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Introducing a Method for Planning a Safe Bicycle Network

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ABSTRACT

Enhance access to schools, jobs and other locations for bike riders is important. In the strategic plan of the Tehran municipality, achieving sustainable development through the development of green transportation infrastructure has been considered, which requires the planning of a bicycle facilities. Therefore, it is essential to accomplish the appropriate design bike routes.

This paper is about a new approach to safe bicycle network planning for city of Tehran. In this approach a multiple criteria decision making model was developed and Davis index method is applied. In macro viewpoint, the criteria selected in this study consist of social-economic variables, land use characteristics, road network parameters and public transportation infrastructure and bike facilities. All criteria were considered by their weights through spatial analyst tools (Arc map Software). The weight values are determined using analytical hierarchy process. The method was used for identification suitable area for bicycle users. In basis of safety parameters, integration and attractiveness a bicycle network designed. Based on this idea, we have two types of cycling networks, an integrated network using a bike sharing system in the CBD area and a local network for the development of personalized cycling in the non-central area. These two networks will be joined together through mass transit system. According to the results of this study, it was found that 519 km of 2291 km of existing road network (except freeways) in Tehran have a high priority for the construction of a cycling route. To determine detail design of bicycle route it is essential to accomplish physical and traffic studies, from the output of multiple criteria analysis has been done in this study[1,2,3,4,5,6,7]. Therefore local-level assessment (by Davis index method) was used in this study.

Keywords: *Bicycle Networks, Planning, Multi-Criteria Analysis, Davis index, GIS.*

INTRODUCTION

Tehran is the capital of the Islamic Republic of Iran and one of the most populous cities in the Middle East. The number of daily trips by motor vehicles is estimated at around 19 million trips. The share of travel by personal vehicles makes up about 40 percent of these trips. Despite the extensive efforts of the Tehran municipality in expanding the urban rail network and developing buses rapid transit (BRT), air pollution and traffic density are the most prominent problems in the field of transportation in the city of Tehran. The predominant view is the planning of the development of motor vehicles infrastructure, while the inefficiency of this attitude has been proven in recent years and it is necessary to control the mobility problem in Tehran using applied demand management practices. One of the most important measures in this context, which is consistent with the goals of sustainable transport development, is the development of green transportation systems, especially cycling.

Now the share of travel by bicycle trips in Tehran is less than 0.4percent [1] while this share in many cities in the world (that special attention to this issue), several times the amount above. One of the requirements for increasing this share is to develop a safe and efficient bike network. This development can take place in two parts of the city center and surrounding areas of the city.This approach is bike sharing system in the city center and personal use of bicycles in peripheral areas of the city, two parts of the ways these systems are connecting massive transit (Subway and BRT) done.

METHODOLOGY

Due to the implementation of the traffic and the range of projects including odd or even demand increased travel by motorcycle, which is among

the most important factors hindering the use of bicycles. In order to address the safety issues of cyclists, the following points should be considered:

- Reducing the speed of vehicles on the road network with traffic calming techniques
- Avoid using motor cycle riders from the bicycle path
- Route design with a math level without any positive hazards, including drainage valves with parallel slots along the route
- The design of the bicycle path, preferably in a straight line
- Proper lighting design and sufficient visibility for the route
- Non-passing bike paths from children's playgrounds

In general, the importance of the issue of safety in the creation of cycling facilities is so high that increasing the risks of lack of safety will prevent citizens about the use of bicycles. As mentioned, one of the factors influencing the use of bicycles is the creation of special cycling routes. Due to the diversity of factors affecting the design of the bicycle strategic network, a multivariate analysis method has been used. The output of this analysis is used as the guide and the background of the assessment (in the next step). In this study we consider, the safety indicators.

Following the review of similar studies conducted in the field in different parts of the world, will be discussed.

In a study that was conducted to assess the utility of existing road networks for bicycle traffic using a multi-criteria evaluation method, using a spatial information system, a model for determining cycling routes is presented. This study focuses on criteria such as traffic volumes, traffic constraints, pedestrian width, authorized speed, pedestrian quality, and limitation of intrusive applications and a model for modifying the existing routes and making it suitable for cycling according to the distance traveled and the criteria mentioned [2].

In another study to prioritize the creation of bike lanes in the city of Bogota in Colombia has been done, the role of factors such as population density, income distribution, individual safety, occupational density, land use, dispersion of crime status and proximity to unsafe locations using the hierarchical analysis process have been investigated. This study shows that income distribution, occupational density and population density are among the most important factors influencing the selection and construction of bicycle paths among the factors studied [3].

Also, in another study on the planning of cycling facilities using the GIS, cycling utilization in Milwaukee has been determined using a multi-criteria decision-making process. In this study, bicycle accidents, business density, the presence of schools, the excitement of recreation areas, the presence of parks and covered populations are known to be effective factors in creating cycling lines [4].

In this paper, identification of suitable cycling routes was performed based on a multivariate decision-making algorithm. In this algorithm, decisions on the various aspects that influence the determination of a suitable cycling network are taken into accounts, which are described below.

Economic-Social Factors

One of the problems is the lack of awareness of the amount of demand desire lines. To solve this problem in this article assumes that travel is likely to occur in areas that have higher population densities. Similarly, the desire to attract travel in areas of high density of workplace at work and students in schools and universities.

Land use Type

In general, bike trips to recreational and sports destinations are more occurred. Therefore, in a multi-criteria decision-making model, land uses are classified into recreational, sporting, tourism, and other types of land uses.

Streets Network

The criterion of the street network is divided into two sub-criteria of functional class and slope. Given the fact that the bike route passes through the city's urban network, the existence of different functions can reduce or increase the attractiveness of bike travel. Freeway routes Due to the incompatibility of their role with the characteristics and performance of the bicycle, from the decision algorithm for the construction of the bicycle path has been eliminated. Therefore, in the decision algorithm, the roads are categorized with three functional local and collector, primary arterial and secondary arterial (with different weights).

One of the roads geometric characteristics, longitudinal slope. However, although electric bikes have no problem for cyclist in steep roads but in sake of decrease accident and increase safety slope have been used in multi-criteria analysis.

Public transportation

Although the public transportation system includes a wide range of types of public transport, but in this article, mass transit systems (is intended including subways and buses rapid transit (BRT) systems).Obviously, whatever the distance between the bike paths and the stations of the public transportation system increase, the likelihood of using a hybrid system(bike system and public transportation) is reduced. Also, the location of cycling routes relative to public transportation terminals which is the accumulation and concentration of public transportation lines, have been considered in this study.

Bicycle facilities

Past efforts in cycling development have led to the creation of bicycle houses, which can also be used to build new bicycle paths. Also, in the municipal buildings of Tehran, which is at the disposal of urban management, there is also a bicycle parking lot and smart rack that can be classified as a bicycle facility. In Figure 1 pattern multi-criteria decision-making hierarchy used in this study, is shown.

Figure1. *Multi-criteria hierarchical decision-making model Selection of bicycle network at the level of Tehran's metropolitan area network.*

As shown in Fig.1, each criterion contains two or more sub-criteria that the following criteria are divided into categories according to importance. In the next section, we will refer to how information is collected, including the values and weights of the criteria.

COLLECTING INFORMATION

In the previous section, the method of study was stated. This study, for the city of Tehran, requires a wide range of information from various sources. Information on economic, social variables, performance of the roadways, position of metro stations, BRT systems, public transportation terminals and the location of bicycle houses from Tehran traffic and traffic organization and information about the land use, The position of the municipal buildings from the Department of Urban Development and Architecture and information on the state of road slope has been obtained from the country mapping organization.

As indicated in the methodology of the study, for determining the multivariate analysis, it is necessary to determine the weights of the branches needed. For this purpose, the comments of the experts of the transport unit (non-motorized) of the Tehran traffic and traffic organization have been used. In Table 1 the values of weights to the criteria, sub-criteria and categories provided.

Table1. *Weight values for the criteria, sub-criteria and categories.*

Criterion	Weight	Sub criteria	Weight	unit	Categories	Weight
Production and attraction	0.21	Population density	0.44	People per hectare	density≥80	0.19
					120≤density<80	0.37
					density<120	0.44
		Employee density	0.37		density≥40	0.21
					80≤density<40	0.29
		Students density	0.19		density<80	0.50
					density≥25	0.24
					50≤density<25	0.30
Land use	0.19	Recreational	0.22	-	-	-
		Tourism and Reception	0.16			
		Cultural	0.14			
		Green space	0.21			

		Sports	0.27			
Street Network	0.24	Slope	0.55	Percent	grade>4	0.55
					4>grade>7	0.36
					grade<7	0.09
		Street Type	0.45	Type	Local and Collector	0.46
					Secondary Arterial	0.32
					Primary Arterial	0.22
Public Transportation	0.26	Metro station distance	0.60	Meter	Radius≥500	0.58
					1000≤Radius<500	0.34
					Radius<10000	0.08
		Distance from BRT stations	0.29	Meter	Radius≥ 300	0.55
					600≤Radius<300	0.30
					Radius<600	0.15
		Inner city terminals	0.11	Meter	Radius≥ 300	0.52
					600≤Radius<300	0.29
					Radius<600	0.19
Bike Facilities	0.1	Bike houses	0.61	Meter	Radius≥ 300	0.50
					600≤Radius<300	0.28
					Radius<600	0.22
		Buildings of Tehran Municipality Departments	0.39	Meter	Radius≥300	0.48
					600≤Radius<300	0.31
					Radius<600	0.21

RESULTS OF THE IMPLEMENTATION OF THE PLANNING MODEL

After collecting information in the form of vector layers and converting them into raster layers, Spatial Analyst software tool in ARCGIS were used to integrate the values of the respective layers and weight and the network of roads was prioritized into three categories. Figures (2) and (3) show, respectively, the combination of the layers of production and attraction of trip as well as the layers of the network of roads, production and attraction of travel, land use and public transport. Figure (4) shows the result of the integration of all layers and the final prioritization.

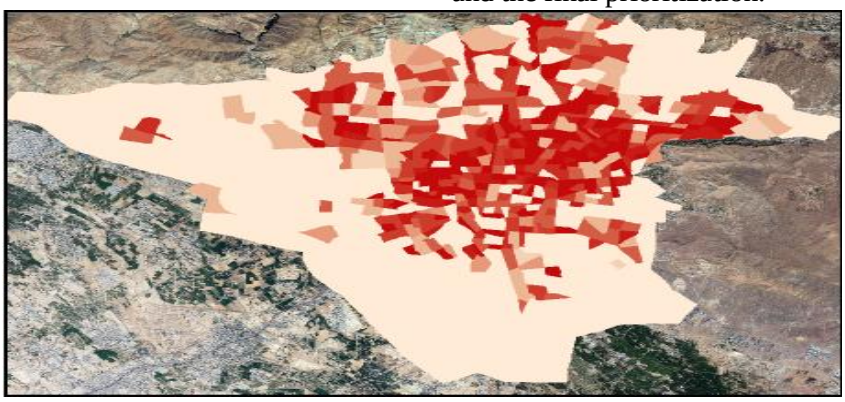

Figure2.*The result of the combination of production layers and travel attraction.*

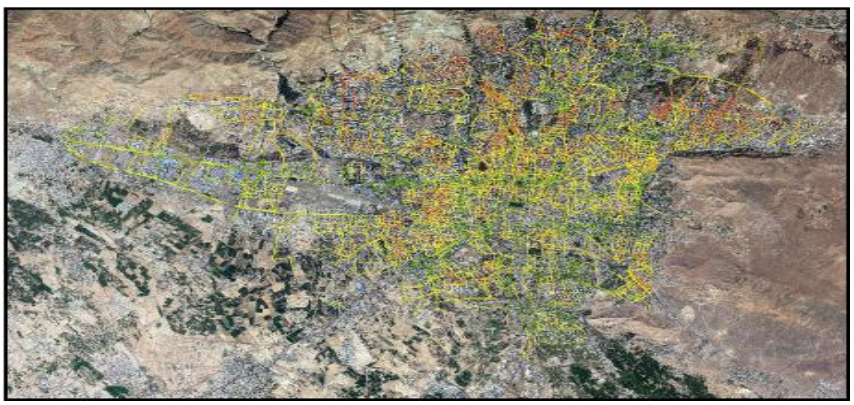

Figure3. *The result of the integration of road network layers, production and attraction of travel, land use and public transportation.*

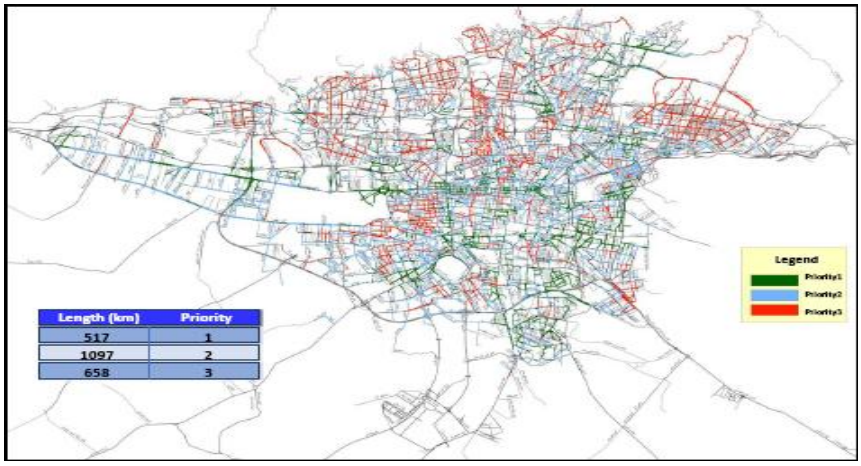

Figure4. *The result of the combination of all layers and the final prioritization of roads.*

Figure5. *Suggested routes in the first Scenario.*

ASSESSMENT THE PROPOSED SCENARIOS FOR CONSTRUCTING A BICYCLE PATH IN THE CENTRAL CITY OF TEHRAN

Considering the priorities of the Tehran municipality in establishing bicycle paths in the central region of Tehran (6, 7, 11 and 12 districts) and considering the strategy of providing bicycle facilities for the last mile journey from major public transport stations to the areas of attraction, scenarios are defined as follows:

Scenario 1: The route of the bike in the streets of Beheshti and Motahari located in the 6th and 7th district of Tehran municipality

Scenario 2: Bike route in the streets of KarimKhan and Taleghani located in the 6th district of Tehran

Scenario 3: Bike route in the streets of the Islamic Republic and Imam Khomeini in the 11th and 12th district of Tehran municipality

In Figures 5 to 7, the first to third Scenarios are shown.

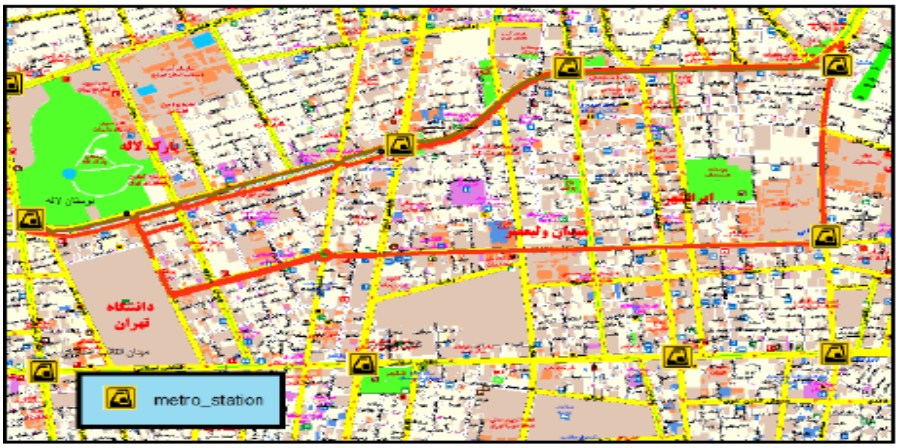

Figure6. *Suggested routes in the Second Scenario.*

Figure7. *Suggested routes in the Third Scenario.*

As mentioned, all of the above scenarios are located in the central area of Tehran. Given the budget and time constraints, one of the scenarios in 2018 is possible. It is worth noting that these scenarios have been extracted from the results of the planning model described in the previous step.

It has been argued that traffic safety is one of the issues to cycling, so it is necessary to assess safety standards. One of the well-known indicators in this topic is the Davis index. Based on this indicator, cycling safety is achieved in the segment of roads. The smaller the index means better path for cycling. Based on the relevant references, the mean value of 0 to 4 represents the high pathway immunity, with 4 to 5, safety levels at a good level and 5 to 6 levels of moderate and relative safety. Values above 6 represent a path that requires special immunization.

Formula 1

$$RSI = [ADT/(L\times 3500)]+(S/56)+[(4.25-w)\times 1.635]+\sum PF+\sum LF$$

RSI = Road Safety Index

ADT = Average daily traffic

L = number of Traffic lanes

S = speed limit

W = width of outside Traffic lane

∑PF = sum of Pavement Factors

∑LF = sum of location Factors

Due to the fact that the road is composed of parts with different characteristics, we used a weighted average to evaluate each Scenario.

$$RSIpath = (\sum RSI\_segment \times Length\_segment)/(\sum Length)$$

RSI_{path} = Bicycle path Safety Index

$RSI_{segment}$ = Segment safety index

$Length_{segment}$ = Segment length

$\sum Length$ = Total length

Due to the large number of variables, the details of each scenario are not mentioned. The general description of the scenarios is described in the following table.

Table2. *General Specifications for Bike path Scenarios.*

Average Daily Traffic	Speed Lim-it(Km/Hr)	Number of Traffic lane		Length(Km)	Scenario
		Minimum	Maximum		
34615	60	6	3	7/17	1
31220	60	6	2	7/62	2
31562	60	6	3	9/9	3

Given the fact that each Scenario consists of several segments, for the convenience of calculating the RSI index, a program for data entry and calculation of the RSI index was prepared. In the figure below, this program is depicted.

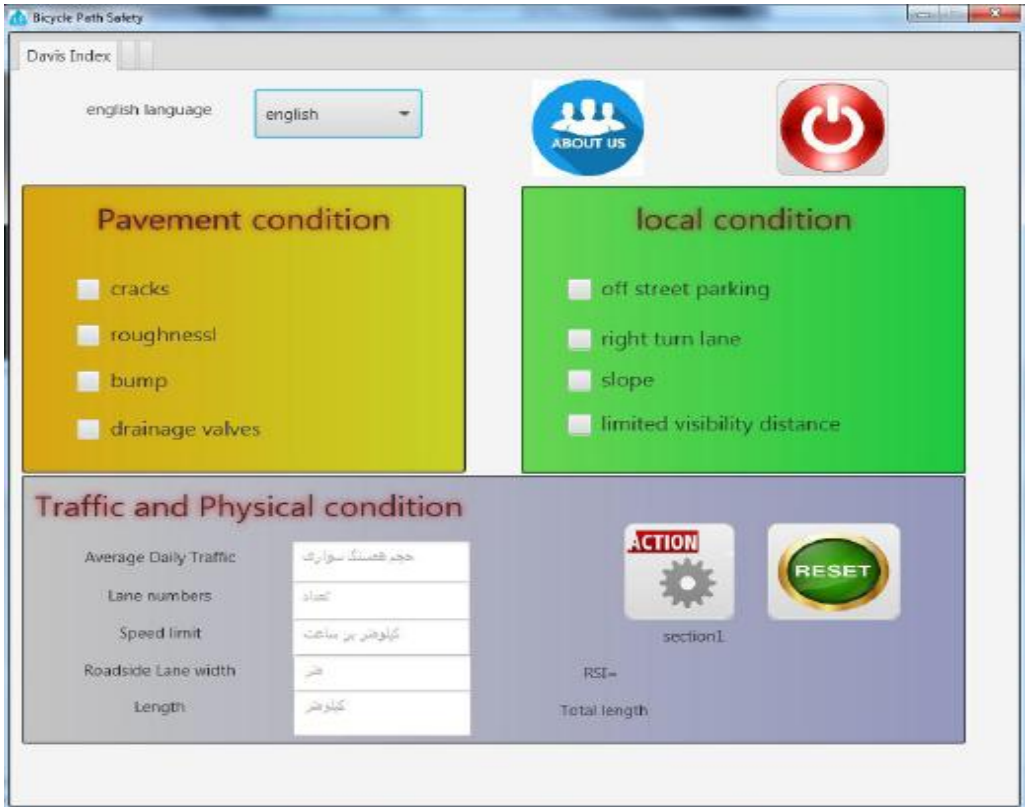

Figure8. *The software interface for calculation the bike path safety index.*

Figure9. *Preparation The Android app for calculation the bike path safety index [9]*

Based on the results, the Scenario 2 has a better status than other scenarios. The physical separation of the path must also be based on the values of the RSI Index.

Table3. *RSI index values.*

RSI_{path} **value**	**Scenario**
11/04	1
9/87	2
9/93	3

According to the above table, implementation of the second scenario was put on the agenda of the Tehran municipality. In the first phase of implementation, the route of the bike was constructed in the northern section of the second scenario, which includes the streets of Karimkhan and Keshavarz Blvd. In this Path, 4 bicycle houses have been opened for the provision of bicycle services. In the following Figures, pictures of bike houses and cyclists are shown after launching this route.

Figure10. *Pictures of bike houses and cyclists after launching Scenario 2.*

CONCLUSION

In this study, in order to determine the appropriate bike network for Tehran, studies were carried out at two macro (planning) levels (in the total area of the city of Tehran) and the local area network (within the spatial boundaries of the highways in the central regions of Tehran).

In macro-level studies, socio-economic variables, land use status and transit network, public transportation facilities and potentials for bicycle facilities were used and multi criteria analysis method was used for combining these variables.

Finally, the cycling network of Tehran ranked in three categories.

Subsequently, local-level assessments focused on traffic indicators, and Davis Index was used for this study.

In order to define scenarios with regard to budget and executive constraints, determining the bicycle path to provide Bike sharing infrastructure in the central area of Tehran with the approach of providing access to the last kilometer from mass transit stations to attraction centers in the form of three scenarios described earlier is foreseen.

The results of the assessment model showed that the bicycle route should be protected in all three scenarios, and the second option should be preferred.

Implementation measures for the second Scenario have been made since the beginning of 2018. Currently, part of this route is in operation.

REFERENCES

[1] Tehran origin – destination survey ,2015. Butler, "Multiple Criteria Bicycle Route Assessment", integrating supply & stakeholder perceptions for a spatial support system Christchurch, New Zealand, 2015.

[2] T. P. Hsu, Y. T. Lin, "A Model For Planning A Bicycle Network With Multi-Criteria Suitability Evaluation Using GIS", Institute of Civil Engineering, National Taiwan University, Taiwan, 2011.

[3] "Regional Bicycle Network Gap Analysis", Regional Transportation Commission of Southern Nevada (RTC), Final Report, 2014.

[4] [D. Carter, W.Hunter, C. Zegeer, J.Stewart, H. Huang, "Bicyclist intersection safety index", Transportation Research Record: Journal of the Transportation ResearchBoard, 2007.

[5] N.Sener, N.Eluru ,& C. R. Bhat, "An analysis of bicycle route choice preferences in Texas", US. Transportation, 2009.

[6] "Bicycle Master Plan of Tehran", Tehran Municipality Traffic Transportation Organization, 2017.

[7] "ARCGIS 9.3 Manual", University of Pennsylvania, 2007.

[8] https://cafebazaar.ir/app/omid_afsahi.davis/?l=fa

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