Evaluating the parameters affecting segments of a road network

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Abstract:
Finding a best rout between two points of a network is a common task in most Geographic Information Systems (GIS). A network and its segments are normally evaluated based on the distance or time required to travel from one node into another. The best path is, then, defined such that the total time or distance between the two nodes is at a minimum. Unfortunately, within road networks using time or distance alone may lead to results not necessarily desired by users. Thus, a number of additional factors which maybe somehow compulsory, need to be taken into account. In other words, a user may additionally be interested to choose his/her rout based the amount of road traffic, climate, road width and class, nearness to tourist or religious centers, hospitals, and petrol stations and so on. As a result, parameters of such may need to be taken into account in order to obtain more realistic and satisfactory decisions in a road network analysis. This paper is concerned with the development of a suitable cost model, derived based on a number of quantitative and qualitative parameters which affect the value of a road segment. Once formed, the model was tested in parts of Iran road network. Due to the diversity of weather conditions and user tastes the model was implemented and evaluated in four separate cases. The preliminary results showed that utilising the parameters presented in this article and the way they are formulated, can lead to routs of more satisfaction to users.

1- Introduction:
In Geographic Information Systems (GIS), network analysis is one of the most powerful tools. Selecting optimum paths for inter-cities traveling, transportation vehicles of domestic, directing the bus fleet of tourism corporations and international transportation companies are some examples of network analysis applications. So different parts of the routes network are evaluated considering their distance and required time to pas each part to analyze the optimum route to take. Unfortunately the route analysis through these two variables of time and distance can determine the exact specifications of network and practically results in dissatisfaction of GIS users. In next sections of this paper it will be shown that considering sufficient and suitable variables in selecting routes based on GIS

environment will results in better suggestions about the optimum route between Tehran and Mashhad following section introduces the proper effective criteria used in cost model.

2- The Criteria in roads cost:

Basically the main criteria effecting on roads are divided in to three groups of road humane and vehicle factors [Sadeghi –2002]the road criteria include that kinds of factors effecting on the value of a specific part of a route network and determines the characteristics and additional facilities and capabilities of that part an its nearby environment. Considering the variety of criteria in cost modeling these criteria are divided in to three groups of road, vehicle and humane factors (Table 1). Considering the short opportunity of preparing this paper and also the lack of sufficient information the modeling contains only some of the road criterion factors (Table 2)

The traffic rates, safety and security of the road, weather condition and road type are some examples of road criterion factors. The vehicle type and extent and type of fuel of that it use and … are examples of second group of factors which show the influence of vehicle in determination of the optimum route. The last group of factors is dedicated to humane factors including the age and skill of driver, the power of sight and familiarity of driver with car technical affairs.

Among above mentioned factors the road criterion factors are more general applicable in route finding analysis since the relevant information to this factors are more accessible than other two groups of factors. So in this paper we work on road factors on the other hand the weight of these parameters is also dependent on the vehicles types so the in the mentioned issues in this regard the cars are considered.

Table 1 – Criteria are divided in to three groups of road, vehicle and humane factors

Cost model criteria	example
Road criteria	Traffic, safety , additional facilities, weather condition, route length, geometric specifications, road type, road area, the potential points of collision, animals passing by, accurate driving signals, junctions and deviations, one-way or two-way direction, geographic direction, existent checkpoints
Vehicle criteria	Vehicle type and model, type and extent of fuel, vehicle weight, its shipment the method of tightening of shipment, the tires type, the lights, headlights, indicator lights and …
Humane criteria	Age, experience, fastening seat belts, wearing sight glasses, familiarity with car technical affairs, using road map and education and..

Table 2 – the road criterion factors which have been modeled in this research

Criteria	Sub criteria
Length	A main factor which was multiplied to other criteria in the structured model
Traffic	A, B, C, D, E levels of service
Safety	Like highway petrol centers, village and city points, side-road parking lots, z, health and medical treatment services, telecommunication centers
Tourism	Sea, lake and streams, dike, recreation places, jungle, mountain region, ski runs, cultural-historical places, antiques, religious regions, deserts, fishing zones,
Facilities	The fuel stations and public service centers and terminals

Weather condition	Moderate, relatively dry, cold , desert weather condition, warm and relatively dry, warm and humid

3- Cost Modeling:

After the identification and determination of criteria and sub criteria effective on the cost model of the routes, in order to devote values to each part of the routes network after determination of effecting criterion factors on the value devoting process, these determined factors should be weighed and combined in a systematic manner [Sadeghi-2003]. These factors are put to gather in a model called cost model in this research. Since some of these factors are quantitative and some others are qualitative, a method should be used to enable the simultaneous evaluation and combination of both groups of factors. The Analytical Hierarchical Process is one of the most developed methods of multi attribute decision making models because this method enables the hierarchical formulation of matters and has this capability to contain both qualitative and quantitative factors in one single model [Ghodsi Pour, 1999]. This method was developed by a researcher called Thomas L. Saaty based on the method of analyzing complicated fuzzy matters by human brain in 1975 to the extent that many applications for this methods have been suggested by different researchers since that time. This process includes series of judgments, decision makings and personal evaluations via a logical method.

A scientist called Tomas L. Saaty in 1975 developed this method on the basis of brain pattern of analysis on complicated fuzzy cases. this is process of judgment, decision-making and personal evaluation through a logical procedure[Satty,1988]. This could be said that this method is dependent on personal imaginations and experiences to hierarchically formulating a matter and on the other hand relates to the logic and conceptions for making the final decisions. Another advantage of the AHP method is that it makes a structure for participation and group cooperation for resolving the problems and making decisions. It also provides a unique, simple and flexible model for resolving a broad range of unstructured problems which is understandable for everyone. So it uses both systematic approach and detailed analysis to solve sophisticated problems and also realize the relative importance of factors in a model and tries to make a equity between these factors and enables the user to select best alternative suits its special objectives.

Conception of sophisticated events and matters can be come a major problem for human mentality so breaking the major structure of a case into its separate elements through a hierarchical structure can contribute to better perception of human mentality. In these kinds of structures every component is placed in a specific level and is assumed as a sub branch of one or all other elements which are placed in higher levels so the first step in AHP is dedicated to the identification of criteria and the relative position of these criteria (Figure 1). After structuring the tree chart and AHP chart, the same level and relevant criteria are compared with one another. Now in order to combine the criteria cording to above mentioned method of AHP the criteria should be granted suitable weights and compared with each other by specialist experts of AHP.

Since the comparison of the criteria required to specify the type and season of the travels so the modeling was performed through four different divisions (summer – tourism traveling, summer - none tourism traveling, winter – tourism traveling and winter – none tourism traveling)

The modeling is addresses in two levels, the first level's elements are the main criteria and the second level is composed of the sub criteria of each main criterion.

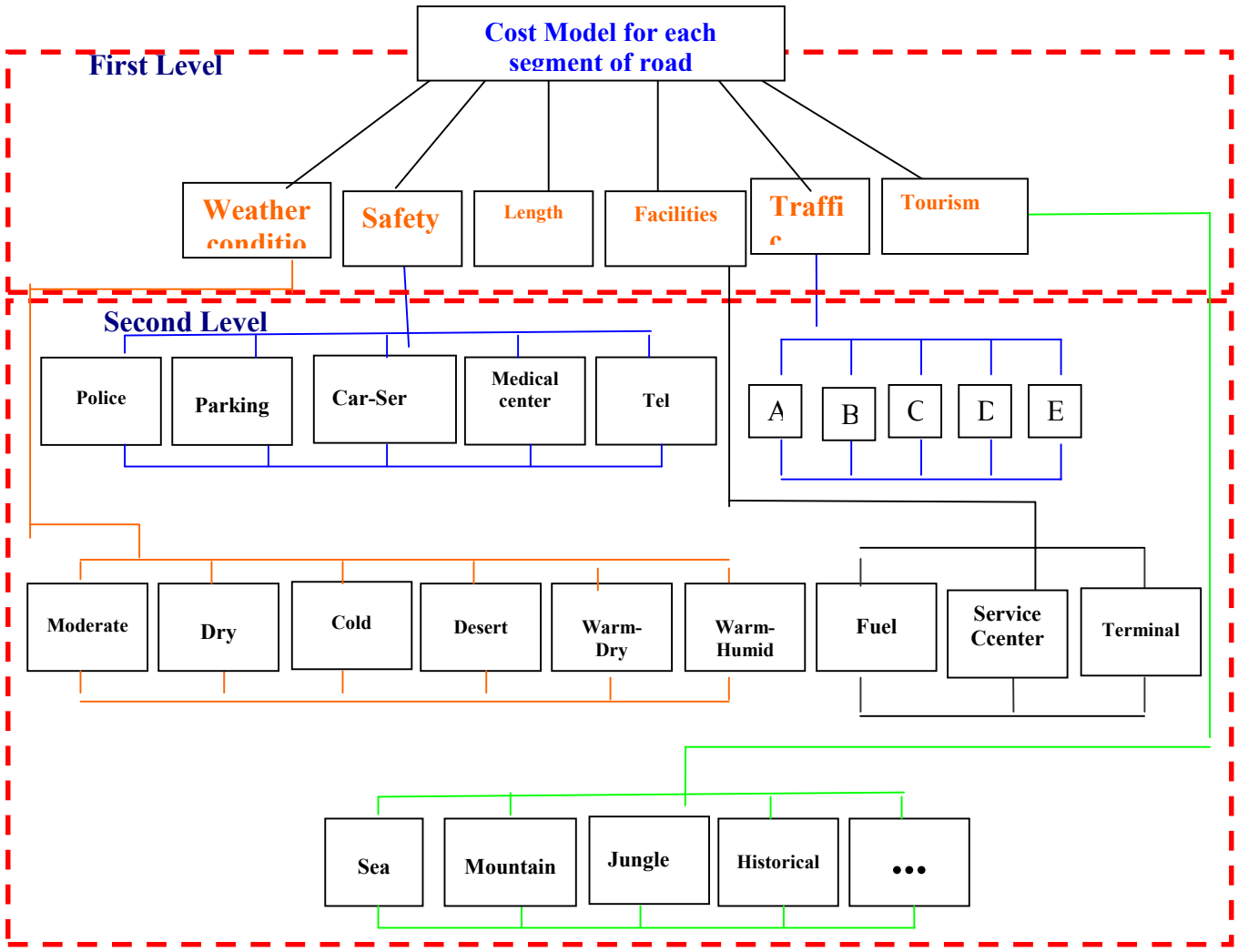

Figure 1 – the AHP diagram of main criteria and sub criteria of interurban cost modeling

- First level Modeling: after preparing a comparative table of criteria and sub criteria of the model and collecting the cost model experts points of view about the first level, two formulas were achieved:

After the paired comparison of criteria in four different statuses in first level this general formula for cost model is achieved:

$$f = \sum_{i=1}^{n} (K_i X_i) \qquad 2$$

In this formula f is the primary cost model of the roads excluding the length criterion, n is the quantity of effective criteria in cost model of the roads and Xi shows the effective criteria to cost model and K is a constant coefficient determined by experts of cost modeling.
The relative preference of one part to another part cost model is resulted from the quantitative result of F in above mentioned formula. In other word that part is selected after cost model analysis which has the highest value in all studied parts of routes network. Also the part with the shortest length is selected so the lengths of the route and F function have reverse relationship with each other. At last this general formula is offered as the general cost model:

$$F = \sum_{i=1}^{n} \left(\frac{K_i X_i}{L_i} \right) \qquad 3$$

The important point in these kinds of modeling is that the coefficients in the formula are normalized it means that the aggregate of these coefficients is equal to 1. The four different phenomena of the general cost model (formula 3) are mentioned bellow:
Summer – tourism traveling: in summer – tourism traveling status considering the high importance of sightseeing attractions criterion (F2), this criterion is granted the highest value in the model (formula 4), also another important case in tourism traveling is the extent of traffic in the roads so considering this case the next highest value is granted to traffic criterion (F3). In order to investigate the accuracy of granted values to different criteria and testing this issue that what would happen if one or more of criteria will be excluded from the model we will work it out in sensitivity analysis section.

$$F_{ST} = \frac{1}{L_i}(0.149\,F_1 + 0.296\,F_2 + 0.193\,F_3 + 0.175\,F_4 + 0.187\,F_5) \qquad 4$$

in this offered formula F_{ST}[1] ، F_{SNT}[2] ، F_{WT}[3] F_{WNT}[4] are cost model of summer – tourism, summer none tourism, winter tourism and winter none tourism traveling respectively. Also note that F1 is the criterion of weather condition, F2 shows the sightseeing attraction, F3 is the criterion of traffic, F4 stands for safety and F5 is the criterion of facilities, Li is the length of every part of the route. The F1 to F5 parameters are not constant but they are functions of their specific sub criteria which will be reviewed in next sections
Summer – none tourism traveling: in this kind of traveling since the sightseeing attractions have the least importance for the travelers the granted value two this criterion is 0. And since the traffic rate is very important for the traveler in this kind of traveling

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Evry "X" criterion can be a separate "F" cost model

[1] Summer tourism
[2] Summer None tourism
[3] Winter tourism
[4] Winter None tourism

and he wants to get to the destination as soon as possible this criterion (F3) is the most important criteria in this specific model.

$$F_{SNT} = \frac{1}{L_i}(0.007\,F_1 + 0.0\,F_2 + 0.961\,F_3 + 0.019\,F_4 + 0.013\,F_5) \qquad 5$$

Winter – tourism traveling: in this cost model (formula 6) since this is a tourism traveling the sightseeing attraction (F2) and traffic criteria (F3) are the most important criteria and the weather condition criterion (F1) has relatively high importance.

$$F_{WT} = \frac{1}{L_i}(0.195\,F_1 + 0.234\,F_2 + 0.214\,F_3 + 0.179\,F_4 + 0.179\,F_5) \qquad 6$$

Winter – none tourism traveling: the traffic criterion is the most important factor (F3) while the granted value to the sightseeing attraction factor is "0" since it has no importance for the user.

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

- Second level Modeling: After the paired comparison of criteria in four different statuses in Second level this general formula and tables for cost model is achieved (Table 3).

Table (3): The cost modeling of sub-criteria.

<table>
<tr><th>Criteria</th><th>Tables and Formulas of Sub Criteria</th></tr>
<tr><td>F1
Weather condition Criteria</td><td>
Table of Weather's Sub-Criteria in summer.
<table>
<tr><th>Desert</th><th>Dry & Warm</th><th>Warm & Humid</th><th>Dry & Cold</th><th>Moderate</th><th>Cold</th></tr>
<tr><td>0.045</td><td>0.079</td><td>0.096</td><td>0.128</td><td>0.275</td><td>0.378</td></tr>
</table>
Table of Weather's Sub-Criteria in winter.
<table>
<tr><th>Desert</th><th>Dry & Warm</th><th>Warm & Humid</th><th>Dry & Cold</th><th>Moderate</th><th>Cold</th></tr>
<tr><td>0.083</td><td>0.049</td><td>0.231</td><td>0.301</td><td>0.308</td><td>0.029</td></tr>
</table>
</td></tr>
<tr><td>F3
Traffic Criteria</td><td>
Level of service for traffic criteria
<table>
<tr><td>Level of service</td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td></tr>
<tr><td>Coefficients</td><td>0.505</td><td>0.267</td><td>0.127</td><td>0.074</td><td>0.027</td></tr>
</table>
</td></tr>
<tr><td>17 X_7)
F4
Safety Criteria</td><td>W_1 واحدهاي خدماتي، W_2 پايانه ها، W_3 جايگاههاي فروش مواد سوخت</td></tr>
</table>

F5 Facilities Criteria	$F_5 = (0.134W_1 + 0.093W_2 + 0.773W_3)$ W_1 public service centers ، W_2 terminals ، W_3 fuel stations

4- Cost Model Test:

In this section the above developed models are to be tested. So first of all we should specify the route which we want to test the cost model on, and then we will proceed to select optimum route through application of the cost model and evaluate the result against the reality.

4-1- Determination of the specific area for cost model teat: In order to assure the accuracy of the results provided by the cost model we should determine a specific area to test it in practice. In order to define the specific area for study some issues should be realized for example that Iran has a variety of environmental and weather conditions in its different points. As it was mentioned in previous sections the structured cost model is dependent to many different parameters and basically the modulation of all roads in Iran's routes network is something more comprehensive and sophisticated than what has been done in this paper and it should be considered as a national total plan. It might be impossible to provide a total model for all the roads of country's routes network on the other hand due to great variation of weather condition in different points of Iran this modeling should be performed regionally also an area should be used to test the model in which there are several routes between two points and these route should have various situations to be compared because considering these factors make the modeling process easier and reduces the complexity of the result model and also the results are more understandable. The routes of Iran have special complexities which are not clear to find in the first glance but through regional investigation these complexities become visible. Considering above mentioned issues these areas are more suitable for testing the cost models.

4-1-1- the region between Tehran and Mashhad: This region gas a special situation for cost modeling, the connecting routes between Tehran and Mashhad are three famous directions which are Firoozkoh route, Semnan route and finally the Haraz route. The descriptions of these routes are as follows: **Semnan route:** This route has different situation from other two mentioned routes. For example this route is the shortest one among these three routes (the length of Semnan route is about 886 kilometer and for Firoozkoh route is 973 and Haraz route is 949 kilometer length) and also has lighter traffic volume comparing to other routes. Most of the route is placed in a dry desert region and has little tourism and other necessary facilities on the way and has different and constant weather condition and specially has no problems in winters for the drivers comparing to other routes. The Semnan route is a main transition route which should have special facilities for this issue. **Firoozkoh route:** This route has less twisting roads and gorges comparing to Haraz route which is exhausting for professional drivers but is

very good for armature drivers who want to pass the way with less dangers. This route alongside with Semnan route is a main transition route and has better weather condition than Semnan route but has less mid-road facilities like city centers, road patrols or restaurants and other necessary facilities than Haraz route the Firoozkoh has less mountain landslides than Haraz route within a year due to its special geographic situation.

Haraz route: this route has much better weather condition than other two routes and due to existence of many cities villages (Pooloor, Larijan, Manzarieh …), tourism country houses and jungles mountains, lakes and various streams along the route makes it so cool for the passengers who pass this regions and has much more tourism attractions than other above mentioned routes. Haraz route Due to its special geographic situation has many twisting roads and its great height (2640 meters in Emam Zade Hashem gorges) is not a transition route like two other routes and has many season mountain landslides (like the huge avalanche which occurred in Bahmen-1379) within a year. This route has more mid-road facilities like restaurants, and patrols and other necessary facilities than other two routes described above. Of course in cold seasons considering the improper weather condition and frozen routes this route is in its minimum of use.

4-2- Cost Model Test on Tehran-Mashhad route:

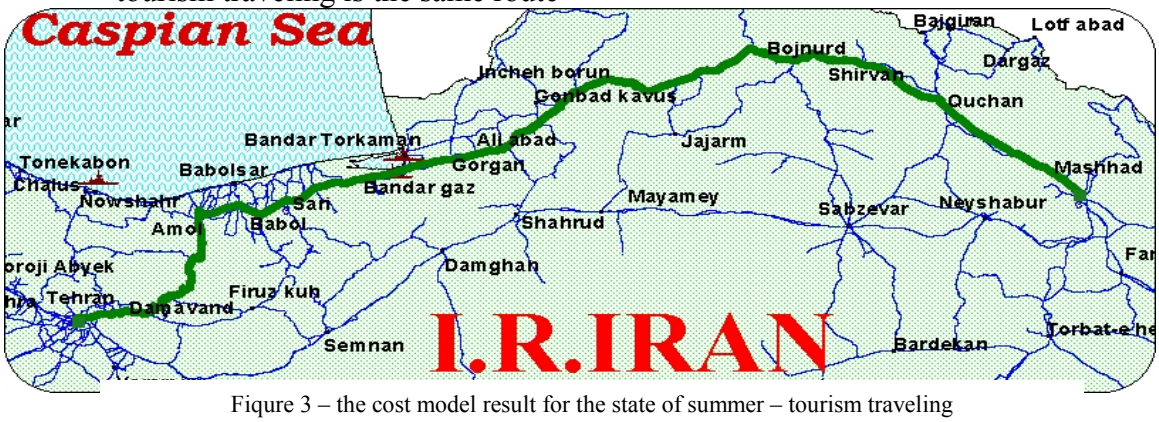
The results of analysis on the various routes based on four phenomena of summer – tourism traveling, summer - none tourism traveling, winter – tourism traveling and winter – none tourism traveling are as follows:

Fiqure 2 – The cost model results in state of summer – none tourism traveling

- **The Cost Model for the state of summer – none tourism traveling:** In this phenomenon the optimum result is the Tehran – Semnan – Mashhad route (Figure 2). In this step if the real route selection of travelers in summer and for none tourism traveling reviewed and the route was exactly the same with the route that model is suggesting then it could be said that the model has done a good job.
- **The Cost Model for the state of Summer – tourism traveling:** The model in this status suggests the Tehran-Haraz-Sari-Mashhad route (Figure 3). As a mater of the fact the travelers with touring interests who want to go Mashhad from Tehran in the summer mainly select this route considering its various tourism facilities and amusing places, tourism country houses and other side-road facilities like restaurants and sightseeing villages and other natural and

environmental visions which are number one among other routes. So a traveler who is not in a hurry to get to Mashhad and looks for recreations certainly select Haraz route. So in this case we get the correct answer from the model.

- **The Cost Model for the sate of winter – none tourism traveling:** The model in this status shows the Tehran-Semnan-Mashhad route (Figure 4). The model answer for route finding between Tehran and Mashhad in winter for none tourism traveling is the same route



Fiqure 3 – the cost model result for the state of summer – tourism traveling

- **The Cost Model for the state of winter – tourism traveling:** The model shows the Tehran-Haraz-Sari-Mashhad route for this status (Figure 5). At the first step it may be imagined that since the Haraz route is closed due to cold weather condition and frozen roads and also the dangerous situation of Firoozkoh route in winters, the Semnan route would be selected. But by careful attention to the case it would be clear that first of all the Haraz route due to its nice natural vision like mountains and jungles and its amusing places like ski runs could not be surrendered secondly it should be noted that this route is not closed all the time in the winters and basically if the routes were closed, that portions of the routes would be excluded in the cost model and route finding analysis and as a result in that status no comparison could be made so the suggested route by the model is correct.

Fiqure 4 – The result of Cost Model for the state of winter – none tourism traveling

5- Conclusion:

first of all and after finding out that merely application of distance and time indexes to evaluate the portions of the routes network in different areas mostly results in incorrect answers so other kinds of effective criteria on routes values were realized. These criteria are divided in to three groups of road, vehicle and humane criteria (Table 1). In this paper considering the time limitations, lack of sufficient information and special situation of modulation like the independency of the studied criteria, the modeling was just performed for road criteria also in road criteria modeling only those kinds of criteria important for car traveling route finding analysis were considered, since the value granting to the criteria could be completely different considering other kinds of vehicles. After leaving out the dependent criteria the final criteria to be used were defined as: traffic, safety sightseeing attractions, weather condition, facilities and the length of the route. The next step is the value granting and combination of criteria and sub criteria. In order to model criteria through cost model, the analytical hierarchical process (AHP) method was used. Modulation of two groups of qualitative and quantitative criteria through questioning and paired comparison of specialist experts and also offering a special method for results appraisal are some special characteristics of this method. Considering the variation of experts' points of view about the comparison of criteria and sub criteria in different seasons and different targets of traveling the modeling process was performed through four different supposed statuses of Summer – Tourism Traveling, Summer – None Tourism Traveling, Winter – Tourism Traveling and winter –None Tourism Traveling. in this model F1 to F5 were not constant numbers but they were separately calculated as functions. After these steps the model was put into test in Tehran-Mashhad route and the result shows that the suggestions of the model are exactly according to what happens actually in the roads. For example the model suggestion for the state of summer – tourism traveling from three existent routs of Semnan, Haraz and Firoozkoh, was the Haraz route which has the most tourism attractions among these three routes. In addition the model suggestion for the state of summer – none tourism traveling was the Semnan route due to its short distance and also suggested the Semnan route for the state of winter – none tourism traveling and Haraz for the state of winter – tourism traveling due to its beautiful nature and lots of side-road facilities and amusing places.

6- References:

Sadeghi Niaraki Abolghasem, 2002, " Defining the Cost Model of Iran Roads Network in GIS " GIS Msc. Thesis, Faculty of Geomantic Engineering, K.N. Toosi University of Technology, 117 pages.

Ghodsi Pour, seed Hassan, 1999, " Analytical Hierarchical Process ", Amikabir university.

Satty, T.L., 1988, "Hierarchies and Priorities" Chapter 8 of "The Thinking With Models: Mathematical Models in the Physical and Social Sciences" by Satty T.L. and Alexander J.M. Pergammon Press, Oxford, P.148-155.

Sadeghi Niaraki Abolghasem, Varshosaz Masood, 13-15 October 2003," Defining the Cost Model of Iran Roads Network in GIS", Map Asia 2003 Conference, Kuala Lumpur, Malaysia.

Lupien, E., Moorland, H., Dagermond, W., 1987, "network Analysis in Geographic Information Systems", Photogrametric Engineering and Remote Sensing, Vol.53.