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Introducing a Risk Parameter for Evaluating the Optimal Path in Location Based Services

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Abstract: This study introduces a risk parameter for evaluating the unreliability of the optimal path analysis in dynamic networks. The parameter is composed of several geometric features of the networks such as connectivity, accessibility and K-shortest paths. Integrating these parameters with pure optimization features improves the operation of optimal path algorithms in transportation networks. This is confirmed by testing the proposed algorithm on a real network. Details of the algorithm and its assessment are presented in the study.

Key words: Mobile GIS, path recalculation, unreliability, geometric indices of graphs, accessibility, K-shortest paths

INTRODUCTION

Mobile GIServices have been accepted as an important business application of Geospatial Information Systems (GIS) among ordinary users (Huang *et al*., 2007; Alivand *et al*., 2008). Location Based Services (LBS) could be classified in such category. LBS use the users' location by mobile communication networks for serving them spatial services (Sadoun and Al-Bayari, 2007). Finding the optimal path between two specific locations in urban transportation networks is one of the important analyses used in this environment (Kupper, 2005). Using this analysis could decrease the traffic congestion besides helping people to find the best route (Wu *et al*., 2007).

Urban traffic congestion is a complicated and ubiquitous problem (Wu *et al*., 2001). Continuous changes of traffic congestion and permanent changes of user location with respect to time demonstrate the importance of time in optimal path analysis in transportation networks (Huang *et al*., 2007; Alivand *et al*., 2008). The effects of time originated new tendency and studies in dynamic routing algorithms (Miller-hooks and Yang, 2005; Neumann, 2005; Ahuja *et al*., 2003; Chabini, 1998). The aforementioned properties show the inefficiency of static algorithms like Dijkstra in dynamic networks (Huang *et al*., 2007; Pallottino and Scutellà, 1998).

One of the most important algorithms used in transportation networks is path recalculation in facing with new traffic conditions (Miller-hooks and Yang, 2005). In this method when the traffic condition in the path or a region of network changes, the optimal path will be recalculated and presented to the user (Frigioni *et al*., 2000). The new calculated optimal path may be much different in comparison with the previous path, due to its spatial characteristics (Alivand *et al*., 2008). That is, if the current traffic situation is available from the beginning, more appropriate paths could be presented to the user, in comparison with the new recalculated path. Since the real situation of traffic could not be evaluated exactly for the future due to the variable and random nature of traffic, recalculating algorithms always have the risk that the new path has great differences with the previous proposed path (Alivand *et al*., 2008).

To decrease the magnitude of the unreliability, present study proposes a new parameter named risk of the path for each path which is an explanation for the deviation of the path from optimum when it faces severe traffic congestion in links' paths. To evaluate the risk parameter, some geometric and topologic measures and indices of a network which are extracted from graph theory have been used. By integrating these features with pure optimization features like K-shortest paths, an appropriate path with minimum risk will be chosen. Since, finding optimal path has applications in various fields like communications, computer networks and etc; the risk parameter could be used in those fields as well. This study focuses on transportation networks and their characteristics.

From the time of presenting the Dijkstra (1959) algorithm for finding the shortest path, the interests for

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finding more effective algorithms increase during the years and a lot of algorithms have been presented by Klunder and Post (2006) and Pallottino and Scutellà (1998). Also, a lot of researches have been done for finding the optimal path in transportation networks (Wu *et al*., 2007; Chabini, 1998).

Golledge (1995) has arranged ten different criteria which are used for choosing a path in such a way that shortest distance and time have the highest importance. Even, the simplicity of a path has been considered in this category. Nevertheless, the risk of the path and the possibility of path deviation from optimum have not been considered in this category.

Many researches have been performed to find the optimal path in dynamic transportation networks in which time has a fundamental role (Huang *et al*., 2007; Ahuja *et al*., 2003; Djidjev *et al*., 2000).

The first important study for finding the optimal path in time dependent networks which the links' weights change in a predictable manner was done by Cooke and Halsey (1966) that a discrete time model has been used. Many algorithms have been proposed for making their method better up to now (Chabini, 1998; Sherali *et al*., 1998).

The important research for finding the optimal path using reoptimization methods has been performed by Gallo (1980), where increase and decrease of traffic congestion in transportation networks have been considered and the effective reoptimization methods proposed based on those situations. By extending Gallo's observation about the properties of optimal path trees when the root node is changed, a more efficient algorithm has been proposed by Gallo and Pallottino (1982).

Most of the studies in path recalculation methods rely on the time complexity of different algorithms. Various methods have been proposed for decreasing the running time of incremental and decremental situations (Huang *et al*., 2007; Frigioni *et al*., 2000; Djidjev *et al*., 2000; Frigioni and Marchetti-Spaccamela, 1998).

Some different algorithms have been mentioned for finding the optimal path in transportation networks due to different user needs. For example, Duckham and Kulik (2003) has introduced the simplest path from the view of description of the path for guiding the people in an unknown city. In this case, a path will be presented to the user which the possibility of user lost is minimum. For example, a path which has the minimum number of intersections and turns has been chosen as the simplest path.

Wu and Hartley (2004) have used the K-Shortest Path method for choosing the optimal path based on user preferences. In their method, first some optimal paths are ranked ascending with respect to the travel time and then the obtained paths are compared based on user preferences and needs. Finally, a path which is coincided with users' needs is selected as the optimal path.

A few researches have been evaluated the risk of optimal path based on the expected travel time (Nie and Fan, 2006). They examined the reliability of shortest path with respect to travel time changes, but there is no study in the risk of optimal path based on danger of a obtained path by recalculation method to be deviated from optimum.

Also, some studies have been done in the area of danger of a path using the connectivity of a network when it faces unpredictable events like disconnection in a link. This problem has been examined in communication networks as reliability and vulnerability of network against the disconnection due to the failing of links or nodes (McHugh, 1990); but there is not any similar work in transportation networks and optimal path analysis based on the studies of the researchers.

THE OPTIMAL PATH IN DYNAMIC NETWORKS

Here, some necessary definitions and concepts are reviewed here in order to better understanding of next sections.

A graph G, is an organized triple (V(G), E(G), Q(G)) which has established from a set of $V(G) = \{v_1, v_2, \dots, v(k)\}$ which contains the nodes or vertices and a set of $E(G) = \{e_1, e_2, \dots, e(k)\}$ which contains the links or edges and a set of incidence functions $Q(G) = \{q_1, q_2, \dots, q(k)\}$ in such a way that a pair of nodes of G, which are not necessarily distinct, are related to each link of E.

A directed graph is a type of graph where the direction of links is important. That is, in a directed graph, the e(i) which connect the v(i-1) and v(i) from the direction of v(i-1) to v(i) is different with the link which connect these two nodes from the direction o v(i) to v(i-1).

G is a weighted graph, if there is a real number, $W(i) = \{w_1, w_2, \dots, w(k)\}$, associated with each edge of G. The weight of a link could be a function of the length, travel time, cost or a combination of the. A graph is named static graph or network when its weights are constant and a graph is named dynamic graph or network which its weights change with respect to time.

Transportation network is a type of directed, weighted and connected graph. In a transportation network model, roads are presented as a set of weighted links. The intersection of these roads establishes the set of nodes.

In a network, a set of links and nodes between two specific nodes which are not repetitive is named simple path or path. Walk is an overall type of a path which could be contained repetitive links and nodes. The shortest path or optimal path in networks is a path that the total amount of its weights is minimal.

LBS users prefer to choose the fastest path as optimal path (Kupper, 2005). Therefore, the links' weights of a network are supposed to be travel time. Since the users move in space and time, both of them are much effective in dynamic urban networks (Alivand *et al*., 2008) Because of travel time of each link is a function of traffic condition and traffic congestion changes continuously in the network (Ahuja *et al*., 2003), it can be concluded that static algorithms like Dijkstra could not provide the best solution to the users and new algorithms should be used (Huang *et al*., 2007; Chabini, 1998).

There are few algorithms for finding the optimal path in dynamic networks (Sherali *et al*., 1998). The algorithms for recalculating a path are probably the most cited ones (Miller-Hooks and Yang, 2005; Huang *et al*., 2007). In these algorithms, first, the optimal path is computed using one of the optimal path finding algorithms in dynamic networks like a simple Dijkstra. Then, if the traffic condition changes in the provided path, a new optimal path will be recalculated from the current location.

It has been proved that a sub-path of an optimal path is also optimal, but there is more than one path in recalculating algorithms that each one is optimal from their origin up to the end (Alivand *et al*., 2008). However, there is no guarantee that the total path be an appropriate path. In other words, since, traffic condition could not be evaluated exactly because of its complex and random nature; there is always a risk for recalculating algorithms that the new path has much difference with the proposed one.

In Fig. 1, the first path is the one that is provided to the user from the beginning. Then because of traffic changes, recalculating algorithm have been used and the second path have been provided from the determined node (A). Now, suppose that the current traffic data are available from the beginning, so the third path is better than the total travel time of the first and second paths (Table 1). The occurred conditions show the deviation of the path in node A. In other words, that node has a high risk of deviation when it faces severe traffic congestions.

When the current path cannot be changed because of traffic congestions, the provided path is one that does not have the optimum conditions. Also, if there is another path from current node to the destination, it may have much longer travel time to reach the destination with respect to previous path. So, these problems lead to unreliability in determining the solution by recalculating algorithms which arise from the impossibility of changing

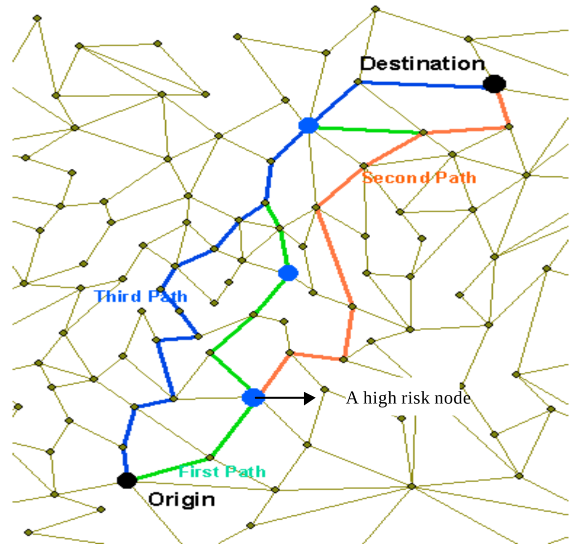


Fig. 1: Problems of conventional methods

Table 1: Comparing the paths for examining the unreliability in optimal path finding

Path's name	Start node	End node	Cost (min)
1st path (Green)	Origin node	Destination node	18
1st sub-path (Green to node A)	Origin node	Node A	17
2nd path (red)	Node A	Destination node	15
3rd path (blue)	Origin node	Destination node	20

the current path to an appropriate path. This unreliability leads to the definition of a parameter called the risk of a path which shows the possibility of changing a path from optimal conditions if traffic congestion occurs in its links. There are many parameters which could be used for computing the risk. These parameters are extracted from graph theory. Many heuristics have been presented for calculating the shortest path up to now (Huang *et al*., 2007; Fu *et al*., 2007; Pijls, 2007). With respect to the nature of the defined risk and networks characteristics, it has been tried to define it as a function of constant features of a network such that the risk of each path could be estimated before the calculations. Therefore, this risk has been considered as a function of some geometric and topologic features of a network. This function is assigned to the nodes of the network and the risk of path is computed based on that function. It shows the deviation risk of a path from optimum if traffic situation changes in links.

DETERMINING THE RISK OF A PATH

Computing the optimal path using pure optimization features has some unreliability in final solution because of the changes of travel times which arise from continuous changes of traffic congestion and unpredictable events (Alivand *et al*., 2008). So, it would be more appropriate to define a new parameter named risk for estimating the rate of danger in changing the path and integrating it with optimization algorithms.

Using the risk parameter, the user does not follow the optimal path with conventional cost functions; instead, if the proposed path has high risk the user can choose a successor path which has lower risk than the proposed path. In other words, a solution is presented here which an appropriate path will be proposed using the risk of the path. In this study two visions have been used to evaluate the risk of a path: 1- statistical features and 2- geometric features which are explained in details as follows (Xie and Levinson, 2006).

Statistical risk parameters: A parameter could be assigned to each link with statistic data for evaluating the risk. Using this data, the rates of travel time changes could be obtained in different times. If travel time of a link faces severe changes, it shows that the possibility of travel time changing in that link is high. Also, accidents rate could be another parameter to evaluate risk.

This method is useful when a large volume of data with high accuracy in each link is available. Also, an exact analysis is needed to determine the rate of changes in each link. Additionally, because of continuous increase of vehicles beside the increase of network capacity, it is necessary that these data are collected completely and constantly which cause further problems (Wu *et al*., 2007).

Geometric risk parameters: The main contribution of this study is to determine the evaluation risk parameters from the geometric and topologic point of view. There are many parameters that could be used for evaluating the risk using geometric features (Xie and Levinson, 2006). Generally, these parameters could be divided into two categories namely static and dynamic features. Static features are constant with respect to time and follow the topologic characteristics of graphs which the rate of their changes is very slow. Dynamic features are different in various times due to their dependency on travel time. Each one of these features assigns an amount to nodes. By integrating these amounts the risk of nodes and consequently risk of paths are determined.

Static features: The main characteristic of these features is to be constant with respect to time. They arise from topologic features of networks, so they should only be recomputed when new roads is added to the network. The two most important parameters to evaluate this feature are Connectivity and Accessibility which will be explained as follows:

Connectivity is one of the topologic characteristics of networks which are computed for network's nodes (Rodrigue *et al*., 2006). It is a measure of number of connected links to each node which their direction is towards their adjacent node (exited nodes). They are called the running away links here. The adjacency matrix is used to calculate the connectivity of each node for evaluating the risk of network's nodes. If the exited links of each node are equal to one and traffic congestion occurs on that link that path has a high risk because of the impossibility of changing the path to an appropriate path. Consequently, if the number of exit links of each node is greater than one, the risk will be decreased. So, the exit order of each node could be a parameter for evaluating the risk.

Also, number of entrance links could be another parameter to evaluate the risk. In this case, if numbers of entrance links to each node are greater than two and traffic congestion occurs on them, the traffic conditions are moved to the exited links of those nodes.

Generally, if the number of exited links with respect to entrance links for each node is greater than one, that node has a lower risk comparing to others. However, this parameter has less importance comparing to running away links parameter, so it has not been considered for evaluating the risk here.

In this research, the risk is divided into three classes, high, medium and low risk. Also, to compute and quantifying the risk, high risk is regarded as 1, Medium risk as 0.5 and low risk as zero (Table 2). Therefore, the quantities of risk may have three values (0, 0.5, 1) which put the computation in an appropriate and simple structure.

Suppose traffic congestions occur at the adjacent link of the node in which the previous path should be changed; a question may arise that how could be sure to exist an appropriate path if the user continue his/her way on the other exited link of that node. To answer this problem the accessibility parameter could be used.

Accessibility is defined as the measure of the capacity of a location to be reached by or to reach different locations (Xie and Levinson, 2006). Different locations have different accessibilities. The concept of accessibility relies on distance which is derived from the connectivity between locations. Connectivity can only exist when there is a possibility to link two locations through transportation. Commonly, distance is expressed in units such as in kilometers or in time. So, accessibility is an understandable concept of connectivity

Table 2: Evaluating the risk with connectivity parameter

Risk rate	High	Medium	Low
No. of exit links	1	2	Larger than 2

High risk = 1; Medium risk = 0.5; Low risk = 0 with an explicit difference that the connectivity is measured for one node, but accessibility is measured between two nodes (Rodrigue *et al*., 2006).

The number of existed walks between two nodes could be determined using accessibility parameter. It could be computed by building the total accessibility matrix (T) which contains directed and undirected paths. This parameter could be used both on directed and undirected graphs.

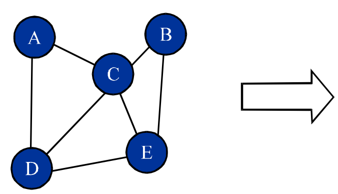
While the destination node is defined by the user in optimal path finding scenario, the existed walks from each node of the network to the destination node could be determined through (Rodrigue *et al*., 2006):

$$T = \sum_{k-1}^{D} Ck \rightarrow \text{Total accessibility matrix}$$

$$C1 = \sum_{j}^{n} c_{ij} \rightarrow \text{Adjacency matrix}$$

$$Ck = \sum_{j}^{n}\sum_{j}^{n} c_{ij}^{l} \quad D = \text{The diameter of the network}$$

The adjacency matrix should be used for finding the total accessibility matrix. Adjacency matrix of a graph (C_1) shows the directed paths (with length of one) between two nodes. The C_2 matrix is obtained by multiplying C1 by its transpose which shows the walks with length 2 between network's nodes. In the same way, the C_3, C_4, …and Ck matrices are obtained with multiplying C1 by C_2, C1 by C_3, … and C1 by C(k-1). The Ck matrix determines the walks with length k between the network's nodes. The diameter of a network is used for finding the value of k. Number of links in the shortest path between the furthest pair of nodes in the network is called diameter of a network which shows the extent of a graph (Rodrigue *et al*., 2006). Therefore, if the connectivity matrices are calculated until the length of k, it can be said that all the existent walks between two nodes with different lengths has been considered. Now, the total of C1 to Ck matrices should be calculated for finding the total accessibility matrix. In this case T shows the all walks between two nodes in the network (Fig. 2). Also,



Adjacency matrix

	A	B	C	D	E
A	0	0	1	1	0
B	0	0	1	0	1
C	1	1	0	1	1
D	1	0	1	0	1
E	0	1	1	1	0

	A	B	C	D	E
A	2	1	1	1	2
B	1	2	1	2	1
C	1	1	4	2	2
D	1	2	2	3	1
E	2	1	2	1	3

C2

	A	B	C	D	E
A	0	0	1	1	0
B	0	0	1	0	1
C	1	1	0	1	1
D	1	0	1	0	1
E	0	1	1	1	0

C1

	A	B	C	D	E
A	0	0	1	1	0
B	0	0	1	0	1
C	1	1	0	1	1
D	1	0	1	0	1
E	0	1	1	1	0

C2

F	E	D	C	B	A	
9	2	2	2	1	2	A
9	2	2	2	2	1	B
14	= 3	3	4	2	2	C
12	2	3	3	2	2	D
12	3	2	3	2	2	E
56	12	12	14	9	9	F

C1

	A	B	C	D	E
A	2	1	1	1	2
B	1	2	1	2	1
C	1	1	4	2	2
D	1	2	2	3	1
E	2	1	2	1	3

C1 Transpose

	A	B	C	D	E
A	0	0	1	1	0
B	0	0	1	0	1
C	1	1	0	1	1
D	1	0	1	0	1
E	0	1	1	1	0

Fig. 2: Calculating the total accessibility matrix for a graph with diameter two

T shows the accessibility of different nodes in the network independently. For finding the accessibility of a node using T, the values of each row or column is summed (Fig. 2), the obtained value for each node shows the accessibility of that node using the total accessibility matrix. Whatever the obtained value for each node is greater that node have much accessibility rather than the other nodes. Figure 2 shows that the accessibility of C (is specified with red color) is higher than the other nodes.

A node with more walks to the destination or in other words more accessibility to the destination node has a lower risk of losing time when changing the current path to another. It is natural to say that if there are more walks between two paths, there are certainly more paths between them.

The number of walks between the origin and destination nodes has been used for determining the risk limitations. Generally, closer nodes to the destination have almost more walks to the destination node in each path. Therefore, the risk of the current node could be computed by dividing the walks of the previous node by the walks of the current node to the destination. Table 3 shows the calculation of risk limitations for each node using this parameter.

Dynamic features: Dynamic features are characteristics which are not constant with respect to time and have the variable nature. Since these variable features are a function of travel time, they should be computed on-line in the time of computations. There are various parameters which can be used, but in this study only K-shortest path parameter is regarded.

K-shortest path method: This method determines the paths in an order according to travel time of each path (Martins and Pascoal, 2003; Brander and Sinclair, 1995). If the time differences between primary paths are negligible, this parameter can be an effective index for determining the risk. Principally, primary paths in K-shortest path method have common links and nodes until the first disjoint path. These common nodes between continuous paths could be used as an index for computing the risk of each node in such a way that a node which crosses more paths has lower risk for changing its current path to an appropriate path, because there are some appropriate paths from that node to the destination.

Suppose some primary paths which have acceptable time difference are computed. If two different paths exit from each node, that node has low risk from the deviation of optimum; That is, if traffic congestion occurs in one path and the user is at a node which another optimal path exited from it, he/she can change the current path to the new path on that node and be sure that one of best possible paths has been chosen (Fig. 3).

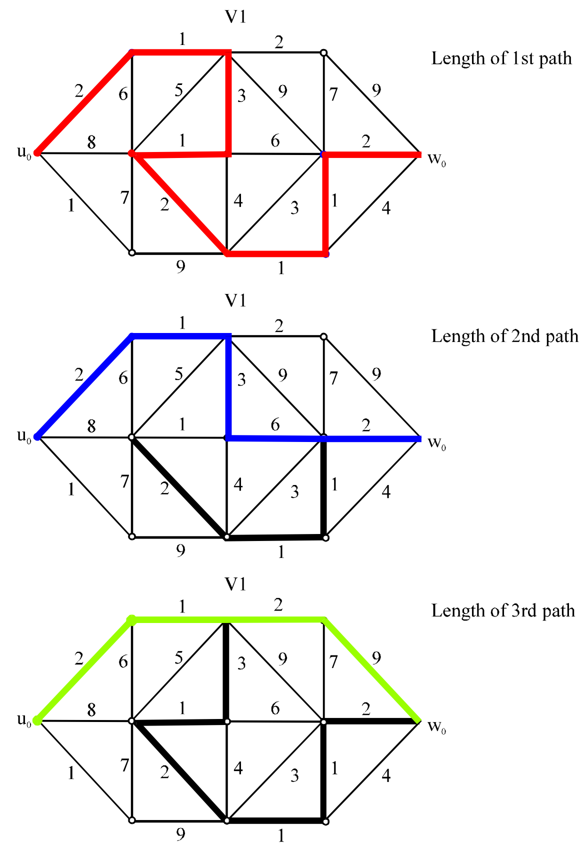


Fig. 3: Presenting Continuous Shortest Path between two specific origin and destination

Table 3: Evaluating the risk using accessibility parameter

Risk Rate	High	Medium	Low
No. of walks to the destination from the previous node a = No. of walks to the destination from the current node	> = 0.7 a	0.7> a > = 0.35	a < 0.35

Table 4: Evaluating the risk with K-shortest path parameter

Risk rate	High	Medium	Low
No. of appropriate existed paths from each node	1	2	3>=

Now, the number of appropriate paths exited from each node could be a parameter to evaluate the risk according to the three categories of risk (Table 4).

Risk modeling: Here, the method of assigning the risk parameter to the nodes and paths will be explained with respect to the defined parameters. Various methods could be used for integrating the mentioned parameters and creating a function for each node (Onwubolu and Babu, 2004). Comparing different methods and of course using fuzzy logic is the issue of future works of the study's authors. Here, linear combination method has been used for integrating the parameters.

Table 5: Modeling the node's risk by linear combination of the three parameters

Risk parameter node No.	Connectivity	Accessibility	K-shortest path	Node's risk
1	1.0	1.0	0.5	2.5
2	0.5	1.0	0.0	1.5
3	0.0	0.5	0.5	1.0

Table 6: Determining the path's risk with respect to the nodes' risk

The risk of the path	High	Medium	Low
(Total amounts of nodes' risk) = α No. of paths nodes * 3	0.6< α	0.3< α =0.6>	α >= 0.3

Now, the three connectivity, accessibility and k-shortest path parameters are rated for determining the risk. Generally, different weights could be assigned to each of these parameters according to their importance or user preferences which do not change the solution. So, the weights of parameters are regarded identical in this study.

Based on the mentioned topics, a table like Table 5 is created to model each node's risk.

After determining the entire network's node's risk, the risk of a path in the network must be computed. To compute the risk of a path, total amounts of nodes' risks of that path could be used to evaluate the risk of a path. So, for each path first, sum of its nodes' risks should be obtained; then, the risk of each path could be determined by dividing the summation of nodes' risk for all of the path's nodes by the number of those nodes.

In order to compare the amounts of provided risk for different paths with respect to three defined classes (high risk, medium risk, low risk); the obtained value should be converted to an index which could compare different path's risk with it. So, the obtained value for each path's risk could be divided by three, with respect to using three parameters for evaluating the risk in a path and compute an index between (0,1) for evaluating path's risk. If the obtained value is smaller than 0.3, that path has low risk; if it is between [0.3, 0.6] the path has medium risk and if it is greater than 0.6 the path high risk (Table 6).

THE PROPOSED ALGORITHM AND IMPLEMENTATION

After determining the risk parameter for each path, the optimal path algorithm using this risk could be computed. To do this, first the appropriate paths between origin and destination are calculated based on the K-shortest paths. There are various methods for finding the ranked paths using the K-shortest path (Brander and Sinclair, 1995) that the Yen's method (Martins and Pascoal, 2003) has been used for this purpose. Determining the paths is continued until the difference between the first and last path does not exceed from a specific value. For example in this study, the paths which this difference does not greater than 5 min have been chosen. Truly, this limitation value is a selected one and could be determined by the user using his/her knowledge of the network conditions or the rate of caution which he/she considers. After determining all the obtained paths, the risk of each one should be computed. First, the Table 5 is obtained for all the nodes which are in the provided paths. Then, the total amounts of nodes' risk are obtained for each path according to the Table 6 and the provided value is divided by the number of each path's nodes. After determining the risk of obtained path, the first path which has the lower risk is chose as the best existent path.

Figure 4 shows a part of region one in Tehran. The goal is to find the optimal path between two marked nodes (in red) between K.N.T. University (O) and Kish's English language institute (D). To do this, the map of the region has been converted to the Geodatabase and has been input to the ArcGIS 9.1.

Then travel times of the links which have received from traffic management center of Tehran, has input to the system. Also, connectivity and accessibility have been computed as preprocessing and have been stored as an attribute data in geodatabase. After doing the primary steps of collecting and preparing data, the proposed algorithm have been written using VBA and ArcObjects developer environment. Then, the mentioned algorithm has been done to the prepared data as described below.

First, the appropriate paths have been determined using K-shortest path and with five min as the time difference between the first and last paths (four paths). These four paths have been shown in Fig. 5 with different colors. Then the risk of nodes and consequently the risk of paths are calculated using Table 5 and 6.

It can be seen that the path number three has the lower risk than the other paths using the provided risk for all the paths. Since, time differences between these paths is very low, the path number three could be regarded as the optimal path and will be presented to the

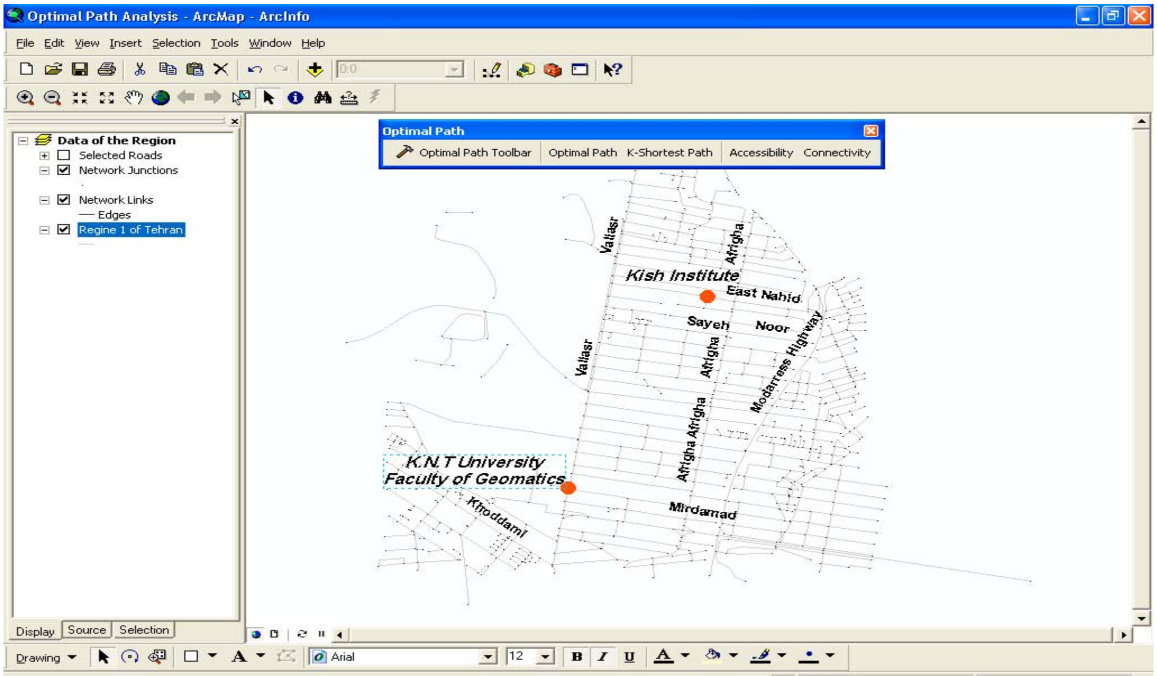
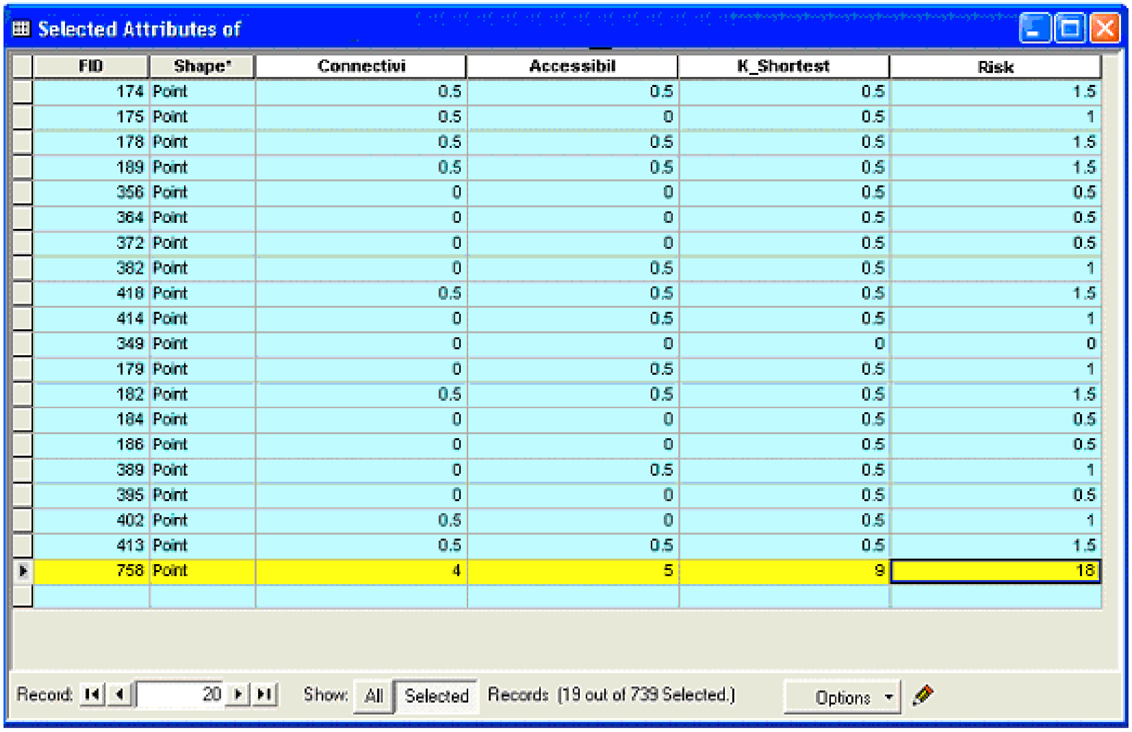


Fig. 4: The studied region for testing the proposed algorithm

Fig. 5: The obtained path using K-shortest path between two specific points



Selected Attributes of

FID	Shape*	Connectivi	Accessibil	K_Shortest	Risk
174	Point	0.5	0.5	0.5	1.5
175	Point	0.5	0	0.5	1
178	Point	0.5	0.5	0.5	1.5
189	Point	0.5	0.5	0.5	1.5
356	Point	0	0	0.5	0.5
364	Point	0	0	0.5	0.5
372	Point	0	0	0.5	0.5
382	Point	0	0.5	0.5	1
418	Point	0.5	0.5	0.5	1.5
414	Point	0	0.5	0.5	1
349	Point	0	0	0	0
179	Point	0	0.5	0.5	1
182	Point	0.5	0.5	0.5	1.5
184	Point	0	0	0.5	0.5
186	Point	0	0	0.5	0.5
389	Point	0	0.5	0.5	1
395	Point	0	0	0.5	0.5
402	Point	0.5	0	0.5	1
413	Point	0.5	0.5	0.5	1.5
758	Point	4	5	9	18

Record: 20 Show: All Selected Records (19 out of 739 Selected.) Options

Fig. 6: Presenting the table of calculating the risk of the path number three in ArcGIS

users. Figure 6 shows the quality of calculating the risk of path number three using the total amounts of its nodes' risk. This path has 19 nodes. Therefore, α is calculated (Fig. 6) as: α (3) = 18/19*3 = 0.31

CONCLUSIONS

The complexity of transportation networks and continuous changes of traffic congestion lead to the significance of time in finding optimal path. Finding the optimal path between two specific nodes for mobile users of transportation networks is one of those analyses which are time dependent. Because of these changes, some unreliability is noticed in final solution of the analysis using conventional methods. To reduce the effects of this unreliability, a parameter named risk of path has been defined. This parameter shows the possibility of a path changing when the traffic congestion occurs in the path which makes the new path far from the optimal solution.

In this study, a risk parameter has been defined as a function of static and dynamic nature of the network according to topologic and geometric characteristics of a network like connectivity and accessibility and also a dynamic feature like K-shortest paths. Then, the overall risk is proposed based on integrating the aforementioned parameters. By integrating the obtained risk with conventional routing algorithms, the optimal path is estimated not only by minimizing the time, but also by minimizing the risk of a path.

The other important point is running time of this algorithm. Although the proposed algorithm may look more time consuming than the conventional methods and seems to be inappropriate for online transportation applications, but it could be decreased using parallel algorithms and based on independence of computations on different steps. Presenting the parallel algorithms is a part of the future work of the authors.

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