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Research Paper

Motivational Factors of Bicycle Sharing in a Car-dependent City: Evidence from Tehran, Iran

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Abstract

Creating motivational factors is a way to increase bicycle use in a city where its share in transportation is low. The current study evaluated factors that could motivate an increase in shared bicycle demand. Results of a survey conducted in Tehran were used to identify the most influential factors. Next, Aimsun software was used to perform a simulation on two major streets in the city to assess the following scenarios: 1) without bicycles, 2) with bicycles and other vehicles, and 3) with bike lanes. The results showed that the entry of shared bicycles into the streets decreased the density of motor vehicles. On Jomhouri St, the density of motor vehicles decreased from 16.39 veh/km for without bicycles scenario to 13.52 veh/km for construction bike lanes. A downward trend also was observed for Keshavarz Blvd., with a decrease of 14.21% from scenarios one to three. The construction of bicycle lanes as a means of increasing public interest in sharing bicycles can have a positive effect on reducing traffic congestion.

Keywords: Motivational Factors, Bicycle Sharing System, Analytic Hierarchical Process, Transportation Demand, Simulations

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1. Introduction

Globally, bike-sharing systems (BSS) are becoming increasingly common in urban areas [Willberg, Salonen, and Toivonen, 2021]. There were more than 4.5 million bikes in the global bike share fleet in 2019, which operated in more than 1500 cities [Fishman, and Allan, 2019]. As of June 2018, the China Internet Network Information Center (CNNIC) reported that the number of shared bike users had reached 245 million [Zhanyou, Dongmei, and Yaopei, 2020]. There were 35 million trips taken by bike share in 2017, representing a 25% increase over 2016. Bicycle share bikes have been used in the United States for 123 million trips since 2010 [NACTO, 2018]. It is important to note that bike share is not restricted to wealthy countries or cities, and, in fact, a large proportion of bike share bikes around the world are located in developing nations [Meddin, 2018; Fishman, and Allan, 2019]. For bike share, a coherent network of quality bicycle lanes and paths is an essential element of the transportation system [Fishman, and Allan, 2019].

Despite the demand for bicycle-sharing systems, the lack of regular use of the system in daily travel indicates a gap between the desire to use the system and a failure to do so. An increase in demand depends on motivating citizens to use bicycles on a daily basis. In general, any new project in a large community must assess the factors influencing demand. With regard to transportation in a city, the more important the goal of the project is to the residents, the greater will be their motivation to undertake a new style of day-to-day travel.

Shared bicycles are becoming an important part of urban transportation, so it is imperative to pay attention to the benefits of using this system [Ashqar et al., 2022]. Researchers have shown that bicycle sharing priorities vary widely between regions and cities, particularly in developing countries [Jahanshahi et al., 2019]. Proper management and forecasting of travel demand can increase user satisfaction [Li et al., 2022]. Public bicycles for transportation are non-motorized vehicles that allow citizens to travel faster and, in cities with large populations, can reduce traffic congestion [Podgórniak-Krzykacz and Trippner-Hrabi, 2021]. A shared bicycle system is an alternative to motor transport which offers high flexibility and can be a solution to reducing traffic [Hamilton and Wichman, 2018]. Problems created by the use of personal vehicles, such as traffic volume and pollution, can be reduced [Morton, 2018; Maioli, de Carvalho, and de Medeiros, 2019].

Cities are moving away from personal automobile infrastructures [Maas, Attard, and Caruana, 2020]. In order to reduce traffic and environmental problems, a shared bicycle system is an emerging system in the transportation industry [Chen et al., 2018]. It is believed that switching from motorized to non-motorized transport can reduce the negative effects of motorized vehicles in cities [Cerutti et al., 2019]. In addition to traffic problems, environmental concerns related to the fuel used to power motor vehicles are essential indicators for the use of shared bicycles as public transportation [Cerutti et al., 2019; Hosford et al., 2018].

The shared bicycle system has considerable room for expansion and development [Cheng, OuYang, and Liu, 2019]. In recent years, the popularity of this system has increased significantly because researchers have sought for factors to promote bicycle use [Lin et al., 2018; Sun, Chen, and Jiao, 2018; Yin, Qian, and Shen, 2019]. Today, more than 500 cities worldwide host communal bicycles and this number is increasing every year [Wood, 2020]. Internal and external factors can influence shared bicycle use. The external factor relates to an individual's attitudes, and the internal factor relates to the overall effect of a bicycle system in relation to the environment [Ge et al., 2020]. Attitudes and thoughts about travel modes and what has affected how a person travels will play

an essential role in choosing the mode of travel [Sarkar, and Mallikarjuna, 2018]. The effect on decision-making that individual attitudes and how travel affects the environment cannot be denied [de Geus et al., 2019]. Cultural and demographic factors can play a role in helping to create a suitable environment for cycling in a city [Nikitas, 2019; Wang et al., 2018]. For instance, it was found that age, the number of cars, the number of bicycles, and access to public transportation affect the demand of females and males for bicycle trips differently. The level of education and the presence of bike houses are also important factors influencing the cycling behavior of men, but not that of women [Mamdoohi, and Amini, 2021]. An appropriate environment along with an understanding of the infrastructure and the foresight and reactions of individuals have been a concern for transportation professionals because they affect travel behaviour [Dill, Mohr, and Ma, 2014]. Introducing a new plan where there is insufficient infrastructure could diminish resident demand for the plan and point them toward another model [Timpabi, Osei, and Adams, 2021; Cheng, Fu, and de Vreede, 2018]. Currently, motor vehicles have become an integral part of human life, likewise the growing urban population Furthermore, the large migration to cities during the past few decades are issues that we observe with increasing frequency [Askari et al., 2013]. As a result, there is an increase in motor vehicles, a significant increase in travel time, delays in the network, and excessive fuel consumption. The above conditions, as well as the increase in motor vehicles and the pollution caused by these vehicles, have caused approximately 500,000 premature deaths in developing countries each year as a result of air pollution [Jaafari et al., 2013]. Bicycles are increasingly becoming popular in developing countries as a result of technological advancements and efforts to save energy and fuel. Using bicycles does not require large investments and can reduce motor vehicle density in a city by increasing the public transportation fleet [Ghaffari et al., 2014]. In this regard, the use of bicycles can be a fun and enjoyable means of recreation and transportation. Furthermore, it can reduce the problems caused by motor vehicles [Rissel, 2010]. As the amount of time that citizens spend in daily traffic increases, not only do citizens lose their financial resources, but also they lose a clean environment through increased air pollution and fuel consumption. Changes in transportation patterns, as well as changes in travel patterns caused by motivational factors, can contribute to an improvement in quality of life.

Lack of management infrastructure and facilities and an inadequate traffic plan to create a new approach in a large and multifaceted transportation industry will reduce the desire of residents to participate [World Bicycle Relief, 2018]. If people become discouraged because a new system has few features, there will either be little demand or it will be a complete failure [Félix, Moura, and Clifton, 2019]. A supportive social environment can help residents accept and use shared bicycles; thus, increasing demand [Chen, van Lierop, and Ettema, 2020]. Given the effect of bicycles on transportation, investing in and encouraging people to use them is a positive step toward increasing demand [Rosas-Satizábal and Rodriguez-Valencia, 2019].

Motivation is the process by which an external stimulus can cause a change in behavior or attitude and that leads the individual toward specific goals [Wu et al., 2019]. Individual selection is a process by which an external stimulus creates the motivation for action that is associated with an individual's reaction [Gardner, 2015]. Providing the motivation to turn a car-centric city into a bicycle-driven one

can contribute to the creation of a healthy and sustainable society [Kaplan, Wrzesinska, and Prato, 2018]. Proper policies, defining the best travel patterns and motivating factors will increase the demand for bicycles as transportation [Ji et al., 2020].

The existence of shared bicycles in a competitive space for vehicles can reduce the use of automobiles [Teixeira, Silva, and Moura e Sá, 2020]. Shared bicycle systems are more successful in densely populated urban areas [Tomasz et al., 2019]. During daylight hours, modelling results show that access demand is higher during peak hours, such as in the afternoon than in the morning [Reynaud, Faghih-Imani, and Eluru, 2018].

Identifying motivators and removing obstacles are factors related to choosing the type of vehicle to be used for daily travel [Timpabi, Osei, and Adams, 2021]. With the development of infrastructure and the provision of facilities, residents can be motivated to use bicycles as transport. Cycling for both work and non-work purposes shows that this non-motor vehicle can be an alternative to motor vehicles in dense cities [Benedini, Lavieri, and Strambi, 2020]. The existence of appropriate infrastructure and facilities can increase the use of shared bicycles [Orozco-Fontalvo et al., 2018; Bieliński, Kwapisz, and Ważna, 2019]. Defining the economic, environmental and social factors that affect attitudes is a common strategy to motivate forward-looking planning [Torrisi et al., 2020]. Individual attitudes play an essential role in choosing which type of vehicle to travel because of different perceptions about the environment and the hidden characteristics of each person [Bahamonde-Birke et al., 2017].

Resident flexibility about the use of a new mode of transportation can contribute to improving attitudes and information analysis [Yang et al., 2019]. Positive attitudes can increase the presence of shared bicycles in transportation [Pogačar et al., 2020]. In cities with large populations, motor vehicle congestion and air pollution mean changing the mode of travel from motor vehicles to bicycles is a necessity [Li, and Kamargianni, 2018]. Providing an infrastructure under the right conditions alone is not enough to significantly increase demand. Changing attitudes about daily travel and creating a model of sustainable development can play a significant role in increasing demand [Gutierrez et al., 2020]. In general, for daily transportation, the human capital, appropriate structure, cultural and social conditions of the individual and focus on the desires of individuals in order to progress towards the goal, will increase desire and motivation and, thus, demand [Shliselberg, and Givoni, 2018].

Tehran is the most populous city in Iran and a metropolis whose population is growing because of many facilities. As a result, motor vehicles are being used and produced at an increasing rate. Moreover, in addition to the high volume of traffic on a daily basis, air pollution from vehicle fuels, which can sometimes cause health problems, has also contributed to many problems. As a result, reviving a new mode of transportation that can be used to improve traffic and environmental problems is essential for Tehran and other cities that are experiencing these issues. Daily bicycle trips and their continuation are dependent upon the perceptions and individual behaviors of the companions in relation to the social and environmental contexts in which they take part. Considering that daily trips are selected by citizens in the transportation industry, this illustrates the colorful role that citizens play in this sector. The interaction with citizens and the use of feedback is part of the policy-making process, therefore factors that motivate citizens to increase bicycle use are important.

Cities like Tehran, which are inherently accustomed to motor vehicles, need a primary incentive to encourage citizens to use a new mode of transportation. Motivating, solving problems and overcoming obstacles using citizens' opinions can strengthen the relationship between them and the shared bicycle system. Most previous studies only have

introduced the factor of increasing demand in order to increase the use of this new system. The current research analyzed the effect of the presence or absence of bike lanes using simulation software. In this respect, the current research differs from previous studies.

Allocating sufficient and systematic budget, developing a smart system for reporting problems and obstacles, investigating and resolving them, allocating a few days of the week to use shared bicycles instead of motor vehicles, using and welcoming the authorities to the new method of transportation even symbolically, and finally the appearance of changes in the city that will encourage citizens to use shared bicycles in daily trips in the city as techniques and policies to achieve the goal of increasing shared bicycle demand. Besides strengthening visual perception, managers and officials should also provide the necessary infrastructure for culture building through environmental advertising, media, virtual networks, and incentive plans.

Once a bike-sharing system can compete with motor vehicles, there is an opportunity to identify and increase demand using a long-term plan. The present study used data collected from questionnaires and traffic data to determine the effect of shared bicycles on traffic. The results were analyzed to identify attitudes that can motivate people to use shared bicycles for transportation. Three practical objectives were examined and analyzed:

- If the motivation of residents is considered as a policy, it is important to know which motivating factor is most vital to encourage the use of shared bicycles. The first step was to examine the factors affecting motivation to increase the use and acceptance of shared bicycles in a city.
- Changes in the motivational factors were investigated relative to each other. It is important to know which changes can affect one factor over another. Therefore, the second step was to analyze the changes in the conditions of one motivational factor relative to the other factors.
- The final step was to analyze the three important factors in the discussion of road transport--flow, density and speed--through simulation of the use of shared bicycles in a city.

2. Research Method

This study was considered to be applied research which intends to achieve a goal by collecting two types of data. The field method was used in the form of a questionnaire to find the best motivator. Then traffic simulations were carried out using traffic data collected from relevant organizations about the number of daily trips by motor vehicle.

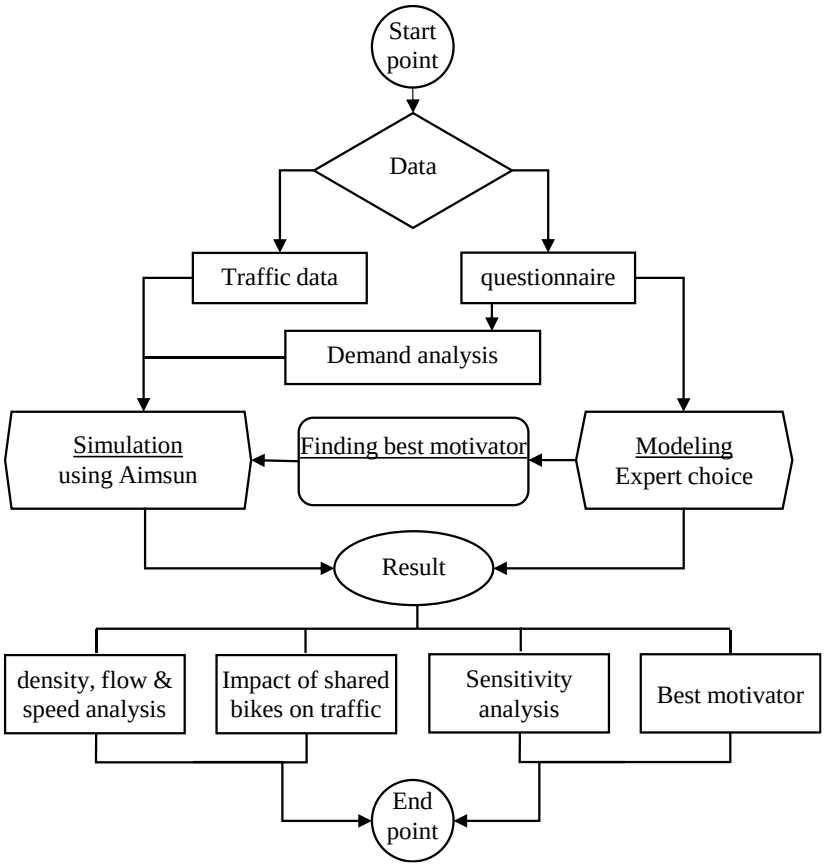


Figure 1. Flow chart of research method

In order to determine the most important motivational factor from the perspective of residents, a questionnaire was prepared to determine their behaviours and attitudes during travel. After the questionnaire was distributed and completed, analysis was performed in SPSS, Expert Choice and Aimsun software. Statistical outputs were obtained from SPSS. Expert Choice provided the best motivational factor as well as sensitivity analysis between motivational factors. Simulations were performed in Aimsun to analyze the important factors of traffic density, flow and speed for two major streets in Tehran. A total of 600 questionnaires were completed and collected in the city. The Cronbach's alpha correlation coefficient was 0.8. The modelling and simulation results were analyzed in Expert Choice and Aimsun software. Figure 1 illustrates the research methodology.

2.1. Analytic Hierarchy Process

The analytic hierarchy process was used to determine the best criteria and to compare between criteria and indicators in critical and difficult situations. Creating a hierarchy with sufficient understanding of the subject was achieved by logical comparison and analysis between factors to decide the effect of each criterion on the others and extract the final weights. In this decision-making structure, criteria based on pairwise comparisons were used, and their relative weights were ranked in order of importance from 1 to 9 (low to high) [Saaty, 1990].

Because there could be inconsistencies in the scales, all judgments made by the analyst were calculated and measured using a consistency index (CI). The standard limit of this coefficient is less than 0.1, and it can be calculated as: [Saaty, 1986. Saaty, 1988. Saaty, 1990. wang et al, 2017]

$$\mathrm{CI} = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

After calculating the rate of compatibility of the matrices, the weight of each alternative was

obtained according to existing criteria and were measured against the target. The final weight of each alternative was obtained as: [Saaty, 1986. Saaty, 1988. Saaty, 1990. Fuller, 2008]

$$w_i = \sum_j w_{ij} \times v_j \quad (2)$$

where w_{ij} is the weight of alternative i relative to criterion j and v_j is the weight of criterion j. Expert Choice first was used to extract the best motivation factor according to weight and pairwise comparison. Sensitivity analysis between criteria was done by changing the importance of the options to express the effect of the criteria as an interaction.

2.2. Simulation

The Aimsun software macroscopic index was used to determine the density, flow and speed. The simulation information entered into the software was the number of vehicles travelling along the streets during a typical day, obtained from traffic organizations. The simulation was performed on Keshavarz Blvd. and Jomhouri St. in Tehran, each of which has its own characteristics (see Figure 2). They have been defined for three scenarios. In the first scenario, all the raw data was assigned to the motor vehicles. In the second scenario, bicycles were added to the simulation cycle and they moved together with the motor vehicles. In the third scenario, bicycle lanes were added to the streets and the bicycles travelled separately from the motor vehicles. The percentage of bicycles used was determined by the residents when bicycle lanes had been constructed. Under scenario two and three, the demand obtained from the responses of residents about the desire to use bicycles for public transport was 45.33%. The preliminary statistics about residents with motor vehicles was simulated for the first scenario. The macroscopic indicators also were examined in the third scenario (see Figure 3).

3. Research Data and Analysis

In this study, simulation software was used to simulate the current and future conditions. The current condition was the use of bicycles in common with the current infrastructure. The future conditions would necessitate the elimination of cycling obstacles to the greatest extent possible, as well as motivating residents to use bicycles more frequently.

During a survey administered in person, 600 responses were collected addressing socio-economic, traffic, health, environment, time and location, infrastructure, cost, and social factors. Figure 4(a) depicts the marital status of the sample. As a result of the survey, the minimum age of the respondents was 18 years old, as everyone in Iran must be at least 18 years old in order to obtain a driving license. Figure 4(b) indicates that the majority of respondents were between the ages of 25 and 30, followed by those between the ages of 30 and 35 and those aged 20 to 25 years of age.

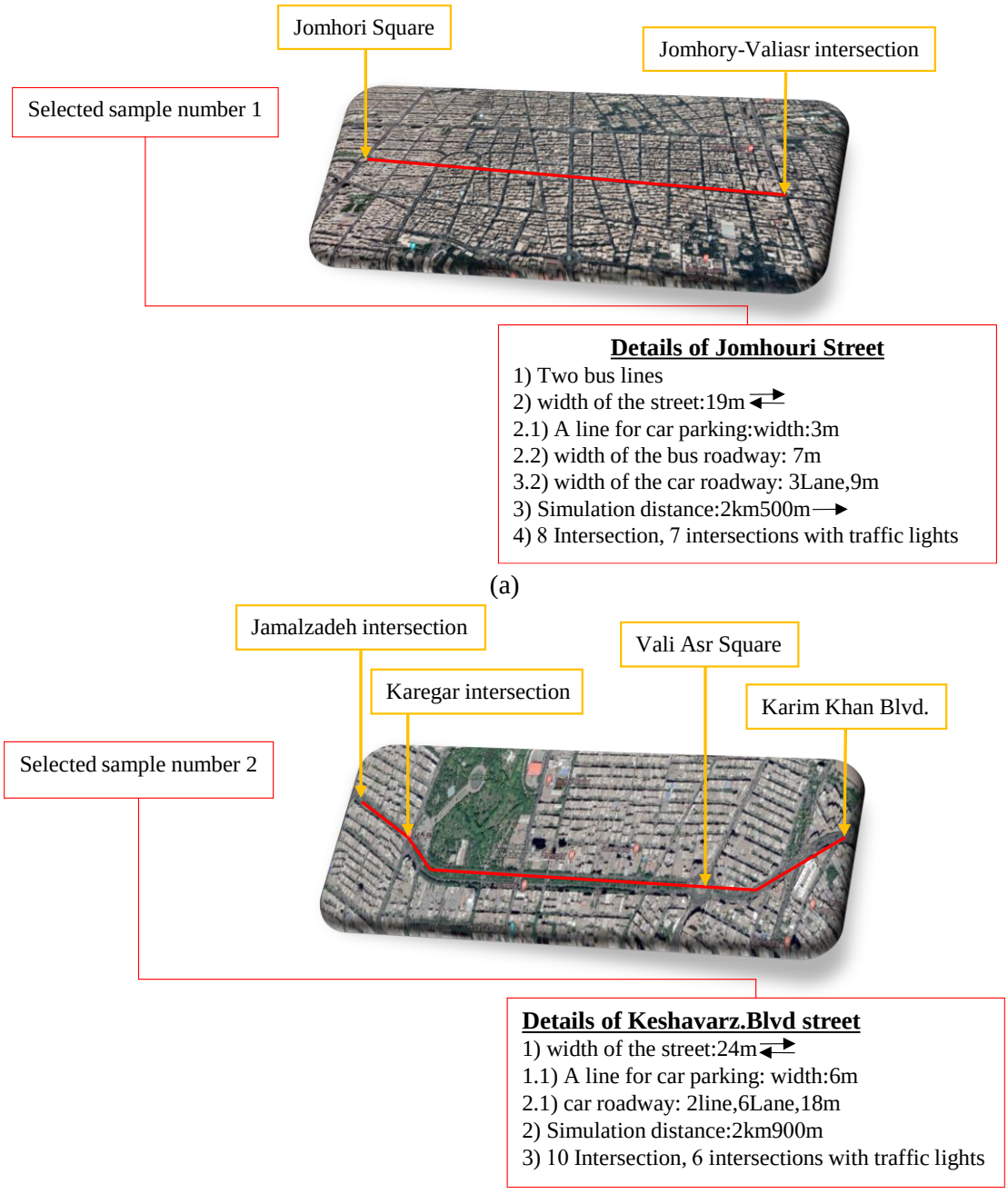


Figure 2. Streets selected for simulation include: (a) Jomhouri St.; (b) Keshavarz Blvd.

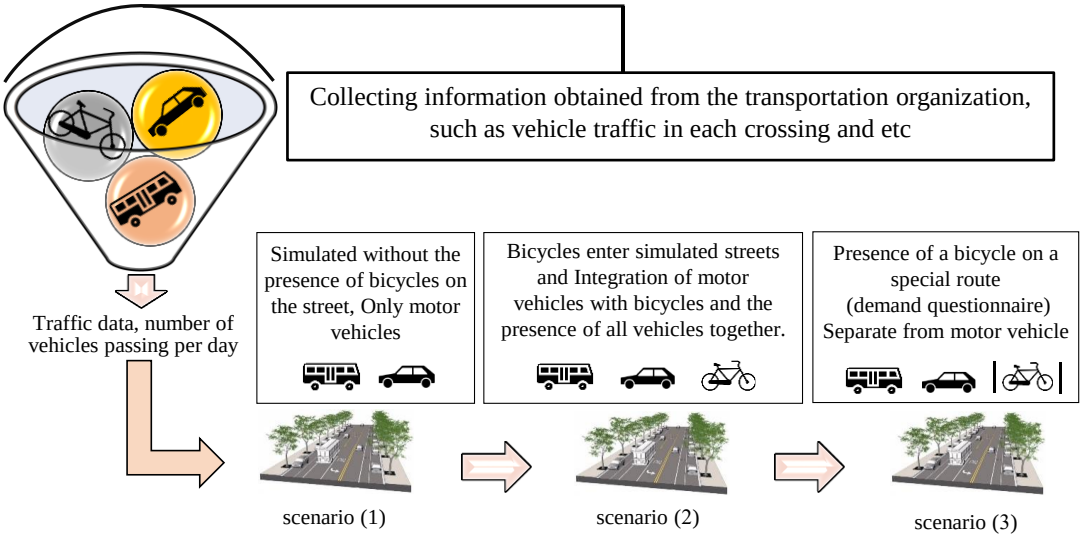
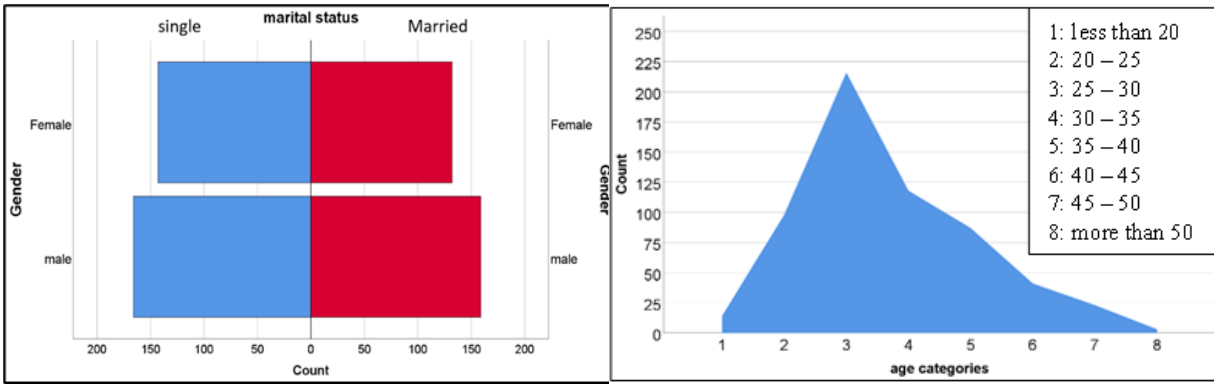
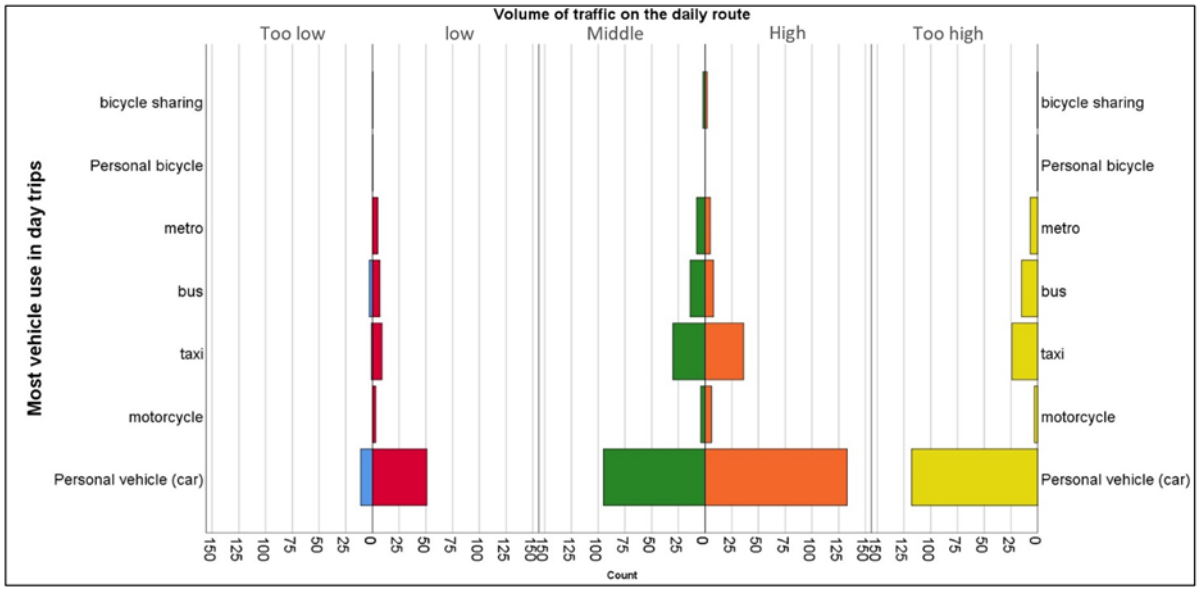


Figure 3. Scenario definition



(a) (b)



(c)

Figure 4. Frequency: (a) gender, martial status; (b) age; (c) volume of traffic on daily route

It is likely that the high desire for owning a motor vehicle may lead to an increase in the number of vehicles and the amount of time people spend travelling on a daily basis (Figure 4(c)). As shown in Table 1, 98.7% of the 600 respondents had at least one motor vehicle in the household, while 55% were prepared to use bicycles if the obstacles were removed and an appropriate infrastructure for cycling was established. This statistic indicates that there is a gap between respondents' behaviour and attitudes which might make them less inclined to use shared bicycles. Due to this gap, there is an opportunity to encourage people to use sustainable forms of transportation, such as shared bicycles, which was one of the primary objectives of this study.

Based on Figure 5, the percentage of respondents using shared bicycles in the current situation is 4.5 percent, while with proper planning and ideal conditions in the future, the respondents have a good tendency to use this mode of transportation (about 45 percent).

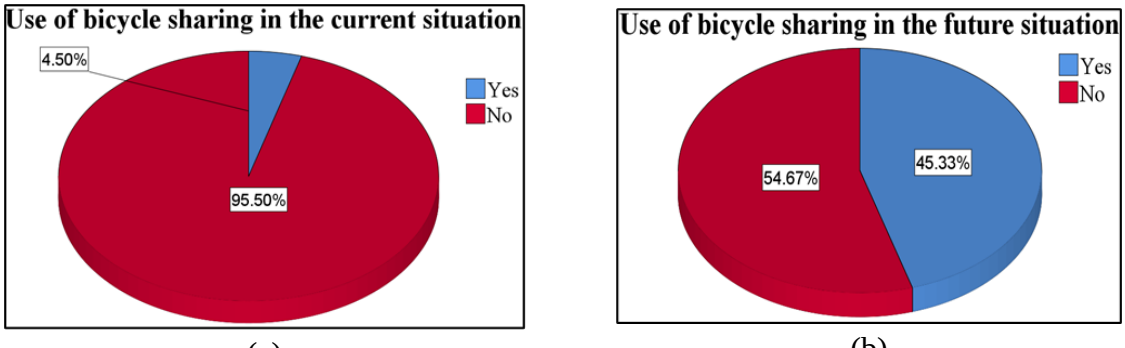
Table 1. Number of cars per family

Number of cars	Frequency	Percent (%)
1	516	86
2	69	5.11
3	7	2.1
none	8	3.1

3.1. Motivational Factor

Motivational factors can be classified under the following headings: environment, health, traffic, location and time, infrastructure, cost, and social [Verma et al., 2016; Guinn and Stangl., 2014; Gutiérrez, Hurtubia, and de Dios Ortúzar, 2020; Marquart, Schlink, and Ueberham, 2020]. A network structure for decision-making indicates that different factors can affect the determination of a goal and its management. Some of these factors relate to human perceptions about bicycle use as a transportation system, and others relate to the effects of the use of shared bicycles that have been observed and analyzed by residents. The dimensions of the different factors that cause a growth in demand as well as the application of policies and measures to increase demand, must be considered.

In the analytic hierarchical process (AHP), the criteria and alternatives are related and depend on residents' perceptions about transportation. The criteria are general aspects and alternatives are more narrowly defined for better analysis and are subsets of criteria. The criteria were divided into the sections according to the literature [Verma et al., 2016; Guinn and Stangl., 2014; Gutiérrez, Hurtubia, and de Dios Ortúzar, 2020; Marquart, Schlink, and Ueberham, 2020] and the needs of individuals and their understanding of transportation: (1) society, (2) cost, (3) infrastructure, (4) location and time, (5) traffic, (6) health, (7) environment. The classification of the criteria and alternatives was done such that all of them were related.



(a) (b)

Figure 5. Use of shared bicycles: (a) current condition; (b) future condition

The motivational factors were prioritized and examined using criteria and weight variables. The hierarchical tree depicted in Fig 6 presents the criteria and alternatives. The red colour of the interface denotes that these options are the main branch of the criteria. The black lines denote the interface between the options and criteria in the decision-making process. The output obtained in this study has an inconsistency index for the entire hierarchy of 0.05. Because this coefficient was less than 0.1, it was considered desirable and the modelling to be valid.

Figure 7 demonstrates final weight outputs from Expert Choice software. The bike lane had a final weight of 0.182. Reduction of fuel consumption from the use of a bike and combining bicycles with motor vehicles to reduce traffic ranked second and third, respectively. This shows that, in addition to correcting perceptions by residents of the bicycle sharing system in transportation, the construction of a bicycle lane can be very desirable.

3.2. Sensitivity Analysis

Sensitivity analysis reveals how much other alternatives will change if the amount of one alternative changes. This is important because analysis of the behaviour of a system shows how sensitive the overall behaviour of the system is to other alternatives. This is challenging because each factor understudy can be influenced by other factors, making it difficult to determine which factor has had the most significant effect. In such cases, sensitivity analysis can provide the answer.

An analysis of the sensitivity was conducted, and the results are presented in Figure 8. We are investigating sensitivity analysis and evaluating the results obtained by increasing each of the criteria in other criteria and alternatives. Thus, we increased the criteria to 0.35, the maximum desirability of this research criterion, and 0.8, the normal limit with high desirability. Colors indicated by green indicate an increase over the initial value and colors indicated by red indicate a decrease over the initial value (see table 1 and 2 in Appendix 1).

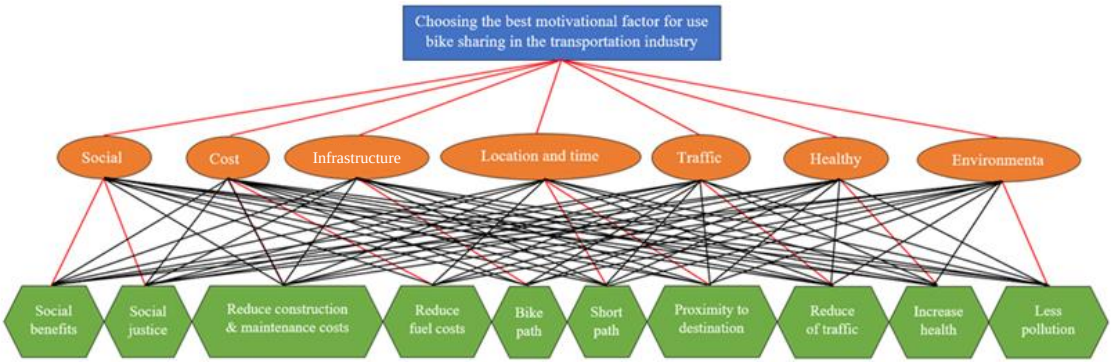


Figure 6. Hierarchical tree

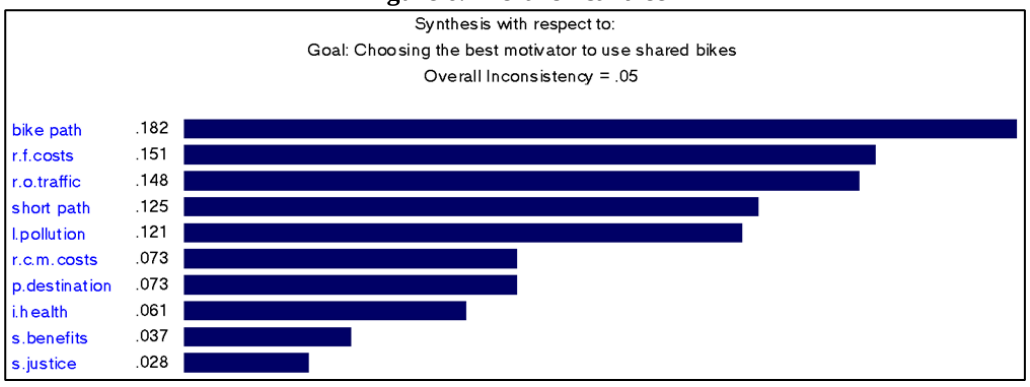


Figure 7. Final weight outputs from Expert Choice software

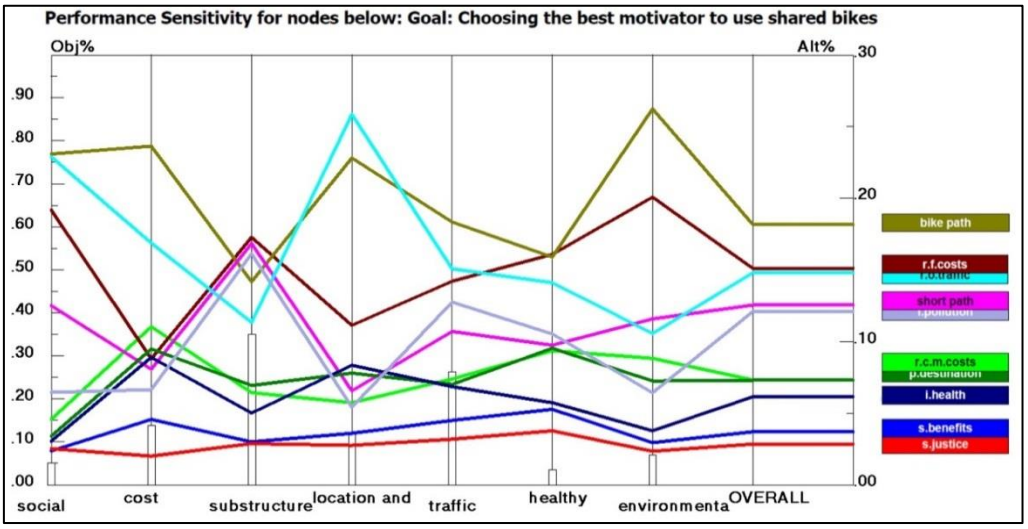


Figure 8. Criteria sensitivity analysis

3.3. Macroscopic Parameters in the Simulation

An analysis of the simulation performed in Aimsun software for Jomhouri St. and Keshavarz Blvd. in Tehran. It was decided to choose these two streets because they are located in the heart of the city and are connected to busy streets. Additionally, they are important commercial, office, and educational locations. As a result of the addition of bicycles on Jomhouri St., the volume of motor vehicles decreased, which is a positive development for the transportation system. The introduction of shared bicycles resulted in a decrease in the density of motor vehicles. Consequently, motor vehicles have a greater degree of maneuverability (see Table 2 and 3).

The issue of speed is another parameter to consider. As a macro-parameter, the speed of vehicles decreased with the entry of shared bicycles into the transportation system, particularly in the second scenario.

Numerous intersections along the analyzed routes led to increases in density in some sections, even after bicycles were introduced. In this case, it may be due to the fact that bike lanes cannot be extended into intersections and traffic lights also interrupt these lanes. In response to a light change and movement commencing, the density will increase as well as the percentage of users. The density of bicycle lanes will increase as the number of shared bicycles increases. It is normal because the width of the bike lanes remains the same, the lane will become more crowded, and the bicycles will become less maneuverable.

Some points on Keshavarz Blvd. yielded results similar to those on Jomhouri Street. The entry of bicycles into the transportation system resulted in a decrease in the density of motor vehicles in the second and third scenarios, while the density of bicycles increased in all scenarios. For the second scenario, the motor vehicle capacity decreased, while for the third scenario, it increased.

The speed of motor vehicles increased on Keshavarz Blvd., as well as Jomhouri St., with the advent of bicycle lanes, which accelerated the speed of motor vehicles. In terms of density, the number of vehicles along the route decreased with the introduction of shared bicycles on Jomhouri St., resulting in a decrease from 16.39 (veh/km) to 14.43 (veh/km). According to the third scenario, where a bicycle lane is present, the density is 13.52 (veh/km).

As a result, the density of vehicles on Keshavarz Blvd. decreased from 43.89 (veh/km) to 37.65 (veh/km) in the second scenario to 24.78 (veh/km) in the third scenario. With the arrival of bicycles, the flow rate for Jomhouri St. decreased from 9,540 (veh/h) to 5,764 (veh/h). As a result of the installation of a bike lane in

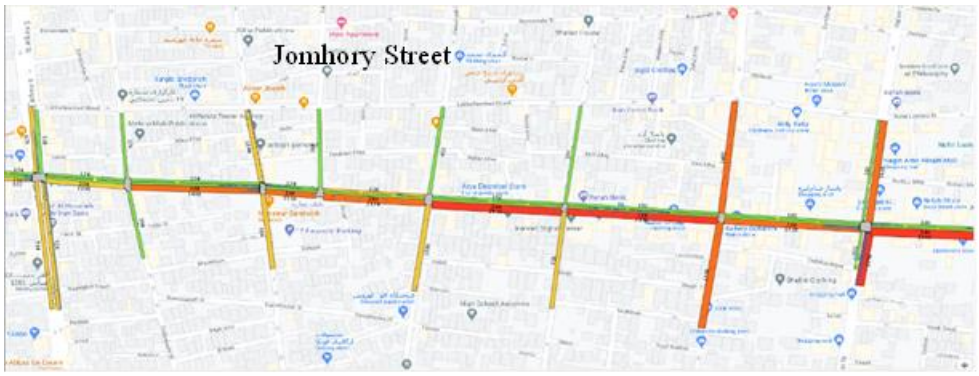
scenario three, this number decreased to 5,651 (veh/h). For Keshavarz Blvd., the flow rate decreased from 12,273 (veh/h) to 8,973 (veh/h). In light of the positive effects of shared bicycles on the crowded streets, an increase in bike use may be expected. Figures. 9 and 10 are taken from the output of the Aimsun software and illustrate the improvement in traffic conditions following the introduction of shared bicycles.

Table 2. Simulation results from Aimsun for Jomhouri St.

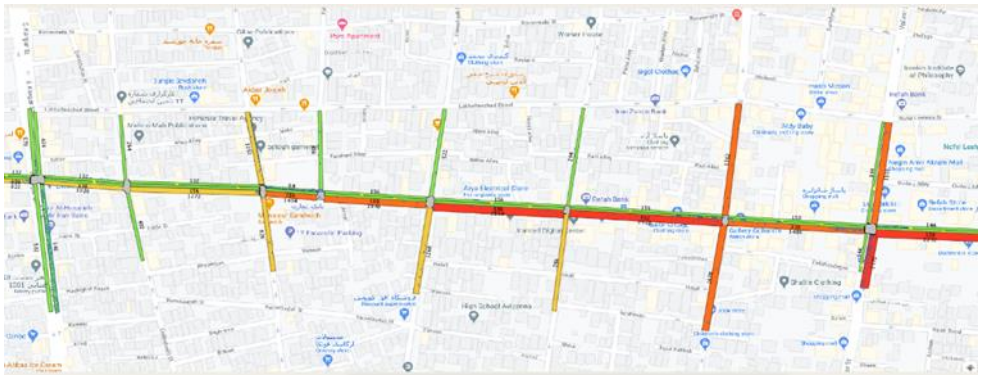
	Vehicle	1. Without a bicycle	2. Integration of motor vehicles with bicycles	3. Presence of a bicycle lane (demand questionnaire)
		Density (veh/km)		
1	Motor vehicles	16.39	14.43	13.52
2	Bicycle sharing	-	9.35	14.06
3	Total density	19.38	23.79	27.59
		Flow (veh/h)		
1	Motor vehicles	9540	5764	5651
2	Bicycle sharing	-	3469	3991
3	Total flow	9540	9233	9642
		Speed (km/h)		
1	Motor vehicles	52.33	59.27	63.83
2	Bicycle sharing	-	18.21	12.78
3	Total speed	52.33	77.48	76.61

Table 3. Simulation results from Aimsun for Keshavarz Blvd.

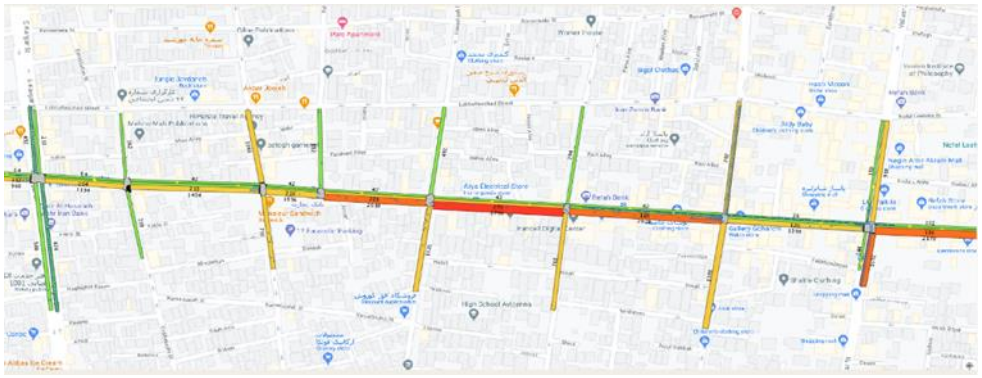
	Vehicle	1. Without bicycles	2. Integration of motor vehicles and bicycles	3. Presence of a bike lane (demand questionnaire)
		Density (veh/km)		
1	Motor vehicles	43.89	37.65	34.78
2	Bicycle sharing	-	13.81	19.32
3	Total density	43.89	51.46	54.1
		Flow (veh/h)		
1	Motor vehicles	12273	9040	8973
2	Bicycle sharing	-	3105	4064
3	Total flow	12273	12145	13038
		Speed (km/h)		
1	Motor vehicles	26.82	28.23	39.81
2	Bicycle sharing	-	9.7	7.72
3	Total speed	26.82	37.93	47.53



(a)



(b)

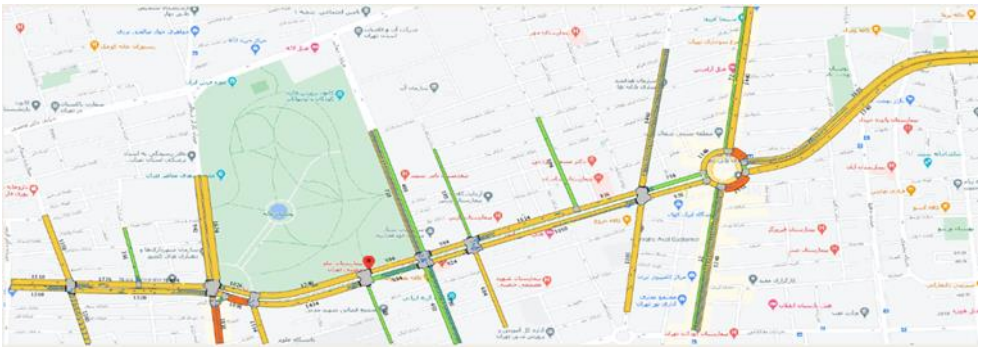


(c)

Figure 9. Simulations: (a) without bicycles; (b) integration of motor vehicles and bicycles; (c) special bicycle routes (based on demand obtained from questionnaire survey) on Jomhouri St.

(a)

(b)



(c)

Figure 10. Simulations: (a) without bicycles; (b) integration of motor vehicles and bicycles; (c) special bicycle routes (based on demand obtained from questionnaire survey) on Keshavarz Blvd. and Karimkhan Zand Blvd.

4. Discussion

Motivation refers to processes such as recognition and need, which can shape the behavior of each person according to the internal and external conditions of each person. Creating motivation makes each person take decisions, evaluate obstacles and advantages, and then give direction to that action and lead the person to the final goal. Creating a suitable culture, providing a platform for education, repeating ongoing plans and their results, etc., are examples of public solutions that can influence people's attitude toward external conditions. For example, allocating a prize to the implementation of a project can act as a motivation and encouragement to oblige people to use a new project by familiarizing themselves with the project in order to test the person's view of the advantages and disadvantages or the level of demand of the project.

Providing motivation is a policy for increasing demand. This study evaluated which motivational factors were influential in encouraging residents to use bicycles for daily travel and to what extent the use of shared bicycles reduced traffic. Shared bikes are a promising solution to the problems of traffic and pollution in cities [Zhao, Deng, and Song, 2014]. Therefore, this study was conducted with the aim of analyzing motivational conditions that will increase the use of shared bicycles in the city of Tehran. It was based on changing attitudes to increase the use of the shared bicycle system in public transportation by helping them understand its effect on traffic. This was confirmed by our survey, where respondents showed a 45.33% increase in willingness to use this transportation system.

Motivation as a policy and creation of an attitude of change in the style from motorized to non-motorized vehicles targets the attitude of individuals about changing the structure of transportation. Embracing a new mode of transportation in daily travel [Dill, Mohr, and Ma, 2014] as well as changing the style of transportation required a change in the attitudes of residents [Capron and Pérez López, 2016]. In general, motivation was an influential factor in increasing demand. This is in agreement with a study conducted in China which found that motivation is an important reason for using shared bicycles [Wu et al., 2019].

The present study indicates that it was the infrastructure, especially the construction of bicycle lanes, that motivated citizens the most. This suggests that the relationship between an increase in demand and the construction of bicycle lanes was positively correlated. The results of the present study are in contrast with those of Titze et al. (2008), who considered improving residential density to be more important than the construction of bicycle lanes. As previously noted, the current study found that bicycle lanes led to an increase in demand for shared bicycles, which is in line with Verma

et al. (2016) and Aziz et al. (2018) findings. It should be taken into account that there are different types of cyclists. For example, a previous study identified four types of cyclists: dedicated cyclists, path-using cyclists, fairweather utilitarians, and leisure cyclists [Damant-Sirois, Grimsrud, and El-Geneidy, 2014].

In the simulations, the flow, speed and density of vehicles were analyzed. The results showed that, although the use of shared bicycles along with motor vehicles was positive for increasing their use to help reduce traffic, it was also determined that construction of bike lanes would further reduce traffic (while posing fewer safety risks to cyclists). These results are consistent with results from Benedini, Lavieri, and Strambi (2020) that motivating people to start cycling and changing their attitudes toward changing transportation modes can reduce traffic. In order to change travel patterns and the problems and barriers that have affected the level of cycling demand, addressing these issues requires bringing some flexibility to the transportation community. Based on the results of this study, the reactions to the use of incentives showed that the construction of bike lanes created the highest level of motivation for the use of shared bicycles, according to opinions expressed by residents of Tehran.

The development of a project such as shared bicycles and its successful management to overcome problems can attract the attention of other countries. Implementing a successful project can lead to the initiation of such a project in other countries. With the use of simulation, it was observed that the shared bicycle system reduced the volume of traffic, which can be considered a good and desirable outcome for our transportation community and a positive outlook on the future.

Based on the research, it was determined that the creation of special bicycle paths is the most motivating factor. The creation of these paths can be beneficial to people and encourage them to use bicycles more frequently. Finally, the possibility of more bike sharing may reduce the city car traffic, as demonstrated in this paper. Consequently, officials and citizens will be more optimistic about achieving a city with lower traffic loads and cleaner air.

5. Conclusions and Future Directions

High traffic and its consequences have made shared bicycles a vital alternative to motor vehicles for public transportation [Kong, Jin, and Sui, 2020; Kim and Cho 2021; Radzimski, and Dzięcielski 2021]. This study used the approach of encouragement and motivation with the aim of analyzing and determining the best motivational factors for encouraging a shared bicycle system for daily trips. Simulations were used to better understand the effect of this non-motor vehicle on the streets of Tehran.

A total of 600 completed questionnaires were collected in Tehran and were used to determine the demand for the use of shared bicycles in the present and future scenarios. The best motivation factor and the sensitivity of the motivational factors were analyzed in SPSS and Expert Choice software. After that, the absence or presence of shared bicycles was simulated for the parameters of density, flow and speed on two major streets in Tehran in Aimsun software. From the results, the following conclusions could be drawn:

- Sensitivity analysis showed that the construction of bike lanes had a final weight of 0.182 and ranked first as the best motivating factor for using a common bicycle system in public transportation from the infrastructure sub-branch.
- Because residents' perception on the efficiency of this system may change in the future in relation to the current level of demand, it was concluded that with the use of motivation and problem solving will produce a 45.33% positive demand for the use of shared bicycles.

- From the simulation results for Jomhouri St. and Keshavarz Blvd. for the factors of flow, density and speed, the use of shared bicycles was assessed as satisfactory. Their use on Jomhouri St. produced a decrease of 11.95% in the density of motor vehicles. After bike lanes were constructed, there was a 17.51% decrease in motor vehicles compared to the initial traffic conditions. The density also decreased 14.21% for Keshavarz Blvd. with the use of bicycles. With the construction of the bike lane, a 20.75% decrease in motor vehicles compared to the initial condition was achieved.
- Reducing the flow and increasing the speed of motor vehicles by the increased use of shared bicycles showed that the decrease in the traffic volume increased the manoeuvrability of motor vehicles on both streets. This indicates that it was beneficial to reduce traffic through the use of shared bicycles and that the construction of bike lanes contributed to this reduction.
- Using the simulation, it was indicated that the volume of daily traffic decreased as a result of people using shared bicycles for daily trips. This is good news for achieving sustainability in the city.
- There is no doubt that the construction of bike lanes alone will not alter the desire of city dwellers to bike, but all the individual factors as well as the physical environment must be enhanced to encourage cycling.
- As the lack of continuity of special bicycle paths may reduce the safety of cyclists, it has been suggested that cyclist-specific traffic signals should be designed and installed. Further research is required in this area.

The following are possible directions for future research regarding the shared bicycle system in transportation. There may be differences in mobility culture from country to country and from location to location. It is therefore recommended that the influence of mobility culture on the demand for shared bicycles be investigated. In addition, measuring the demand for electric shared bicycles and analyzing the traffic parameters associated with this mode of transportation may be important topics for future research. It is also worthwhile to note that as this study focuses on simulations of shared bicycles on urban streets, future research regarding the necessity of bike paths in urban highways and the simulation of these might prove useful in the future.

In addition, research into the social acceptance of shared bicycles in metropolitan cities, building a shared bicycle culture, and studying the current state of shared bicycles in cities and how they function, are among the things that can be researched on a wider scale.

6. References

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Appendix 1: Sensitivity Analysis Result Tables

Table 1. Result of increasing the sensitivity of the criterion to 0.35

criteria	Alternatives	Percentage of change	main percentage
Social	s.benefits	3.3	3.7
	s. justice	2.7	2.8
	r.c.m.costs	6.4	7.3
	r.f.costs	16.4	15.1
	Bike path	19.7	18.2
	Short path	12.5	12.5
	p. destination	6.1	7.3
	r.o.traffic	17.4	14.8
	i. health	5.2	6.1
	l. pollution	10.3	12.1
Cost	s.benefits	3.9	3.7
	s. justice	2.6	2.8
	r.c.m.costs	8.2	7.3
	r.f.costs	13.6	15.1
	Bike path	19.5	18.2
	Short path	11.4	12.5
	p. destination	7.8	7.3
	r.o.traffic	15.3	14.8
	i. health	6.8	6.1
	l. pollution	10.8	12.1
Location and time	s.benefits	3.7	3.7
	s. justice	2.8	2.8
	r.c.m.costs	6.9	7.3
	r.f.costs	14	15.1
	Bike path	19.4	18.2
	Short path	10.9	12.5
	p. destination	7.4	7.3
	r.o.traffic	17.8	14.8
	i. health	6.7	6.1
	l. pollution	10.3	12.1
Traffic	s.benefits	3.8	3.7
	s. justice	4.3	2.8
	r.c.m.costs	7.3	7.3
	r.f.costs	15	15.1
	Bike path	18.2	18.2
	Short path	12.3	12.5
	p. destination	7.3	7.3
	r.o.traffic	14.8	14.8
	i. health	6.2	6.1
	l. pollution	12.2	12.1
Healthy	s.benefits	4.2	3.7
	s. justice	3.1	2.8
	r.c.m.costs	8	7.3
	r.f.costs	15.4	15.1
	Bike path	17.4	18.2
	Short path	11.6	12.5
	p. destination	8	7.3
	r.o.traffic	14.6	14.8
	i. health	6	6.1
	l. pollution	11.6	12.1
Environmental	s.benefits	3.5	3.7
	s. justice	2.7	2.8
	r.c.m.costs	7.7	7.3
	r.f.costs	16.5	15.1
	Bike path	20.4	18.2
	Short path	12.3	12.5
	p. destination	7.3	7.3
	r.o.traffic	13.6	14.8
	i. health	5.5	6.1
	l. pollution	10.5	12.1

Table 2. Result of increasing the sensitivity of the criterion to 0.8

criteria	Alternatives	Percentage of change	main percentage
Social	s.benefits	2.6	3.7
	s. justice	2.6	2.8
	r.c.m.costs	5	7.3
	r.f.costs	18.6	15.1
	Bike path	22.4	18.2
	Short path	12.5	12.5
	p. destination	4	7.3
	r.o.traffic	21.7	14.8
	i. health	3.5	6.1
	l. pollution	7.3	12.1
Cost	s.benefits	4.4	3.7
	s. justice	2.2	2.8
	r.c.m.costs	10.2	7.3
	r.f.costs	10.3	15.1
	Bike path	22.3	18.2
	Short path	9.1	12.5
	p. destination	9	7.3
	r.o.traffic	16.4	14.8
	i. health	8.3	6.1
	l. pollution	7.9	12.1
Location and time	s.benefits	3.6	3.7
	s. justice	2.8	2.8
	r.c.m.costs	6.1	7.3
	r.f.costs	12	15.1
	Bike path	21.7	18.2
	Short path	7.9	12.5
	p. destination	7.7	7.3
	r.o.traffic	23.3	14.8
	i. health	7.8	6.1
	l. pollution	6.9	12.1
Traffic	s.benefits	4.3	3.7
	s. justice	3.1	2.8
	r.c.m.costs	7.4	7.3
	r.f.costs	14.5	15.1
	Bike path	18.3	18.2
	Short path	11.2	12.5

	p. destination	7.1	7.3
	r.o.traffic	15	14.8
	i. health	6.7	6.1
	l. pollution	12.6	12.1
Healthy	s.benefits	4.9	3.7
	s. justice	3.6	2.8
	r.c.m.costs	8.9	7.3
	r.f.costs	15.9	15.1
	Bike path	16.4	18.2
	Short path	10.3	12.5
	p. destination	9.1	7.3
	r.o.traffic	14.3	14.8
	i. health	5.8	6.1
	l. pollution	10.9	12.1
Environmental	s.benefits	3.1	3.7
	s. justice	2.5	2.8
	r.c.m.costs	8.5	7.3
	r.f.costs	19	15.1
	Bike path	24.5	18.2
	Short path	11.8	12.5
	p. destination	7.3	7.3
	r.o.traffic	11.5	14.8
	i. health	4.3	6.1
	l. pollution	7.6	12.1
Infrastructure	s.benefits	3/2	3.7
	s. justice	2/9	2.8
	r.c.m.costs	6/7	7.3
	r.f.costs	16/6	15.1
	Bike path	15/4	18.2
	Short path	15/5	12.5
	p. destination	7	7.3
	r.o.traffic	12/4	14.8
	i. health	5/4	6.1
	l. pollution	14/9	12.1

Appendix 2. Questionnaire

in the name of god

Research questionnaire in the field of analysis and evaluation of the use of shared bicycles

Greetings and Regards;

The following questionnaire has been developed with the aim of analyzing and evaluating the demand and the factors affecting it in the city of Tehran.

This questionnaire is related to my research project entitled "Analysis and evaluation of the use of shared bicycles using statistical software and Aimsun simulation software (case study of Tehran city)". Your answers can increase the accuracy and For the performance of this research to be effective, therefore, the success of this research owes to the time and precision that you will put in answering the questions of this questionnaire.

thanks for your cooperation

First part: Individual questions and how to travel

1.Gender: Male ◯ Female ◯

2. Marital Status: Single ◯ Married ◯

3. Age: ◯

4. Monthly Income (Tomans):

Less than 2 million ◯ 2 million to 4 millio ◯ 4 million to 6 million ◯ 6 million to 8 million ◯

8 million to 10 million ◯ more than 10 million ◯

5. Level of education:

Sub-diploma ◯ post-diploma ◯ bachelor's degree ◯ doctorate and above ◯

6. Occupation:

Student ◯ teacher or university professor ◯ employee ◯ doctor ◯ retired ◯ military worker ◯

freelancer ◯ unemployed ◯

7. Number of personal vehicles in the family:

One ◯ two ◯ three ◯ more than three ◯ no vehicles ◯

8. On average, how many times a week do you use shared bikes?

1 time ◯ 2 times ◯ 3 times ◯ 4 times ◯ 5 times ◯ 6 times ◯ 7 times ◯ more than7 times ◯

9. On average, how many times a week do you use motor vehicles (car, bus, etc.)?

1 time ◯ 2 times ◯ 3 times ◯ 4 times ◯ 5 times ◯ 6 times ◯ 7 times ◯ more than 7 times ◯

10. How much do you spend on fuel for your personal vehicle every month?

Less than 50 thousand Tomans ◯ Between 50 and 100 thousandTomans ◯ Between 100 and 150 thousand Tomans ◯

Between 150 and 200 thousand Tomans ◯ Between 200 and 250 thousand Tomans ◯ Between 250 and 300 thousand Tomans ◯

Between 300 and 350 thousand Tomans ◯ Between 350 and 400 thousand Tomans ◯ Between 400 and 450 thousand tomans, ◯

Between 450 thousand and 500 thousand tomans ◯ more than 500 thousand tomans ◯

11. How much do you spend on public transportation every month?

Less than 50 thousand Tomans ◯ Between 50 and 100 thousandTomans ◯ Between 100 and 150 thousand Tomans ◯

Between 150 and 200 thousand Tomans ◯ Between 200 and 250 thousand Tomans ◯ Between 250 and 300 thousand Tomans ◯

Between 300 and 350 thousand Tomans ◯ Between 350 and 400 thousand Tomans ◯ Between 400 and 450 thousand tomans, ◯

Between 450 thousand and 500 thousand tomans ◯ more than 500 thousand tomans ◯

12. What is the volume of motor vehicle traffic on the route you travel daily?

very low ◯ low ◯ moderate ◯ high ◯ very high ◯

13. As a child, how much did you want to use a bicycle?

very high ◯ high ◯ medium ◯ low ◯ very low ◯

14. What is your access to shared bicycle stations?

Low ◯ Medium ◯ High ◯

15. Do you know about the routes available for cycling in the streets of Tehran?

Yes ◯ no ◯ approx ◯

۱۶. How many kilometers do you travel every day?

Less than 2 km ◯ 2 km to 5 km ◯ 5 km to 8 km ◯ 8 km to 11 km ◯ 11 km to 14 km ◯ 14 km to 17 km ◯

17 km to 20 km ◯ More than 20 km ◯

۱۷. The most important of the existence of shared bicycles in the transportation industry from the point of view Which of the following options is yours?

Saving time ◯ reducing travel costs ◯ preserving the environment ◯ reducing traffic volume ◯ reducing air pollution ◯

preserving natural resources ◯ getting away from the stress caused by traffic ◯ passing the traffic plan ◯

not needing a certificate ◯ saving additional costs related to daily fares and... ◯

۱۸. From your point of view, among the options below, which option or options are among the main problems of cycling in Tehran? (You are allowed to choose up to 3 options)

Absence of special bicycle paths ◌ lack of sufficient safety ◌ air pollution, lack of proper infrastructure ◌

roughness and inappropriate slope of roads ◌ high volume of motor vehicles ◌ unfavorable weather conditions ◌

non-observance of citizen's rights and right of way ◌ other reasons: .....

19. What is the most important factor or factors preventing the use of shared bicycles in the public transportation industry from your point of view? (up to 3 options are allowed to choose There are many options)

the long distance from the origin and the destination ◌ the inability to carry loads with a large volume ◌

the inability to travel with the family Improper condition of bicycles ◌ low level of cycling culture, family restrictions ◌

lack of proper support ◌ loss of character ◌ appearance of confusion while cycling ◌ low social status ◌

use of cycling in the city ◌ other reasons...

20. In your opinion, the level of cycling culture How is it in Tehran?

very high ◌ high ◌ medium ◌ low ◌ very low ◌

۲۱. Which of the following vehicles do you use most in your daily trips?

Personal car ◌ motorcycle ◌ taxi ◌ subway bus ◌ personal bicycle ◌ shared bicycles ◌

۲۲. How much activity and movement do you have per day?

High ◌ Medium ◌ Low ◌

۲۳. In general, how do you evaluate the benefits of using shared bicycles in the public transportation industry against factors such as fatigue and...?

Favorable ◌ Moderate ◌ Unfavorable ◌

۲۴. Do you prefer the use of bicycles to motor vehicles for daily trips?

Yes ◌ No ◌

۲۵. Do you want to use shared bicycles with other motor vehicles in combination in daily trips?

Yes ◌ No ◌

26. Are you willing to use shared bicycles in the transportation industry by creating a suitable platform in order to prepare suitable infrastructures and spread the culture of cycling in the city, as well as removing some obstacles?

Yes ◌ No ◌

27. In your opinion, how much is the social acceptance of cycling in the public transport sector in the current situation?

very high ◌ high ◌ medium ◌ low very ◌ low ◌

28. What kind of weather do you prefer for cycling?

Hot and cold ◌ hot and dry ◌ moderate and dry ◌ moderate and cold ◌ cold ◌

29. Which of the following factors is considered as a motivating factor in using bicycles in public transportation?

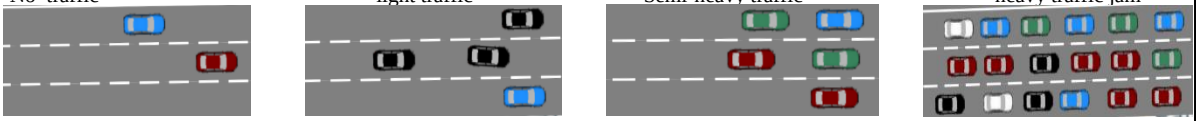
Shortening the distance to the destination ◌ increasing health ◌ creating less pollution ◌ improving social justice ◌

reducing fuel costs ◌ reducing road construction and maintenance costs ◌ good combination with motorized transport ◌

reducing the amount of traffic ◌ building bicycle paths ◌ other reasons...

30. If the conditions for using shared bicycles are provided for you, or if, according to the current conditions, you can use bicycles Do you use shared bikes, when do you prefer to use shared bikes?

No traffic ◌ light traffic ◌ Semi-heavy traffic ◌ heavy traffic jam ◌



Second part: questions of Prioritizing vehicles and travel method according to the type of travel

a) According to the feasibility in the current conditions of Tehran city, if you decide to make the daily trips specified below, number your chosen vehicles according to the type of trip from the first priority to the six priority.

		walking	Personal car	Bicycle sharing	Taxi	Bus	Subway
1	Business trip						
2	pleasure trip						
3	shopping trip						
4	Study trip						

b) If the inhibiting factors and obstacles to the use of shared bicycles are minimized and suitable infrastructure such as culture building etc. is provided for the citizens of Tehran city to travel with shared bicycles in the future, according to the stated issue. Prioritize from 1 to 6.

		walking	Personal car	Bicycle sharing	Taxi	Bus	Subway
1	Business trip						
2	pleasure trip						
3	shopping trip						
4	Study trip						

If the number 1 is the least likely and the number 5 is the most likely for you to use shared bicycles, mark the probability of use according to the stated situations.

	The examined modes	1	2	3	4	5
1	It is common to use shared bicycles in the city.					
2	In case of construction of safe cycling routes in the city.					
3	Get to your destination sooner by using this bike.					
4	Parking for motor vehicles is difficult to find.					
5	If you need daily exercise.					
6	Citizens should respect each other's rights and respect the right of priority.					
7	Your destination is inside the traffic plan.					
8	If the fuel price of motor vehicles increases.					
9	Increase in public transport fares.					
10	Increasing the number of stations and frequency of shared bicycles in the city.					

Fourth part: Prioritizing questions of vehicles and travel methods in relation to the distance

select following distances, which means of travel or vehicles do you use for daily trips. Specify by marking. (You are allowed to choose up to 3 options).

	Distance (km)	walking	Personal car	Bicycle sharing	Taxi	Bus	Subway
1	Less than 2 km						
2	2 km to 5 km						
3	5 km to 8 km						
4	8 km to 11 km						
5	11 km to 14 km						
6	14 km to 17 km						
7	17 km to 20 km						
8	More than 20 km						

Fifth part: Questions related to possible travel demand

If the factors preventing the use of shared bicycles are minimized and suitable infrastructure is provided for the citizens of Tehran to travel with shared bicycles, and you are able to use these bicycles on the street level, according to these comments Apply yourself by putting a mark in the table below.

	objects	I will never use	I will rarely use it.	I will use sometimes	I will use it often	I will always use
1	To go to the gym					
2	To go to the park					
3	to go to work					
4	To go to the pharmacy					
5	To go to the library					
6	To go to the local supermarket					
7	To go to the barbershop					
8	to go to school					
9	to return home					
10	To refer to the offices					
11	To visit shopping centers					
12	To refer to public transport stations					
13	To take a short route					
14	To travel long distances					
15	Using a bicycle for exercise					

sixth part: supplementary questions

Express your opinions according to the following items.

	objects	I quite agree	I agree	No idea	I disagree	I completely disagree
1	I am interested in cycling.					
2	Using a bicycle is not attractive to me.					
3	Using a bicycle reduces the cost of street maintenance.					
4	Using shared bicycles in public transportation reduces fuel consumption.					
5	Cycling is relaxing.					
6	I like cycling with friends and colleagues.					
7	Cycling boosts morale.					
8	Cycling brings health due to increased mobility.					
9	It is difficult to ride a bike in normal clothes.					
10	I have no problem with cycling on busy streets.					
11	Weather conditions affect the amount of use of bicycles.					
12	Due to the long distance between the origin and the destination, I cannot use shared bicycles in daily trips.					
13	Advertising can play a significant role in creating the culture of using shared bicycles in public transportation.					
14	Cycling increases intelligence and creativity.					
15	Lack of sufficient safety is the most important reason for not using bicycles on the streets.					
16	By using shared bikes in the public transportation industry, I feel like I am serving my city.					
17	Using shared bicycles can solve the traffic challenges of Tehran to some extent.					
18	I feel good that I can serve the environment by using shared bikes.					
19	Shared bikes are only suitable for short distances.					
20	Using a bicycle as a mode of transportation lowers a person's social status.					
21	I don't have a problem with cycling on steep roads.					
22	Using a bicycle causes sweating, and this sweating creates an unpleasant feeling for going to work, school, etc.					
23	With the increase in the number of users of shared bicycles in the city, I am encouraged to use this type of bicycles.					
24	I am interested in using a bicycle, but due to the fact that this is not widespread, I do not use a bicycle in the city as public transportation.					
25	Being embarrassed by the public's view of riding a bicycle is an obstacle that prevents me from using this vehicle for daily transportation.					
26	I have complete information about the traffic regulations for cycling.					
27	Cultivating the use of shared bicycles in public transportation increases the daily use of this non-motorized vehicle in the city.					
28	I will not use a bicycle in crowded streets due to non-observance of the right of way of vehicles.					
29	Using shared bikes for daily trips can reduce the monthly cost of public transportation fares and private vehicles.					
30	The use of shared bicycles is required in densely populated neighborhoods.					

Seventh part: Questions related to possible demand

Consider the method of going to work, school, university, etc. for one day. Show the method of this one-day trip, respectively, by marking.

		1	2	3	4	5	6
1	walking						
2	Taxi						
3	Subway						
4	Bus						
5	Shared bike						
6	personal vehicle						

		1	2	3	4	5	6
1	walking						
2	Taxi						
3	Subway						
4	Bus						
5	Shared bike						
6	personal vehicle						

finish