IMPROVEMENT PRIORITIZATION IN BIKE LANE ATTRIBUTES BASED ON THE VIEW OF DIFFERENT GENDER AND AGE CYCLIST GROUPS (CASE STUDY: QAZVIN CITY, IRAN)

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Resume

A survey of cyclists in the city of Qazvin, Iran, was conducted by focusing on improving the bike lane attributes (increasing width, increasing attractiveness or appeal of the bike lane (painting, planting …), improving pavement conditions, improving sight distance and removing obstacles in the bike lane). It was seen that there was no difference between age groups. Two important priorities for the men group were increasing the lane width and improving the sight distance, while the women considered improving the pavement conditions and the appeal of the bike lanes. Increasing the lane width and improving the pavement conditions for the recreational group and increasing the lane width and improving the sight distance for the non-recreational group were the most important improvements. It can be said that increasing the width of the bike lane was the most important factor for almost all groups.

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1 Introduction

Many countries have tried to encourage people to use bicycles more, but despite the support for public transportation and bicycles, their use is low. Research in some developing countries in 2009 showed that 84% of city trips had been made by private car [1]. For example, while in Curitiba (Brazil), only 11 and 17% of the adult population uses a bicycle for commuting and leisure, respectively [2], in countries with high income, these values were higher (26% for leisure and 41% for commuting) [3-4].

Although increasing the proportion of cycling in trips faces many obstacles, it is one of the best ways for sustainable transportation and development. Therefore, it is necessary to put some improvements into practice to encourage the use of public transportation and bicycles for those who go from home to work, school and shopping every day [3, 5]. There are many surveys and studies about barriers that may hinder the use of bicycles for commuting. The most common barriers reported in the previous articles are lack of adequate infrastructure (bike lanes), lack of safety, lack of company and climate [6-7].

De Sousa Suely et al. conducted a survey of 380 college students in three Brazilian cities, [8]. Their questionnaire was based on the theory of planned behavior and included: cycling infrastructure, lack of safety, distance to be traveled, physical fitness, slopes and climate. They found a lack of dedicated cycling infrastructure. De Camargo et al. [9] recruited 84 adults of both sexes and characteristics related to cycling (commute, leisure time users and activists) in focus groups interviews. The most-reported barrier was lack of safety, followed by lack of bike lanes. Parkin et al. [10] applied UK 2001 census data with logistic regression for cycle choice. They found that hilliness was the most important factor that had affected the proportion that cycles to work. The following three factors were physical conditions of the highway, rainfall and temperature. Garrard et al. used the census of cyclists observed at 15 locations of Melbourne, Australia's central business district (CBD). They found that the most important facilitator for female commuter cyclists was maximum

separation from motorized traffic [11]. "Barriers" are the factors that by their negative effects on cyclists (or a group of cyclists) hinder cycling and "facilitators" are those that by their positive effects, encourage cycling [12].

Segadilha and Sanches [13] compared the shortest path between orientation and destination (by using geographical information system (GIS)) and chosen path (by using global positioning system (GPS) data) for the cyclist in Brazil. They examined which factors caused them to choose a longer route. They demonstrated that the speed and volume of motorized traffic and the pavement quality were top factors that affected the cyclists. In contrast to Segadilha and Sanches, Harvey et al. found that cyclists became more comfortable with cycling in heavy conditions and did not affect their chosen route [14]. Dill and Voros studied a set of factors that could affect bicycle demand in Portland, Oregon region of the USA. They observed that the availability of bike lanes and higher levels of street connectivity has led to an increase in using a bicycle [15]. Surveys and examinations demonstrated that travel time could strongly influence bicycle route choice [16-17].

Jain and Tiwari [18] surveyed bicyclists in Pune, India. The bicyclists interacted with pedestrians better than the vehicles. A parked vehicle was considered more dangerous during the parking maneuver. The used questions include a set of factors such as on-street parking, pedestrians as barriers, pavement quality, road width, the density of land use and slope. Another study by Krizek [19] confirmed the results of Jain and Tiwari [18]. Majumdar et al. [20] examined a set of attributes affecting bicycle route choice, including the presence of the motorized vehicle on road or traffic volume, road width, on-street parking, route visibility, etc. They found road width as the most important attribute.

Basu and Vasudevan [21], conducted a questionnaire survey in four major Indian cities. to rank some bicycle friendly infrastructures and policies. Dedicated bicycle lane was found to be the most preferred bicycle friendly infrastructure and whereas facility to carry bicycle on public transportation was found to be the least preferred one.

On the one hand, the share of cycling in Iranian cities is very low, for example, the share of cycling in the city of Tehran [22], Ahvaz [23] and Mashhad [24] are 1%, 2% and 1.5%, respectively. On the other hand, the share of women is less than men. For instance, the share of women cycling is 25% of the total number of cyclists in the city of Tehran [25]. Of course, it has been seen that women less cycle for non-recreational purposes in developing countries with low bicycle transport mode share [10-11].

Cycling facilities and infrastructure in developing countries, such as Iran, are not suitable enough and the budget needed to improve them is limited. Therefore, it should be examined how any improvement in the attributes of infrastructure and bike lanes affects the demographic groups of cyclists and encourages them. As the municipality has tried to build the all possible bicycle lane in the city, it is practically not possible to increase the length of these facilities easily. On the other hand, the municipality is trying to increase the quality and willingness of people to use the existing bike lanes.

Many previous studies have used aggregate data to analyze, but in this research, the survey of different groups of cyclists has been examined separately. First, the data were categorized according to age and gender and then the priorities of different groups for improvement in the attributes of bike lanes were compared to each other. The research methodology has been described in the next section. The data collection is introduced in the third section. The fourth section has been devoted to statistical analysis and comparison of different groups of cyclists. The results have been discussed in the fifth section. Finally, the sixth section has summarized and concluded the research.

2 Methodology

In this research, the options for improving the bike lanes conditions have been prioritized based on the opinions of cyclists. It should be mentioned that bike lane means a segregated path or track for the bicycles. It can be on the street or on the sidewalk. It depends on the transverse profile of the road. Questionnaires have been completed by interview. The demographic composition of people in a city can be different, so the investigation aimed to examine priorities for improving the conditions of bike lanes for different user groups.

The questionnaires were divided according to age (over and under 40 years old) and gender (male and female). Respondents were given five options to improve the conditions of the bike lanes, which they should choose the importance of each option based on the Likert scale (between 1 and 5). Using statistical tests, the priority of bike lanes improvement options for each group of users was examined. Then, the differences of opinions in different groups have been studied. The questions were prepared based on the opinions of traffic engineers at the Qazvin department of transportation. In other words, the experts considered these options the most important options for improving bike lanes among some options.

Questions about the bike lane were: increasing width, increasing attractiveness or appeal of the bike lane (such as painting, planting), improving pavement conditions, improving sight distance and removing obstacles in the bike lane. The questionnaire also included other questions, such as demographic characteristics and the goal(s) of cycling. At the end of the analysis, options were arranged based on different groups of cyclists based on the results.

Table 1 *Distribution of respondents*

Variable	Mean	SE Mean	St Dev	Minimum	Q1	Median	Q3	Maximum
Age	38.498	0.861	15.435	13.00	27.000	36.00	51.50	80.00
Gender	0.804	0.022	0.3978	0.000	1.0000	1.00	1.00	1.00

To compare opinions between different groups, statistical methods should be used, the most important and well-known of which is ANOVA. This method can only prove the existence of differences. So, Tukey's method is used to compare groups individually and rank them.

3 Data collection

The paper targets bicycle lane improvement options, so respondents should be bike users and familiar with bike lanes. Here, bicycle users were defined as cyclists who use bicycles at least once a week. Total of 457 Questionnaires were collected from people on the street, from which 321 were riding a bicycle. Cochran's formula was used to estimate enough number of questionnaires. Considering the population of about 400,000 people in Qazvin city and the error level of 5 %, at least 384 data are required and more than this amount have been collected here. The survey was conducted during different days of a week.

There are many studies that have used Global Positioning System (GPS) data to investigate the behavior of cyclists [26-28]. Although those data have uncertainty, they can continuously provide a wide range of information to the researcher. In this research, survey and questionnaire methods were used because the paper aimed to investigate the opinions and feelings of cyclists about bicycle lane attributes. The GPS data cannot help here, because by using the GPS data, it is possible to find out whether a cyclist has used a path or not, but it is not possible to extract her/his satisfaction and opinions. Table 1 shows the distribution of respondents.

The age range of the respondents was between 13 and 80 years with an average of 38 years. Only 3 % of the participants were over 65 years old, so respondents within the age range of middle-aged adults and old adults were categorized as the elder group (age > 40). In other words, two age groups were defined, which were young (age < 40) and elder (age > 40).

The survey of cyclists using bike lanes was conducted on the main central business district (CBD). Qazvin city is one of the small cities in Iran. Most land uses and population in Qazvin are centralized, so most bike lanes are also located in CBD. The total length of bicycle infrastructure in Qazvin is about 10 km.

The participants were asked what is the main purpose of their trips by bicycle. Non-recreational purposes included commuting to work, school, or university, while recreational cycling included exercising, just enjoying cycling (riding around), or shopping. Shopping was also considered a recreational destination, because in shopping trips, unlike business trips (such as getting to work, university or school), the user is not under pressure and is not done regularly. The respondents could state recreational, non-recreational or both as the purpose of cycling.

The existence of a multimodal system like bike-and-ride is necessary to encourage people to use bicycles. The goal of this paper was not studying the factors that can influence using a bicycle, but to measure the satisfaction of cyclists with bicycle facilities (bicycle lane). In other words, considering the existing limitations in the expansion of cycling facilities in a small and dense city like Qazvin, the goal is to improve the existing facilities based on the opinion of users [29-31].

4 Analysis

This section statistically analyzes the survey of bike lane users according to age and gender groups to prioritize improvement options, then uses other data in the questionnaire.

4.1 Male cyclists

First, the men's group was studied and then the women's group. Tables 2 and 3 represent the result of the men's survey.

Test results ANOVA One-way showed a significant difference between men in terms of priority of options (P-Value = 0.013). To determine the priority of options Tukey test was applied. From the point of view of male cyclists, the most important improvement was increasing the width of the bike lane, followed by sight distance and pavement conditions.

4.2 Female cyclists

The analysis process for men was also applied to the group of women. ANOVA One-way results are shown in Table 4. If the confidence interval is chosen 90 %, there would be a difference between the women's group (P-Value = 0.071). Then, Tukey test was used to rank the improvements, which showed that the improvement of pavement conditions was the most important, followed by bike lane appeal and increasing the width of the bike lane (Table 5).

Table 6 compares the survey results of female

Table 2 *ANOVA of men's priorities*

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	4	19.14	4.785	3.22	0.013
Error	615	915.01	1.488		
Total	619	934.15			

Table 3 *Ranking of men's priorities*

Factor	N	Mean	Grouping	
Bike_lane_width	124	3.4919	A	
Sight_distance	124	3.3306	A	B
Bike_lane_pavement_conditions	124	3.282	A	B
Bike_lane_obstacles	124	3.258	A	B
Bike_lane_appeal	124	2.952		B

Means that do not share a letter are significantly different.

Table 4 *ANOVA of women's priorities*

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	4	10.43	2.606	1.61	0.071
Error	310	501.43	1.618		
Total	314	511.85			

Table 5 *Ranking of women's priorities*

Factor	N	Mean	Grouping
Bike_lane_pavement_conditions	63	3.317	A
Bike_lane_appeal	63	3.238	A
Bike_lane_width	63	3.206	A B
Sight_distance	63	3.143	B
Bike_lane_obstacles	63	2.794	B

Means that do not share a letter are significantly different.

Table 6 *Comparison between women and men's priorities*

Priority	Male	Female
1	Bike_lane_width	Bike_lane_pavement_conditions
2	Sight_distance	Bike_lane_appeal
3	Bike_lane_pavement_conditions	Bike_lane_width
4	Bike_lane_obstacles	Sight_distance
5	Bike_lane_appeal	Bike_lane_obstacles

and male cyclists. It can be seen that there would be differences, which are more examined in following sections.

4.3 Young cyclists

The survey of young cyclists (age < 40) has been assessed by One-way ANOVA. Table 7 shows that by considering a 95% confidence interval, there was a significant difference within the young group (P-Value = 0.035). Tukey test (Table 8) demonstrated that increasing the width of the bike lane and improving the sight distance have the highest priority for this group.

4.4 Elder cyclists

By considering 95% confidence, it can be seen that there was a difference within the elder group (P-value = 0.015). In the elder group, such as the young group, increasing the lane width and improving the sight distance had the priority. The results are shown in Tables 9 and 10.

Table 11 compares the priorities for young and older cyclists. In general, it can be said that the priorities of

Table 7 *ANOVA of young cyclists` priorities*

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	4	15.71	3.928	2.60	0.035
Error	775	1170.67	1.511		
Total	779	1186.38			

Table 8 *Ranking of young cyclists` priorities*

Factor	N	Mean	Grouping	
Bike_lane_width	156	3.4615	A	
Sight_distance	156	3.3333	A	B
Bike_lane_pavement_conditions	156	3.2821	A	B
Bike_lane_obstacles	156	3.256	A	B
Bike_lane_appeal	156	3.026		B

Means that do not share a letter are significantly different.

Table 9 *ANOVA of older cyclists` priorities*

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	4	18.59	4.647	3.12	0.015
Error	820	1221.60	1.490		
Total	824	1240.19			

Table 10 *Ranking of older cyclists` priorities*

Factor	N	Mean	Grouping
Bike_lane_width	165	3.4242	A
Sight_distance	165	3.3273	A B
Bike_lane_obstacles	165	3.097	A B
Bike_lane_pavement_conditions	165	3.0727	B
Bike_lane_appeal	165	3.0606	B

Means that do not share a letter are significantly different.

Table 11 *Comparison between young and older` priorities*

Priority	Young	Elder
1	Bike_lane_width	Bike_lane_width
2	Sight_distance	Sight_distance
3	Bike_lane_pavement_conditions	Bike_lane_obstacles
4	Bike_lane_obstacles	Bike_lane_pavement_conditions
5	Bike_lane_appeal	Bike_lane_appeal

both groups were similar. It should be noted that since the number of men who participated in the survey was significantly larger than women, the priorities of both young and older groups were more like men's opinions.

The analysis showed that the priorities for improving the bike lanes were different within gender and age groups. For further examination, the survey data were categorized based on the purpose of cycling. As has been mentioned, the questionnaire also included the purpose of cycling. Two general purposes of recreation and non-recreational were considered.

Table 12 shows the distribution of purpose of using the bicycle for different age and gender groups.

It can be seen that men used bicycles for non-recreational purposes more than women. There is no significant difference between young groups and older groups in this regard. This can be due to the equal distribution of men and women in all age groups. In general, the survey indicated that most of the cyclists in the city of Qazvin are cycling for recreational purposes.

It can be said that the reason for the meager share of the bicycle in Qazvin is that bicycle is not yet recognized as a mode of transportation and is often used

Table 12 *Distribution of data based on cycling purpose*

	Gender		Age	
	Male	Female	Young	Elder
Recreation	63	80.5	70	68.7
Work	37	19.5	30	31.3

Table 13 *ANOVA of recreational cyclists` priorities*

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	4	20.12	5.029	3.64	0.006
Error	1160	1600.68	1.380		
Total	1164	1620.79			

Table 14 *Ranking of recreational cyclists` priorities*

Factor	N	Mean	Grouping	
Bike_lane_width	233	3.4421	A	
Bike_lane_pavement_conditions	233	3.3176	A	B
Bike_lane_appeal	233	3.2833	A	B
Bike_lane_obstacles	233	3.1717	A	B
Sight_distance	233	3.0558		B

Means that do not share a letter are significantly different.

Table 15 *ANOVA of non-recreational cyclists` priorities*

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	4	42.13	10.532	6.09	0.000
Error	490	846.93	1.728		
Total	494	889.06			

Table 16 *Ranking of non-recreational cyclists' priorities*

Factor	N	Mean	Grouping	
Bike_lane_width	99	3.434	A	
Sight_distance	99	3.404	A	
Bike_lane_obstacles	99	3.394	A	
Bike_lane_pavement_conditions	99	2.859		B
Bike_lane_appeal	99	2.778		B

Means that do not share a letter are significantly different.

for recreational purposes. It was assessed whether there is a difference between the priorities of cyclists based on the purpose of cycling.

4.5 Recreational cyclists

Tables 13 and 14 show the result of the survey of recreational cyclists. It can be seen that there was a difference within recreational cyclists by considering a 95% confidence interval (P-value = 0.006). Three top improvements were as follows: increasing the lane width, improving pavement conditions and improving the appeal of the bike lanes.

4.6 Non-recreational cyclists

As recreational users, it can be seen that there was a significant difference within non-recreational cyclists for the bike lane. The first three priorities were increasing the lane width, improving the sight distance and removing the obstacles in the bike lane (Table 15 and 16).

Given the above results, it can be said that the priorities of cyclists were different according to the cycling purpose. Table 17 compares the choices of recreational and non-recreational cyclists.

Table 17 *Comparison between recreational and non-recreational cyclists` priorities*

Priority	Recreational	Non-recreational
1	Bike_lane_width	Bike_lane_width
2	Bike_lane_pavement_conditions	Sight_distance
3	Bike_lane_appeal	Bike_lane_obstacles
4	Bike_lane_obstacles	Bike_lane_pavement_conditions
5	Sight_distance	Bike_lane_appeal

Table 18 *The priorities of different groups*

Priority	Male	Female	Elder	Young	Non-recreational	Recreational
1	width	Pavement_ conditions	width	width	width	width
2	Sight distance	appeal	Sight_ distance	Sight_ distance	Sight_ distance	pavement_ conditions
3	pavement_ conditions	width	obstacles	pavement_ conditions	obstacles	appeal
4	obstacles	Sight_ distance	pavement _conditions	obstacles	pavement_ conditions	obstacles
5	appeal	obstacles	appeal	appeal	appeal	Sight_ distance

Table 19 *Descriptive statistics of data*

Overall priority	Variable	Sum	Mean	Variance	Min	Max
1	Bike_lane_width	8	1.333	0.667	1	3
2	Sight_distance	17	2.833	1.767	2	5
2	Bike_lane_pavement_conditions	17	2.833	1.367	1	4
3	Bike_lane_obstacles	23	3.833	0.567	3	5
4	Bike_lane_appeal	25	4.167	1.767	2	5

5 Results and discussion

The priorities of different groups are summarized in Table 18 so that the data can be better analyzed. The table shows that the priorities of different groups were different for improving the bike lane attribute. Now it should be examined what were the general opinions of the participants.

Previously, the opinions of different groups were compared using statistical methods, but here those opinions are summarized. The third column in table 1 is the sum of the values of the first column of Table 2, so that it can be find out which attribute has a higher priority for improvement in general. For example, the bicycle lane width attribute has a priority value of 1 in all groups, except for the female group, whose priority is 3. So, its total or sum priority is 8. So, the lower the value of the total priority, the more important it is. Table 1 is sorted by sum column value.

The values of Table 19 are depicted in Figure 1. The lower the value distribution and the smaller the values, the higher their priority.

Lane width has been given the highest priority because it can be considered one of the most important safety and comfort factors for cyclists. According to the field survey, most of the lanes in Qazvin have a width of 1.5 meters or less and on the other hand and many of them are as two-way bike lane, which leads to safety and maneuver problems in peak hours. It is noteworthy that the priority difference of this attribute, compared to the next attribute(s), is very high and it shows that the inappropriate lane width was the main problem for cyclists to use the bike lane. It can be seen in Figure 1 that in other attributes there is a dispersion of opinions between different groups, but regarding the width of the bicycle path, the dispersion is very small and almost all groups agree on its priority.

Sight Distance and pavement conditions were the next priorities. Pavement conditions and appropriate sight distance help cyclists to travel safely and at their desired speed on the bike lane. In other words, the unproper pavement conditions makes it more difficult to move faster and also the unproper sight distance makes it unsafe to move faster.

Obstacles on the bike lane are the next priority. Perhaps it was expected that this attribute would have a higher priority because the presence of an obstacle in the bike lane greatly disrupts the movement and greatly

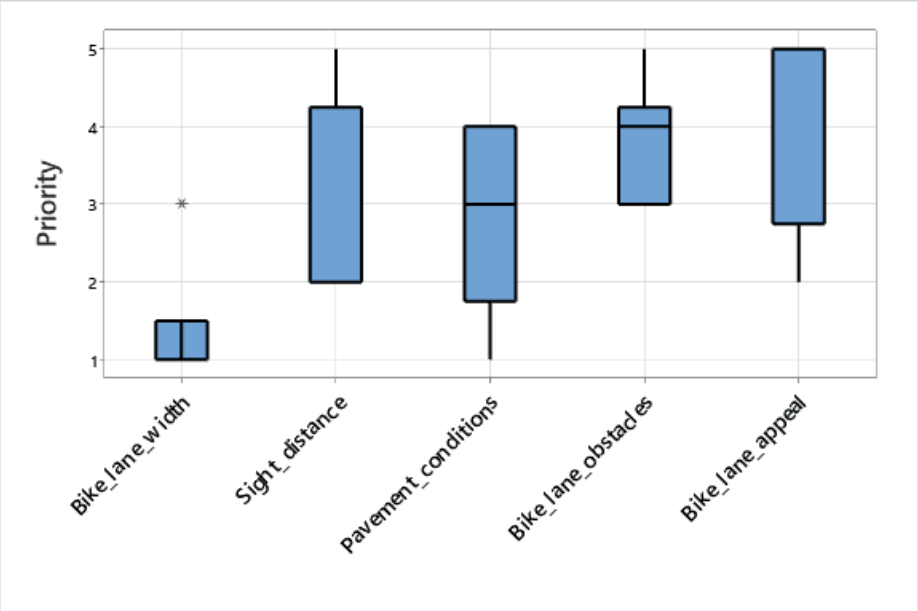

Figure 1 *Boxplots of priority data*

reduces the quality and safety of the bike lane. But in the city of Qazvin, most of the bicycle lanes are completely separated from the traffic flow by using physical barriers and the interference of parked cars or other obstacles with cyclists is little. Therefore, this attribute was not so important according to the respondents. Improving the appearance of bike lanes has been the last priority. This is to be expected because the priority of cyclists has been to use the bike lane safely and at a suitable speed.

In the following, the findings in this research are compared with similar researches.

There are many researches about the factors affecting the willingness to use bicycle. For example, one of these studied factors is environmental conditions [10, 14]. Another factor is the existence of a bicycle lanes, which has received a lot of attention and researchers have found that the absence of a bicycle lane reduces the willingness to use a bicycle.

In the CBD of small and dense cities, the possibility of building bicycle lanes is limited and bicycle lanes cannot be developed easily to encourage more people to use a bicycle. Therefore, the focus should be on increasing the quality of the existing bike lanes. Very few researchers have studied the opinions of cyclists regarding bike lane attributes.

Jane and Tiwari [18] and Krizek [19] found that the most important factors affecting the bike lane are obstacles and pavement quality. Here, pavement conditions have taken the second place and have been very important from the point of view of cyclists. However, obstacles had lower priority because as explained, the entry of cars into the bicycle lane was limited. Majumdar [32] examined three factors, including route visibility, obstacles and lane width and found that the lane width was the most important attribute, which is similar to the results of this research.

6 Conclusions

The proportion of bicycles in the transportation of developing countries, such as Iran, is very low and should be helped to increase by improving infrastructure. One of the most important infrastructures is bike lanes. Given the limitation of financial resources, it is necessary to consider which attributes of bike lanes are more important to improve from the cyclists' point of view. Priorities for improving attributes of bike lanes can vary for different groups of cyclists. Therefore, a survey of cyclists in the city of Qazvin was conducted.

Questions about the bike lane were: increasing width, increasing attractiveness or appeal of the bike lane (such as painting, planting), improving pavement conditions, improving sight distance and removing obstacles in the bike lane. It was seen that there was no difference between the priorities of different age groups and their most important priorities were increasing the lane width and improving the sight distance. Two important priorities for the men group were increasing the lane width and improving the sight distance, while the women considered the improvement of the pavement conditions and the appeal of the bike lanes more important. Increasing the lane width and improving the pavement conditions for the recreational group and increasing the lane width and improving the sight distance for the non-recreational group were the most important improvements in the attribute of the bike lanes.

Generally speaking, it can be said that increasing the width of the bike lane has been the most important factor for almost all the groups and should be a priority because it would increase both comfort and safety. It was seen that in the city of Qazvin, the bicycle was mostly used for recreational purposes and has not yet been

accepted as a mode of transportation. Therefore, more attention should be paid to safety of the bike lane to increase the tendency to use the bicycle.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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