mathematical model

In this section, we develop a mathematical model in order to determine the optimal routes for transport vehicles in such a way that the overall weight obtained from AHP is maximum besides the overall cost. In fact, the output of AHP determines the weight of each route (w_{ij}) developed in the mathematical model and is considered as the second objective function. In fact, the goal is to determine optimal routes for minimizing cost and maximizing the overall weight of routes, in which some criteria such as street capacity (Road Service Level), average speed, land use, pavement status, line width, type of street (boulevard or non-boulevard), low density areas, ARC length for each route between i and j are considered in AHP method. In general, based on the proposed methodology, after performing AHP method and obtaining input and then providing the mathematical model and solving it using GAMS, the optimal routs of public vehicles are obtained by considering two goals: (1) reducing the total cost, (2) increasing the total weight of the routes obtained by the AHP method.

The basis for the development of the mathematical model is considering the real world assumptions, real world information, and public transportation organization. In the following, the basis of the mathematical model and its assumptions are explained.

In this paper, public transportation lines optimization is presented in the form of a capacitated vehicle routing problem. Consider a graph network representing a metropolitan area defined as $G(N, A)$, N denotes the number of nodes and A denotes arcs representing the relationship between the nodes of the network. In every urban network, there are such metropolitan areas and these areas include demand nodes for serving passengers. These nodes within the defined network are subway or bus stations where waiting passengers are considered as demand parameter. Also, main parking is considered in these urban areas for vehicles where public vehicles start their trip from there. In fact, by providing modeling, besides reducing municipal costs, we want to reduce the pollution by providing optimal routes.

Some most important assumptions of the model are as follows:

- Each person is serviced only by one public transportation vehicle.
- There are a number of predefined available vehicles in the organization. These public vehicles have different capacities.
- Each specific area can be serviced by these public transport vehicles so that all passengers are serviced.
- Public vehicles start their trip from their parking lot and then return to that parking lot after the end of the daily trip.
- Each vehicle has a maximum service time.
- The distance between two points in the network is considered as Euclidean distance.
- The time and cost of traveling a specific route are the same among all vehicles.
- The objective of the problem and the proposed model is to minimize the total costs imposed on the organization.

In the following, symbols, Indices, sets, parameters and variables of the problem are presented and finally, mathematical model is provided.

Indices and sets

i, j: indices of demands (stations) on the urban graph network ($i, j \in N1$)

d: index of municipal parking lots ($d \in N2$)

v: index of public municipality vehicles ($v \in V$)

N: the set of all points in the network ($N = N1 \cup N2$)

A: the set of defined arcs by the points within the network

$N1$: the set of all demand points on the network ($N1 \subset N$)

$N2$: the set of all parking points on the network ($N2 \subset N$)

Parameters

D_i: Demand of station *i*

f_v: Fixed cost of using the public vehicle *v*

d_{ij}: The distance of node *i* from node *j*

CV_v: Capacity of public vehicle *v*

$velo_v$: Average velocity of public vehicle *v*

$Tmax_v$: Maximum time of using public vehicle *v*

t_{ij}: The time of traveling the path between nodes *i* and *j* which is obtained by $t_{ij} = \frac{d_{ij}}{velo_v}$

w_{ij}: obtained weight for the path between nodes *i* and *j* which is obtained through AHP method and based on the defined criteria.

Variables

x_{ijv}: A binary variable which takes the value of 1 if the public vehicle *v* goes from node *i* to node *j*; 0 otherwise.

u_v: A binary variable indicates using or not using the vehicle *v*.

Now, the mathematical model is presented using the following equations:

$$Minimize\ \ Z1 = \beta\Big(\sum_{(i,j)\in A}\ \sum_{v\in V} d_{ij}\, x_{ijv}\Big) + \sum_{v\in V} f_v\, u_v \tag{1}$$

$$Maximize\ \ Z2 = \sum_{(i,j)\in A}\ \sum_{v\in V} w_{ij}\, x_{ijv}$$

$$\sum_{j\in N1} x_{ijv}\ = \sum_{j\in N1} x_{jiv} \quad , \quad \forall i \in N1, \forall v \in V \tag{2}$$

$$\sum_{v\in V}\ \sum_{i\in N} x_{ijv} = 1 \quad , \quad \forall j \in N1 \tag{3}$$

$$\sum_{i\in N} \sum_{j\in N1} x_{ijv} \le M\, u_v \quad , \quad \forall i \in N2, \forall v \in V \tag{4}$$

$$\sum_{j\in N1} x_{ijv} = u_v \quad , \quad \forall i \in N2, \forall v \in V, \forall c \in C \tag{5}$$

$$\sum_{i\in N1} x_{ijv} = u_v \quad , \quad \forall j \in N2, \forall v \in V, \forall c \in C \tag{6}$$

$$\sum_{i\in N}\ \sum_{j\in N1} D_i\, x_{ijv}\ \le\ CV_v \quad , \quad \forall v \in V \tag{7}$$

$$\sum_{i\in N}\ \sum_{j\in N} \frac{d_{ij}}{velo_v}\, x_{ijv}\ \le\ Tmax_v \quad , \quad \forall v \in V \tag{8}$$

$$o_i - o_j + (M)\, x_{ijv} \le M - 1\ \ , \forall\, i \in N \backslash N2 \cup \{1\}\ and\ \ \forall j \ne i\ \ and\ \ \forall v \in V \tag{9}$$

$$x_{ijv}, u_v \in \{0,1\}\ \ , o_i \in Z^{+}\ \ , \forall (i,j) \in A, \forall v \in V \tag{10}$$

The aim of Eqn. (1) is to minimize the total cost imposed on the organization including Routing costs and the cost of using vehicles by the organization.

Constraints (2) indicate flow balance (If a vehicle enters a node it should leave that node) that is specific to vehicle routing. Constraints (3) indicate the necessity of servicing to all demand stations by the public transportation vehicle.

Constraints (4) indicate that only when a public transportation vehicle is utilized we can use it, in other words, its cost should be paid before its utilization.

Constraints (5) indicate the necessity to start servicing public transportation vehicles from parking lots considered by the organization. Constraints (6) indicate the necessity of ending in parking lots by vehicles. Constraints (7) indicate the necessity of observing capacity limitation of public transportation vehicles in servicing demand points. Constraints (8) indicate the time limitation of using public transportation vehicles. Constraints (9) indicate the necessity of removing sub tours in vehicles routing which is in fact complement to constraints (5) and (6). Constraints (10) are about the type of problem variables.

3. Case Study

Tehran is one of the largest developing Metropolises in which a large amount of movement is done in a day and crowded streets, Long paths and heavy traffic are the most important features of this city and faces many problems including housing, health, air pollution, environmental pollution, migration, marginalization, increased crime, lack of cultural and educational spaces, lack of green space, traffic and transportation problems, especially in the public transportation sector. During past years, many efforts and investments have been made to control the traffic and pollution of Tehran, but most of them have not led to a satisfactory result. The public transportation system in Tehran includes regular buses, fast buses, and fast rail lines. Given the 86% increase in the population and the 60% increase in vehicles, it is necessary to have an integrated, fast, safe, and comfortable transportation system. One of the areas in Tehran where the need of using the transportation system especially bus is more urgent is area 1 of zone 4 of Tehran Municipality.

3.1. Research Area

Zone 4 as the largest zone in Tehran is a very good example for transportation studies because it has various transportation systems and utilization. On the other hand, given the high amount of information, paying attention to Tehran metropolis is a time consuming process. This zone is located in the east of Tehran metropolis with the Alborz slopes vision and green surfaces within and outside the zone like valleys of the Lar Dam, Lethian and the green valleys of Fasham, Oshan, Maigon and the recreational sports areas of Darbandsar, Shemshak and Abalei.

During the last three decades, zone 4 has faced surface development more than other zones. This zone has 9 areas and 21 neighborhoods. Geographically, it has a great gradient and is located in the foothill section, although it is composed of Mountains and plains. From the human geography point of view and in the demographic section, according to the 2006 census, zone 4 has the highest population and is the second zone in Tehran in terms of breadth. The population density is 122 people per km. In addition, in terms of sexual structure, 51 percent of the population is men and 49 percent are women. According to statistics, 34 percent of the population is workers and the highest percentage is for area 6 in which there is the largest group of the active population (Deputy of Transportation and Traffic of zone 4 of Tehran Municipality).

The public transportation system of Zone 4 includes a bus system, minibus, taxi, personal transporters and subway. According to the statistics provided by the Tehran Bus Company, 19 bus lines go from zone 4. There are a total of 358 bus stations in the zone and the remainders are for scattered lines (BRT), from which 12 are Rapid Transits are reminders are regular buses.

4. Computational results

In this paper, we have used hierarchical methods of the Analytical Hierarchy Process Model (AHP), along with the EXPERT CHOICE software in order to optimize public transportation lines in which Arc GIS software is used to display transportation lines maps.

Finally, in order to determine the optimal routes based on the defined objectives: (1) Minimizing total cost, (2) optimizing route weights according to mathematical model development, the proposed model is solved by GAMS software and CPLEX solver as the efficient exact method (Alinaghian et al., 2015; Davoodi and Goli, 2019; Tirkolaee et al., 2019). The details of this process and results are explained below.

4.1. Position of Bus Rapid Transit stations

The public transport system of Zone 4 has a Bus Rapid Transit system with 12 lines. Based on information received from taxi driving of zone 4 of Tehran Municipality, this zone has 49 taxi lines, a number of which has internal source and destination stations and source and destination of some of them is another zone of Tehran. There are 4 taxis stations within zone 4. Since each taxi line is required to have a source station and a destination station, it can be concluded that the source or destination of about 22 taxi-lines are outside the study area (Deputy of Transportation and Traffic of zone 4 of Tehran Municipality).

The next important issue in public transportation planning is determining the bus station coverage. The presence or absence of a bus station near the source and destination is an important factor in choosing a public transportation system by a person. If the station is not available, other aspects of the public transportation service are not considered for that trip.

The transportation service station must be at a reasonable walking distance from the source and destination so that the possibility of choosing that service by a person in the vicinity of the area increases. The coverage area of the bus stations is an area covered by a path at the walking distance of the station.

Figure 1 shows the lines of access to BRTs in the zone. As you can see in the figure, the BRT stations are located on the south and west of zone 4.

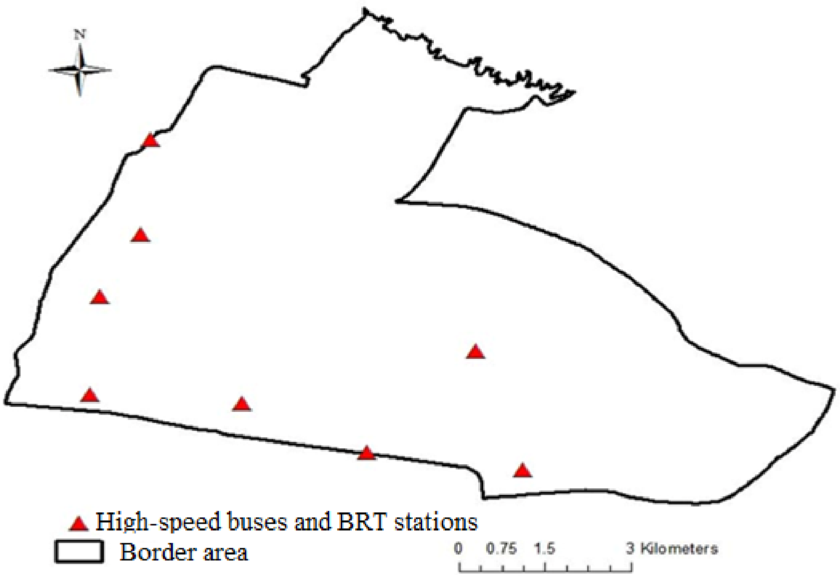

Fig. 1. The position of the Bus Rapid Transit stations.

4.2. Final Results of evaluating Criteria

One of the important steps before integrating the relevant factors and maps is to determine the relative importance of effective factors and assign appropriate weight to each of them. The integration of informative factors regardless of their importance in routing cannot m include their actual value in the final integration and therefore units with different values fall in one parameter, while each of these parameters has a particular importance in line routing. For this reason, the pair comparison method was used. This weighting method is a part of AHP (Ahmadi and Nasr Azadani, 2018). Weighing to each effective factor on routing is done in EXPERT

CHOICE software. Determining classes for effective factors and calculating the final weight of factors is one of the most critical problems in this model and the class with the highest score is of the highest value.

Using GIS analyzer tool and Analytical Hierarchy Process (AHP) method are desirable to solve the problem. So based on the specific conditions of the mentioned zone and available information about it, it is tried to convert the above criteria into quantitative values in order to be evaluated in GIS environment.

Based on the proposed model, and considering the availability of Information Bank of zone 4 of Tehran, on the first level, the following criteria are considered for use in the GIS environment in order to identify the optimal route of initial Bus Rapid Transits which are easy and quick to use.

At this stage, through Logic Valuation 1 using Analytical Hierarchy Process in GIS environment and based on the first level criteria (necessary conditions) an initial identification of the bus is done.

In the weighing method, through valuation logic, different classes, different weights and also flexible combinations of maps are obtained those include domains of numbers.

Then, the importance of criteria in relation to the objective (bus lines identification) is determined using Analytical Hierarchy Process (AHP) method. The final weight of each criterion is obtained from the product of the relative weight of that class in the relative importance of the criterion.

In this research, we use Analytical Hierarchy Process in tow stages. In the first stage, the relative importance of the criteria is determined and in the second stage, the relative importance of the sub-criteria is determined using this method. The relative importance of each sub-criterion is determined based on the valuation logic and ultimately, final weight is obtained from their multiplication. According to the weights of the relative importance of criteria (the result of pair comparison using AHP method), the relative and final weight of sub-criteria are obtained.

In the present study, since the identification of places is done through maps and GIS technology, there is no option and the final value and weight of sub-criteria are determined through pair comparison between criteria and between sub-criteria. Pair comparison between criteria or sub-criteria is done by values 1-5. Value 1 means the same importance and superiority for two criteria or sub-criteria and value 5 means the highest importance and superiority of a criterion or sub-criterion than the other one. The pair comparison is obtained through a questionnaire. A pair comparison is performed between Criteria or between sub-criteria of each criterion separately. Pair comparison is performed by urban transportation Experts familiar with the problems of zone 4 of Tehran Municipality, most of them were Experts of Tehran Comprehensive Transportation and Traffic Studies, Deputy of Transportation and Traffic of zone 4 of Tehran Municipality and Tehran Traffic Control Company. After completing the questionnaires by experts and collecting them, the median of experts' results and the final result of each pair comparison (a number between 1 and 5) are calculated. The results of the questionnaire are given to Expert choice software in order to calculate the final weight of sub-criteria.

The results of the Expert choice software are presented in Table 1.

Table 1. Final weight of the main criteria and sub-criteria using AHP method.

Main criteria	Weight	Sub-criterion	Weight	Minor criteria	Weight
				0-300	0.0709
		Residential	0.546	300-500	0.231
				500-800	0.06
				0-300	0.0778
		Educational and cultural	0.208	300-500	0.162
				500-800	0.059
				0-300	0.696
Utilization	0.257	Green space and entertainment	0.049	300-500	0.229
				500-800	0.075
		Medical and health	0.073	0-300	0.77
				300-500	0.162
				500-800	0.068
				0-300	0.779
		Commercial and office	0.124	300-500	0.143
				500-800	0.079
Access	0.121	Highway	0.031		
		Street	0.433		
		Grade 2 asphalt road	0.36		
		Grade 3 asphalt road	0.13		
		Off road way	0.046		
Resident populatio	0.559	Low density	0.062		
		Medium density	0.121		
		Dense	0.257		
		Very dense	0.559		
Bulk line stations (BRT and subway)	0.062	0-300	0.638		
		300-600	0.247		
		600-1000	0.077		
		More than 1000 meters	0.038		

As the results show, among the criteria, the resident population criterion has the highest value and importance, and according to the experts, the Bulk line stations (BRT and subway) criterion has the lowest value.

Among utilization criteria, Residential has the highest value, and then the educational and cultural criterion is also important. Among access criteria, the street is more important than other ones. In the population dimension, experts give higher importance and value to the very dense population. In bulk line stations (BRT and subway) criterion, the range of 0 to 300 meters has higher importance.

4.3. Final map of transportation stations

As seen in the maps, when the layers needed for the research are made, they are multiplied by the respective weights in the next stage. By observing the maps, it can be said that the bus and subway stations are located in south and west of Tehran's 4th zone. In this zone, the population density is low, and very dense areas are located in the south of the zone. There are 5 access ways including Highway, street, grade 1 asphalt road, grade 2 asphalt road, and off the roadway in access section. In utilization section, we have category 1: Medical and health; category 2: Educational and cultural; Category 3: Residential; Category 4: Incompatible utilization (military-security zones, facilities); Category 5: Commercial and office; Category 6: Green space and entertainment and Residential has the most effect and Green space and entertainment has the lowest effect on routing. After that, these layers and weights are given to ARC GIS software and final map of line routing is achieved. Figure 2 shows this routing. Purple color denotes a new routing for public transportation stations.

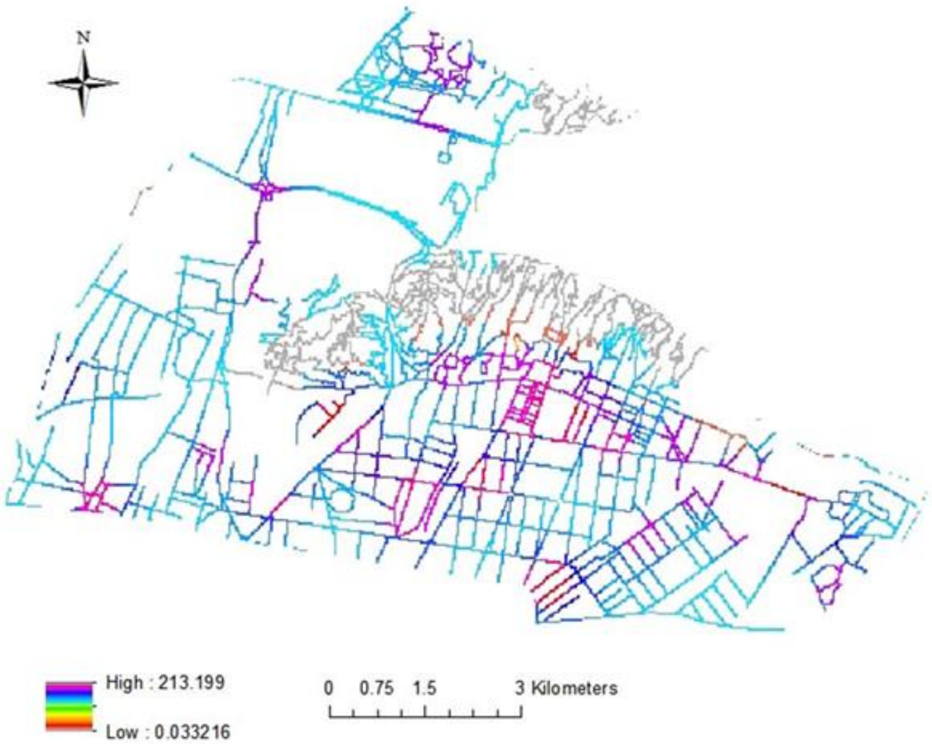

Fig. 2. Optimal routing for transportation lines based on the maximum weights obtained by AHP method.

4.4. Solving the problem related to area 1 of zone 4

After determining the weights of the urban area, we try to solve the problem based on the input parameters like the number of passengers in the station, capacity of vehicles, maximum available time of vehicles and the location of parking lots on the map of zone 4. Input parameters are given in Table 2.

Table 2. Values of the input parameters for the case study.

Parameter distribution function			
D_i	uniform(10,24)	D_i	uniform(10,30)
f_v	uniform(200,240)	CV_v	uniform(40,150)
d_{ij}	uniform(2,5)	w_{ij}	uniform(0,1)
$velo_v$	uniform(30,50)	$Tmax_v$	uniform(8,10)
β	1.2	-	-

The case study is investigated for area 1 of zone 4 which includes 30 bus stations and 2 bus lines. The aim is to determine an optimal route based on the provided mathematical model in GAMS software and providing optimal routes on the map. Obtained results including the value of objective, solving time of GAMS software are given in Table 3. The maps of optimal routes are given in Figures 3, 4, and 5, respectively. The sequence of optimal state and the current state of trips are given in Table 4.

Table 3. Results obtained from solving the mathematical model.

Problem	**Total travel cost (Multiplying Total trip length by Conversion factor)**	**Total cost of travel (sum of two buses) (s)**	**Total weight of traversed paths (objective function 2)**	**Run time (s)**
Optimal solution by software	1035980	55620	294	3549
Current status	1128450	60785	-	-

Table 4. Travel sequences obtained in the case study after solving the mathematical model.

Problem	**Trips sequence**
Optimal solution by software	Parking- 1-2-3-4-5-6-7-8-9-1/=//2-10-13-11-14-21-15-20-26-27-Parking (first bus) Parking-30-28-25-22-23-19-16-17-18-25-29-Parking (second bus)
Current state	Parking- 30-28-27-1-2-3-21-4-5-6-7-8-10-9-12-13-11-14-15-20-26-Parking (first bus) Parking-29-24-18-17-16-19-23-22-25-Parking (second bus)

By comparing the optimal results of solving the mathematical model with the current state, it is clear that obtained outputs are completely different. And in the optimal solution, savings are achieved than the current state in terms of the total travel distance and the total travel time.

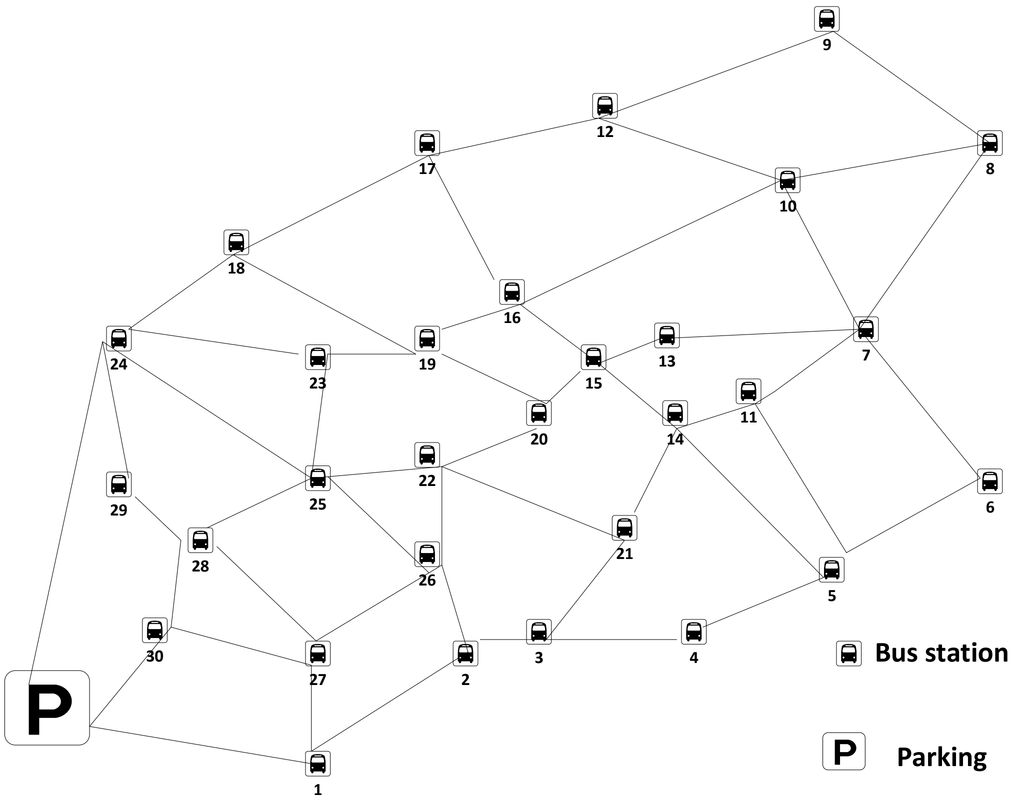

Fig. 3. Graph of area 1 in zone 4.

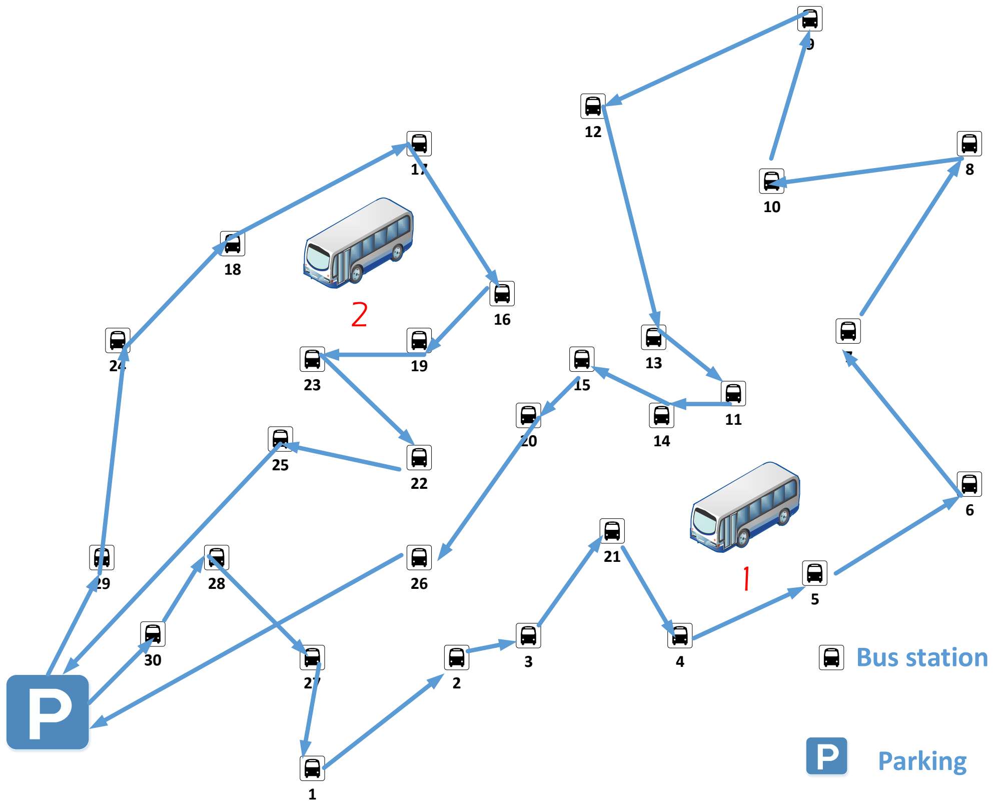

Fig. 4. The current routing of area 1 in zone 4.

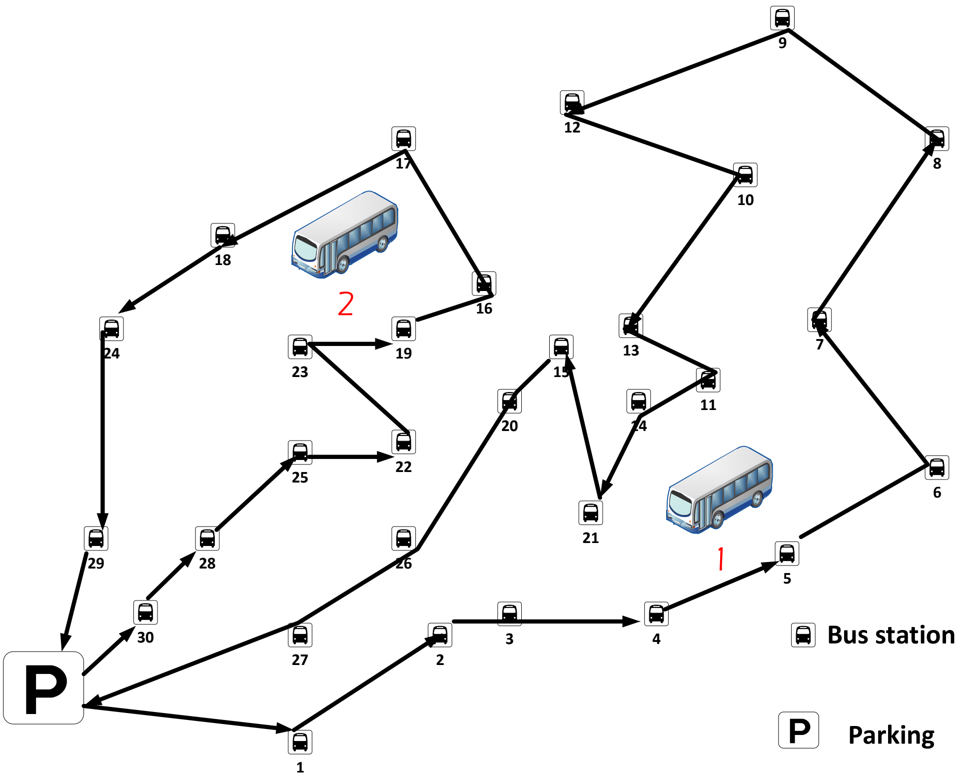

Fig. 5. The optimal routing of area 1 in zone 4 using the mathematical model.

Finally, the optimal route in Figure 4 is achieved by two buses to cover 30 stations. All stations are covered with a total cost of 1035980 units.

5. Conclusion and outlook

In this study, with the aim of optimizing the route of public transportation lines using hierarchical methods, first the history of public transportation lines optimization and theoretical foundations, and then related works are studied. The spatial information includes four main criteria: utilization, population density, access network and BRT stations, each of which has sub-criteria. Utilization criterion includes residential, educational and cultural, health and medical, commercial and office, and recreational sub-criteria. Because the considered zone has a high population density, it is divided into 4 categories: category 1 (low density), category 2 (medium density), category 3 (dense), category 4 (very dense). This criterion is the most important one in routing. Access criterion includes 5 sub-criteria: highway, off the roadway, grade 3 asphalt road, grade 2 asphalt road and street (in order of importance from bottom to top). Bus and BRTs stations are divided into 4 radiuses. Station with the less the radius is more important for routing. Weighing is performed after collecting these layers and performing weighing, results are given to ARC GIS software. In the final map, purple color denotes new routing for transportation lines. After determining the weights of routes using AHP method and based on the considered criteria, these parameters are used to develop mathematical model. Finally, the case study is solved by GAMS software. Our suggestions for future work are as follow:

1- Development efficient heuristic and meta-heuristic algorithms for solving case study problems in high dimensions,

2- Considering environmental objectives including carbon dioxide emission from vehicles,

3- Considering time windows for servicing to urban bus stations to determine the servicing interval for passengers.

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