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Multi-Criteria Decision-based Model for Road Network Process

Sadeghi-Niaraki, A .[1] , Kim, K .[1] and Varshosaz, M .[2*]

[1]Department of Geoinformatic Engineering, Inha University, Incheon, South Korea

[2]Department of Photogrammetry and Remote Sensing, Faculty of Geodesy and Geomatics Engineering, K.N. Toosi University of Technology, Tehran, Iran

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ABSTRACT: This paper addresses a multi-criteria decision based methodology to develop a road network cost function for route finding analysis in a Geographic Information System (GIS). Over the years, several studies relating to route planning process in GIS and Intelligent Transportation Systems (ITS) have been conducted, most of which rely on the use of one-dimensional variables like distance or time as a cost function. This paper, in contrast, investigates multi-dimensional variables to define the cost function using a multi-criteria decision making approach. To this end, first additional realistic variables which have quantitative as well as qualitative characteristics are taken into account. These include climate, sight-seeing information, road type, and so on. Second, they are combined using a Multi-Dimensional Cost Model (MDCM) using the Analytical Hierarchical Process (AHP). The models developed were implemented and closely evaluated in northern parts of Iran. The resulting routs showed to be more accurate than those obtained utilizing one-dimensional cost functions.

Key words:GIS, AHP, Multi-Dimensional Cost Model, Route finding analysis

INTRODUCTION

Decision support systems have been widely used in analyzing different urban and environmental affairs (Gharakhlou *et al.,* 2010; Vafaei and Harati, 2010; Goswami, 2009; Monavari and Mirsaeed, 2008; Alam *et al.,* 2008; Mahiny and Gholamalifard, 2007; Faryadi and Taheri, 2009; Shobeiri *et al.,* 2007; Pijanowski *et al.,* 2009). A common process in Geographic Information Systems (GIS) is route finding which is directly related to recent developments in Intelligent Transportation Systems (ITS), and to the field of in-vehicle Route Guidance Systems in particular (Fu & Rilett, 1998). In this process, each segment of a road is evaluated based on its direction and a measure of impedance/cost along the network. Being crucial in route finding, the measure is usually defined using a cost model/function, which refers to the amount of impedance, or resistance that can be expected through a network link from the origin to the destination node. Accurate definition of the cost model which is issued to each segment of the network leads to accurate route finding results.

Typically, the "cost" or the "impedance" of individual segments of the network is estimated using one-dimensional variables like time (Orda & Rom, 1990; Ziliaskopoulos, 1993), distance (Ben-Akiva *et al.,* 1984), and traffic (Shadewald *et al.,* 2001). However, the use of one-dimensional cost models can easily lead to, unrealistic results where different factors affect a user's decision in determining the most favorable path. By far, there have been some works that have posited more than a single variable to estimate a segment's cost. Unfortunately, most of these studies have not used a combination of multi-dimensional quantitative and qualitative variables. As a result, their approaches do not take qualitative variables into account, which leads to unrealistic outcomes. In addition, many researches have focused on urban roads instead of inter-city roads. For instance, Jun et al. (2004) proposed the use of regional supply, distance, the road network, and construction cost variables. Furthermore, Thirumalaivasan and Guruswamy (2003) reported various cost factors that play significant roles in determining the travel time, such as the traffic volume, the type of road, the road width, and the number of junctions and turns. However, their method was based on an empirical rather than a mathematical or general method.

To obtain a suitable and practical result with a GIS using a route finding algorithm, a methodology that can take various variables into consideration is

*Corresponding author E-mail: varshosazm@kntu.ac.ir

required. This methodology should determine several specifications of the road network that correspond with reality in order to achieve user satisfaction. Therefore, to yield appropriate route finding results in GIS, the present study first has determined several efficient variables that require more than the distance or time requirements for each road segment. Next, the Analytical Hierarchical Process (AHP) developed by Thomas L. Saaty was employed to weight all variables of the cost model. The AHP enables a hierarchical formulation and allows the combination of both qualitative and quantitative characteristics in the decision making process (Vahidnia *et al.*, 2009). The AHP has been applied extensively in decision-making problems (Saaty, & Vargas, 2001; Saaty, 1988; Saaty, 1980; Zahedi, 1986; Vargas, 1990; Souder, 1986). AHP presents an easy way for making complex decisions, using simple mathematics (Forman & Selly, 2001) The AHP procedure will be further explained in the subsequent section. Additionally, the cost model was determined using a linear combination of several weighted variables.

The objective of this research is to present a method of performing an optimal path analysis using several variables instead of a single variable on road segments. The main emphasis is to investigate the influence of multi-dimensional factors using a multi-criteria decision analysis on optimum path finding.

MATERIALS & METHODS

In this section, a number of efficient variables essential for route finding in GIS are obtained. In addition, an efficient method is then used to combine these variables in a unique function. In this research, the road network between Tehran and Mashhad cities was selected as a study area; Tehran is the capital and Mashhad is one of the largest cities in Iran (Fig. 1). The total area and length of the GIS based road network data (with a scale of 1:250,000) in the study area are approximately 482,000 square kilometers and 13,495 kilometers, respectively. This study uses some of the accessible and independent road variables that will have a major influence on the road network (Table 1).

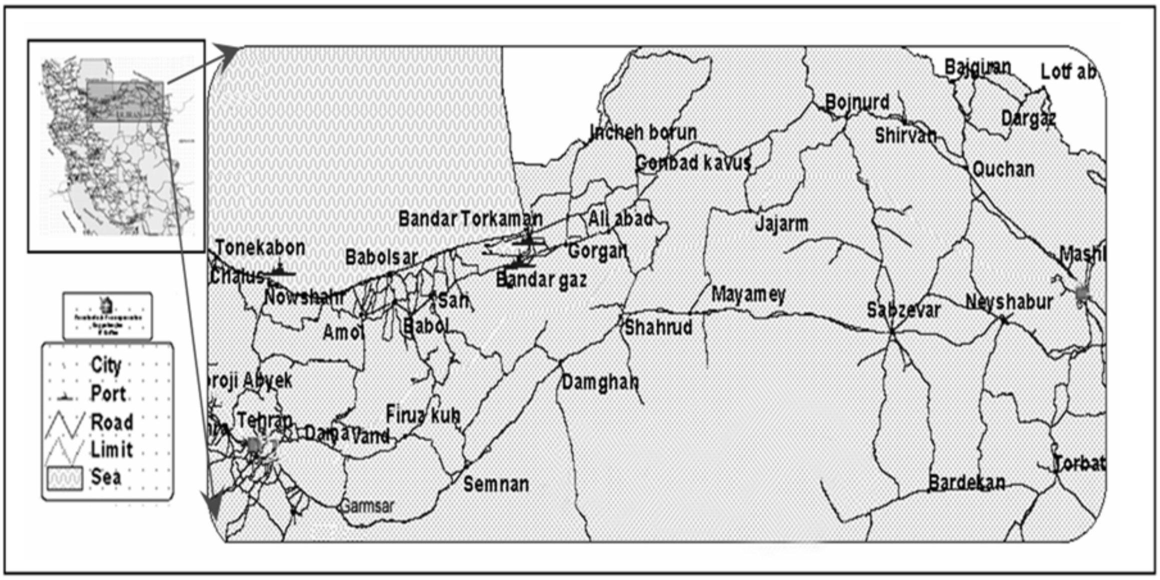

Fig. 1. Portion of Iranian inter-city road network used for study area

Table 1. The variables for the cost model of each road segment

Variables	Sub Variables
Climate	Moderate, relatively dry, cold, desert, warm, relatively dry, warm and humid.
Tourism	Sea, mountain region, jungle, historical places, rivers/and streams, dikes/lake, recreational places, ski resorts, deserts, and pisciculture station.
Road traffic	Several types of levels of service (A, B, C, D, and E).
Security	Police stations, side-road parking places, car-service location, medical treatment services, telephone boxes, maintenance office, urban/rural points.
Facilities	Gas stations, services, and car/passenger terminal.
Length	Main factor applied to other variables in the model.

In general, multi-criteria decision making methods require information about the relative importance of criteria. The relative importance is typically established by a set of preference weights (Alesheikh et. al, 2008). The AHP is one of the most developed multi-criteria decision making methods. In Schomaker, and Waid (1992) and Zaperto, Smith, and Weistroffer (1997), AHP was compared with five other techniques, including the utility theory method and multiple regression technique. The results showed that AHP is the least difficult to implement and the most accurate.

In the AHP process, the first step is decomposition, or structuring of the problem into a hierarchy. This hierarchic structuring reflects the natural tendency of the mind to sort elements of a system into different levels and to group like elements in each level (Stewart, 2005). In this study, the AHP structure addresses two levels. The elements of the first level are the main variables and those of the second level are composed of the sub-variables of each main variables (Table 1). A comparative judgment matrix is the next step of the AHP process. Basic scales of absolute numbers are considered in a reciprocal matrix in the AHP paired comparison judgments. Their numerical values are: 1 = equal, 3 = moderately dominant, 5 = strongly dominant, 7 = very strongly dominant and 9 = extremely dominant, along with intermediate values for inverse judgments (Saaty, 2005). Decimals are employed to compare uniform criteria whose comparison falls within one unit.

Since the AHP analysis of this research was designed for cost modeling for an inter-city road network, pairwise comparisons were conducted using the judgment of 35 Road Maintenance and Transport Organization (RMTO) experts who are professionals in the transportation and traffic field. RMTO is a part of the Road and Transportation Ministry and is responsible for the inter-city road network in Iran. The knowledge of these experts is the most reliable information in this research. The AHP process was explained in detail to all of these experts before asking questions for the pairwise comparisons process. Indeed, it was found that the pairwise comparisons of all variables to derive the cost model in this study are more complex; attaining a clear understanding of the concepts of these variables and their relationships is not a trivial task. In addition, the experts were asked to avoid personal opinions and to determine the best options for comparison judgments.

The next step of the AHP process is a comparative judgment matrix. The elements on the first level are arranged into a matrix and the decision maker makes judgments concerning the relative importance of the elements with respect to the overall goal (Saaty, & Vargas, 1991). In the present research, it was assumed that passenger cars are used in the cost modeling, as opposed to the use of other vehicles such as buses or trucks. It was found that some variables and sub-variables have different relative importance levels to each other in different seasons and for different goals (such as tourist trips in the summer or non-tourist trips in the winter). For example, the weather conditions in the summer are the worst possible conditions for traveling in the desert area whilst it is more pleasant to travel compared to in cold weather conditions in the winter. The tourism variable for non-tourist travel has the least importance for travelers, while on tourist trips this is very important. Therefore, in this research the goal of the AHP method can be delineated into the following four categories, allowing four MDCM goals to be defined: MDCM for the summer season and tourist trips (MDCM-ST), MDCM for the winter season and tourist trips (MDCM-WT), MDCM for the summer season and non-tourist trips (MDCM-SNT), and MDCM for the winter season and non-tourist trips (MDCM-WNT). Designing the MDCM in four different situations has many advantages such as simplification of the pairwise comparisons for experts due to very clear categorization of each variable, flexibility in choosing the preferable cost model for route finding based on the users' situation and their preferences.

Additionally, because the AHP is a multi-criteria decision making technique, combination of the priorities of the alternatives, derived under different criteria, is crucial. For this, after multiplying the weight of each variable by its variable, the results are summed together to find the cost function. This cost function is then employed to obtain the final ranking of the alternatives. In the present study, alternatives are the paths found between the origin and destination in the study area.

RESULTS & DISCUSSION

As explained in the preceding section, in order to create the models after designing the AHP structure and the comparative judgment matrixes, relevant variables in the same level were compared to each other by RMTO experts. The AHP process was explained in detail to all of the RMTO experts before asking questions for the pairwise comparisons process. As stated earlier, the judgment processes were performed in two levels, where first and second level modeling includes main variables and sub-variables, respectively. For the aforesaid MDCM situations, four and eight pairwise comparisons in the first and second levels of the AHP structure were performed, respectively. For this, Equation (1) shows the general MDCM formula of the aforementioned AHP processes after performing the pairwise comparisons by RMTO experts. Thus, the cost model of each segment is a linear combination of all weighted variables and sub-variables in two levels. The weights in the equations were normalized, implying that the aggregate of the weights is equal to 1. In the case of n variables, a set of weights can be written as (2). Since the length variable (L_i) of each segment has a special behavior compared with other variables, it has a reverse relationship with other variables.

$$F(MDCM) = \sum_{i=1}^{n} \left(\frac{K_i X_i}{L_i} \right) = \frac{1}{L_i}(K_1 X_1 + K_2 X_2 + K_3 X_3 + \ldots K_n X_n) \quad (1)$$

$$K = (K_1, K_2, K_3, \ldots, K_n)$$

where

$$\sum_{j=1}^{n} K_j = 1 \quad (2)$$

where $F(MDCM)$ demonstrates a general aspect of the MDCM model, X_i presents the variables/sub-variables, and K_i denotes the variables/sub-variables weight. The detailed process for determining K_i in the different AHP models in both noted levels will be addressed in the following sections. Since the MDCM AHP structure was designed in two levels, the modeling process was similarly performed in two parts, which are described in the following.

As previously noted, the MDCM model for the road network encompasses four different situations: MDCM-ST, MDCM-WT, MDCM-SNT, and MDCM-WNT, where (1) is the general equation of these models and (2), (3), (4), and (5) demonstrate specific situations of the cost model at the first level. The difference between these four models is only the weights of the variables, which have been derived from AHP pairwise comparisons in any situation from the first level of the AHP structure. Equation (2) presents the MDCM-ST model, where it is assumed that the goal of route finding is a tourist trip in the summer. In this equation, due to the high importance of the tourism variable and the road traffic, these are given the highest values. Equation (1) states the MDCM-SNT condition. In this equation, as the tourism variable has the least importance for travelers, the given value for this variable is nearly zero. Due to the importance of the road traffic variable for travelers in summer and assuming that non-tourist travelers and drivers want to reach their destinations as soon as possible, road traffic has the highest weight. Furthermore, in the MDCM-WT scenario (4), the tourism and traffic variables are the most important variables and the climate variable is relatively high as well. The traffic variable is the most important factor in the MDCM-WNT situation (5), while the value given to the tourism variable is nearly zero.

$$F_{ST} = \frac{1}{L_i}(0.149 F_1 + 0.296 F_2 + 0.193 F_3 + 0.175 F_4 + 0.187 F_5) \quad (3)$$

$$F_{SNT} = \frac{1}{L_i}(0.007 F_1 + 0.0 F_2 + 0.961 F_3 + 0.019 F_4 + 0.013 F_5) \quad (4)$$

$$F_{WT} = \frac{1}{L_i}(0.195 F_1 + 0.234 F_2 + 0.214 F_3 + 0.179 F_4 + 0.179 F_5) \quad (5)$$

$$F_{WNT} = \frac{1}{L_i}(0.040 F_1 + 0.0 F_2 + 0.901 F_3 + 0.032 F_4 + 0.027 F_5) \quad (6)$$

where F_{ST}, F_{SNT}, F_{WT}, and F_{WNT} present the MDCM-ST, MDCM-SNT, MDCM-WT, and MDCM-WNT models, respectively, F_1 is the effect of the climate variable, F_2 is the number of tourist places, F_3 is the extent of road traffic, F_4 is the security of the road, F_5 is the facilities around the road, and L_i is the length of the individual road segment.

Additionally, to verify the above models, inconsistency ratio (IR) analyses were performed for each model. The proper IR reveals the appropriate pairwise comparison process of RMTO experts to determine the given models. The results of IRs have been stated in the model evaluation section. Furthermore, a comprehensive explanation of the process to quantify all main variables and sub-variables of the above models is presented in the following sections.

Subsequent to obtaining the MDCM models in the first level, the modelling of the sub-variables were designed in second level. Quantification of these sub-variables is required for implementation of the models in a GIS. In the present study, two different categories were created to quantify the sub-variables of the MDCM models. The first includes the sub-variables of the two main variables, i.e. the road traffic flow and the climate variable, which have clear and differentiable effective zones. Based upon each road segment circumstance, only one sub-variable among the traffic or climate variables is assigned to the road segment. For instance, as noted earlier, the road traffic variable has five sub-variables. In each road segment, depending on its traffic volume, its associated traffic sub-variables weight will be assigned to the road segment. To quantify this type of variables, all sub-variables of these two noted variables were determined using an AHP pairwise process by RMTO experts. The second includes the sub-variables of the three main variables of tourism, security, and facilities. Each road segment may be affected by multiple sub-variables. As such, a buffer method technique was proposed to quantify the sub-variables. A detailed explanation of these methods is provided in the subsequent sections. Furthermore, to verify the subjective priorities assigned to the pairwise comparisons of the sub-variables, the IR, described in the model evaluation section has been performed for the following AHP process.

The climate variable belongs to the first category. The climate variable includes six sub-variables: cold, moderate, dry-cold, warm-humid, dry-warm, and desert climate. The present paper assumes that the climate variable is roughly fixed across the study area. However, the variation of this variable has been considered only by defining two different situations, summer and winter seasons. After carrying out the AHP methodology for these sub-variables for both summer and winter conditions, Table 2 is obtained through a survey of RMTO decision-makers.

The traffic variable is also a significant variable in the MDCM modeling. Typically, there are two types of methods used to consider traffic extent. The first is the use of average daily traffic (ADT) or annual average daily traffic (AADT) data. The second is the application of the Level of Service (LOS) method. The calculation of traffic volume by employing the ADT or AADT cannot take into account many cases such as consideration of traffic with regard to the type of road, the volume-to-capacity ratios, and the type of area. Thus, in this work, the LOS variable, which considers the aforementioned cases, was adopted. The concept of LOS is also described in the Highway Capacity Manual. It involves qualitative measures that characterize operational conditions within a traffic stream and their perception by motorists and passengers. Roadway LOS is a measure of roadway congestion ranging from LOS A (least congested) to LOS F (most congested). LOS F is a zone in which the operating speeds are controlled by stop-and-go mechanisms, such as traffic lights. This is known as a forced flow operation. The stoppages disrupt the traffic flow so that the volume carried by the roadway falls below its capacity; without the stoppages, the volume of traffic on the roadway would be higher or, in other words, it would reach its capacity (Yu, Zhu, & Zhang, 2007). To quantify the LOS, an AHP structure including all different level of LOS in its branch was built. The traffic experts then made a pairwise comparison judgment to evaluate the traffic process. Table 3 shows the results of the AHP process for the road traffic variable with respect to LOS.

Table 2. Climate quantification results

Climate	Summer	Winter
Cold	0.378	0.029
Moderate	0.275	0.308
Dry-Cold	0.128	0.301
Warm-Humid	0.096	0.231
Dry-Warm	0.079	0.049
Desert	0.045	0.083

Table 3. Traffic quantification results

LOS	A	B	C	D	E
Weight	0.505	0.267	0.127	0.074	0.027

In order to quantify the sub-variables of tourism, security, and facilities, after calculating the weights of these sub-variables in the second level by the AHP process, buffer methods were applied. The surroundings of the Iranian road network typically include popular sightseeing areas. Thus, the tourism variable is significant in tourist travel. In this study, the tourism variables are divided into nine sub-variables. The weight of each sub-variable was assessed with the use of the AHP method by RMTO experts. Since the modeling in the first level was performed in two different seasons, two different weights were determined for all tourism sub-variables in summer (6) and winter (7) conditions. Furthermore, the security (8) and facilities (9) variables include several variables that affect the road network in term of safety and services, respectively. The weights of each sub-variable can be assessed using the AHP judgment procedure.

$$F_{2(summer)} = (0.227X_1 + 0.217X_2 + 0.187X_3 + 0.187X_4 + 0.063X_5 + 0.126X_6 + 0.050X_7 + 0.063X_8 + 0.025X_9) \quad (7)$$

$$F_{2(winter)} = (0.145X_1 + 0.194X_2 + 0.182X_3 + 0.207X_4 + 0.048X_5 + 0.256X_6 + 0.118X_7 + 0.048X_8 + 0.099X_9) \quad (8)$$

where $X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8$ and X_9 denote the sea, recreational places, jungle, mountain regions, rivers/streams, ski resorts, historical places, pisciculture stations, and dikes/lakes, respectively.

$$F_4 = (0.088Y_1 + 0.088Y_2 + 0.033Y_3 + 0.406Y_4 + 0.298Y_5 + 0.069Y_6 + 0.017Y_7) \quad (9)$$

where F_4 presents the security variable, $Y_1, Y_2, Y_3, Y_4, Y_5, Y_6$ and Y_7 show the number of police stations, road maintenance offices, urban/rural points around the road, side-road parking places, car-service points, medical treatment service locations, and telephone boxes, respectively.

$$F_5 = (0.134Z_1 + 0.093Z_2 + 0.773Z_3) \quad (10)$$

where Z_1 is the number of gas stations, Z_2 is the number of car/passenger terminals, and Z_3 is service centers.

In fact, the value of the equation (1) demonstrates a general aspect of the MDCM models (equation 2-5). The value of equation (2-5) includes several sub-equations (6-9) and two tables (2 and 3). In fact, equation (1) is a combination of multiplying the inverse distance $(1/L_i)$ and a polynomial $(K_1X_1 + K_2X_2 + K_3X_3 + ...K_nX_n)$. The value of inverse distance is inverse length. Because the polynomial is only the combination of multiplying some coefficients and some numbers without value, it does not have any value. Thus, the value of equation (1) as well as the final value of all equations (2-5) is inverse length. It should be noted that the models can be implemented in any route-finding algorithm. This study utilizes the route-finding algorithm of the ArcView software package. ArcView utilizes a modified Dijkstra algorithm (Dijkstra, 1959) implemented using d-heap's with d = 2 (Weiss, 1997).

A number of issues relating to the evaluation of a novel model are raised at the time of its determination. Typically, two elements of a decision support system evaluation are verification and validation. Model verification is to ensure that the model is correctly built from a formal point of view, while model validation assesses the model's effectiveness to the user, i.e. its ability to improve the decision-making process and improve the ability of the decision-making process (Sojda, 2007; Qureshi, Harrison, & Wegener, 1999). In the present study, after the model verification, validation of the models was considered to verify the weight determinations and selection of variables for the models.

A measure termed IR is used to verify the consistency of the decision makers' judgment for model verification. Inconsistency of judgment likely occurs when decision-makers make mistakes during the process of pairwise comparisons. The IR examines subjective priorities assigned for the pairwise comparisons and determines the extent to which all the pairwise judgments differ from ideal consistency among all comparisons. The IR provides a useful reference about how to interpret information returned from an individual or a group. IR in the AHP is a unique tool that can evaluate the inconsistency of each individual decision maker. As previously mentioned, the 35 RMTO experts surveyed here were the decision makers in this work. IR of various pairwise comparisons, which were explained in previous sections in different levels, were evaluated for each expert opinion separately. If the IR of each expert's evaluation was greater than 0.1, then his/her assessment can be deemed inconsistent. In this case, the decision-maker has to constantly reassess their judgment until an IR of smaller than 0.1 is achieved. The following discusses how this research deals with the inconsistency issue.

If the IR of the MDCM models was greater than 0.1, then the experts were asked to constantly re-evaluate their judgments in the pairwise matrix until an IR of less than 0.1 was achieved. In the first level of the MDCM models, consistency was evaluated as follows: The final IRs of MDCM-ST, MDCM-WT, MDCM-SNT, and MDCM-WNT models were approximately 0.075, 0.087, 0.0756, and 0.084, respectively. Thus, all of these ratios were smaller than 0.1 and reflect a fairly coherent set of assessments for modeling in level one of the AHP structure. In addition, in the second level of modeling, the IR measurement of each individual evaluator for each sub-variable was no greater than 0.1 in the final re-evaluations. The ratios show that the inconsistency of the AHP process for the sub-variables climate (winter situation), climate (summer situation), traffic, tourism (winter situation), tourism (summer condition), security, and facilities were 0.045, 0.039, 0.098, 0.075, 0.080, 0.034, and 0.041 respectively, which all are generally quite acceptable for practical purposes.

Following the model verification, a model validation was performed to confirm that the models were appropriately built from a conceptual and operational point of view. It is clear that validation of a model based on multi-dimensional quantitative and qualitative criteria through comparison to one-dimensional criteria would be a complex task. This is not only because of the difficulties in acquiring quantitative information, but also, for theoretical reasons, attaining qualitative experimental validation data is simply not feasible. Such qualitative data are subjective and could provide incorrect information. Therefore, in the present research, an attempt to validate the performance of the model was carried out through a comparative analysis between the MDCM results in GIS and data from an available RMTO survey in the study area (RMTO, 2004).
The path obtained from both the MDCM-ST and MDCM-WT models in the road network passes through Tehran, Damavand, Amol, Bojnurd, and Mashhad cities, and is named path (I) in this research (“Haraz route” in Fig. 2). This path has more pleasant weather conditions as well as many tourist attractions compared to other routes between Tehran and Mashhad. Furthermore, after implementing the MDCM-SNT and MDCM-WNT models in the road network, the results of the optimum path analysis for both yielded a path that started from Tehran and passes through several cities such as Garmsar, Semnan, and Sabzevar and arrives at Mashhad; this is designated path (II) in this study (“Semnan route” in Fig. 2). This path is the shortest path with the least road traffic volume compared to the other routes between the origin and destination. This route was built in a dry-desert region with little tourism capacity and it does not have climate problems in the winter.

To verify the utility, generality, accuracy, and reliability of the MDCM models, comparisons should be carried out between the suggested path implemented with MDCMs in the GIS road network and the paths normally chosen by drivers, which are delineated on the basis of a RMTO survey. In this research, the RMTO survey outputs in the study area were used as independent data to validate the MDCM models. The RMTO surveying project was performed on June 2004 by RMTO (RMTO, 2004). As shown in Fig. 2. the RMTO survey results illustrate that there are three well-known paths in the study area, known as the “Semnan route”, “Haraz route”, and “Firuz-kuh route”, between Tehran and Mashhad cities (RMTO, 2004). The selection of other paths by drivers was much less frequent than the three aforementioned routes.

The lengths of the Semnan, Firuz-kuh, and Haraz routes are 886, 973, and 949 km, respectively. In this respect, the results also indicate that the drivers who chose the “Haraz route” prefer this path when making tourist trips either in the winter or summer over other paths. This is because of its various tourist facilities (e.g. restaurants), interesting places, and pleasant climate relative to other routes. Although this route has a high level of traffic and is somewhat more difficult in winter, regarding the advantages and assuming the unimportance of time for the traveler, it is the best choice. On the contrary, the survey results demon-

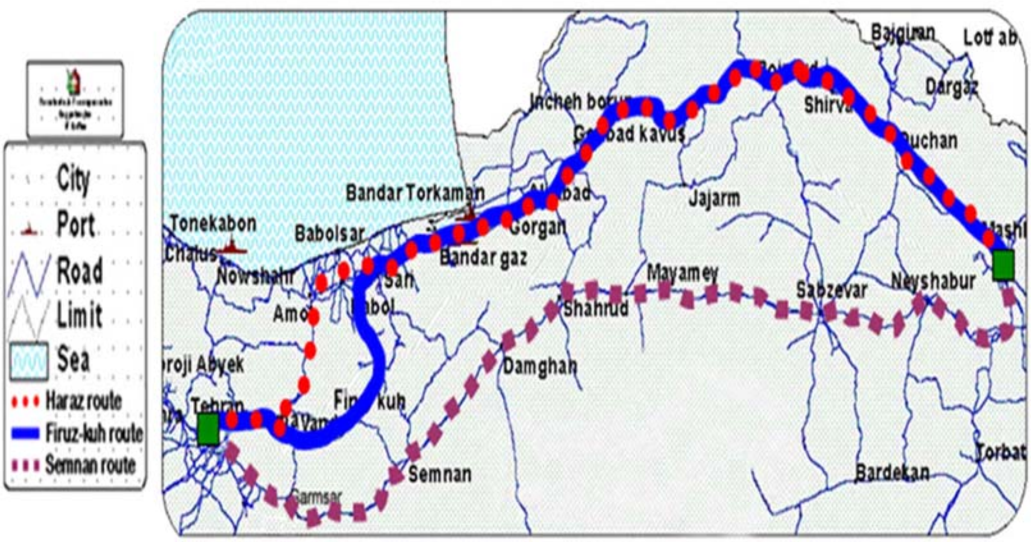

Fig. 2. The result of RMTO surveying in study area between Tehran & Mashhad

strated that in reality most drivers on non-tourist trips choose the "Semnan route" in both summer and winter when on business trips. These reasons for this include the fact that it is the shortest route and it has the lowest road traffic rate and the fewest climate-related problems in winter. Furthermore, this trip is not a tourist trip, thus implying that the tourism variable is not of high importance for travelers. Lastly, the above results demonstrated that the MDCM models output correspond well with the findings of the RMTO survey.

This paper considers the conventional one-dimensional results to demonstrate the advantages of the suggested multi-dimensional method over the standard single dimensional approach. In this step, the differences between the implementation of the four MDCMs and a conventional method based on a single variable such as distance are evaluated. The route finding result, based only on distance, passes through Tehran, Firuz-kuh, Semnan, Sabzevar, and Mashhad. After considering the results given by the experts, a major problem was found in this path in terms of the real world; drivers almost certainly would not select this path. For more information regarding this problem and for determining why drivers do not use this route, a topographic map of the area is shown. This route has many twisting gorges that are difficult to pass. Therefore, this example underscores a major problem associated with the use of the conventional method.

The analysis between the MDCM outputs (paths I and II) and the conventional approach results with the RMTO survey results revealed the following. Path (I) was adapted to the path that is chosen by travelers on tourist trips in both summer and winter, i.e. both the MDCM-ST and MDCM-WT models have been designed with high precision in terms of corresponding with reality. In contrast, the conventional model results showed major differences with the path selected by the tourist travelers. Additionally, path (II), the MDCM-SNT and MDCM-WNT models outputs, coincided with the path selected by drivers on business trips in both summer and winter. On the contrary, the path of the conventional model based on distance did not accord with reality. The results of the evaluation analysis showed that there are no differences between the MDCM models outputs and the path chosen by travelers in reality. In general, the models provide an accurate picture of the road network in the study area. Hence, it can be concluded that taking into account of various qualitative and quantitative criteria affected on each road segment in reality, leads to the result of route finding analysis are more close to reality. This result coincides with what the driver choose their path to get to the destination. Since the accurate path of route finding analysis is based on the user' preference, the validation process of the result of MDCM models is complex. In this research, the result of the surveying performed based on asking many drivers from origin and destination was utilized to validate the result of MDCM modeling.

CONCLUSION

Aiming to resolve problems of one dimensional cost functions used in network analysis, this paper proposed a new model based on the use of a multi-dimensional cost function in GIS. For this, a model was developed by assessing, weighting, and combining several variables (travel, climatic conditions, season, road characteristics, and so forth) into a single cost model. The model was, then implemented in the Iranian road network and evaluated within GIS for its accuracy and reliability. The results indicated that, compared to the current techniques, the model leads to results which fit more precisely to the real routs selected by the users. An important advantage of the proposed approach over the others is that it incorporates quantitative along qualitative parameters affecting a user's decision, all in a single model. . Therefore, it can be concluded that this modeling approach appears to be adequate for the designed purpose, and it is applicable to GIS based route finding analysis. However, it is suggested that the use of multi-decision making techniques other than AHP to be also studied in the future. Furthermore, using the MDCM through WEBGIS would greatly enhance tourist services and tourist infrastructure. This will contribute further to the development of the tourist industry, as a large number of users would be able to utilize the MDCM results from any place in the world.

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