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Research Article

Investigation of Bus Special Lane Performance Using Statistical Analysis and Optimization of the Signalized Intersection Delay by Machine Learning Methods

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Nowadays, the performance analysis and evaluation of public transportation systems have great importance in traffic engineering science. So far, the bus system has not been very effective in some cities in Iran, and many management approaches such as the allocation of special lanes and regular bus scheduling, which are needed to increase the efficiency of this system, have not been sufficiently considered. The purpose of the present study is to optimize the delay of the signalized intersection of bus lane and investigate the factors affecting the urban bus usage by citizens in public transportation of Rasht city and especially their satisfaction. Therefore, the intersection delay was optimized by gathering the traffic volume data in peak hour time of a signalized intersection along the bus lane and using machine learning methods. In addition, by collecting two different questionnaires, taking 84 samples (first questionnaire) and 374 samples (second questionnaire), the satisfaction of citizens and business people on the boundary of the bus lane was considered. The results indicated that about 95% of the businesses around this route believe that the construction of the bus lane led to a decrease in the income of more than 110 dollars per month. Further to this, despite the lack of facilities, poorly designed routes, and lack of the bus system fleet, the bus lane of Imam Khomeini had a high degree of satisfaction among the citizens. The result of various models showed that the adaptive network-based fuzzy inference system (ANFIS) had the highest R^2 and the lowest amount of root mean square error (RMSE). In fact, this model had a better performance to predict and optimize the delay of signalized intersection than the fuzzy model. The optimum amount of intersection delay was determined as 56 seconds. With this value, the delay of bus movements in the bus lane had a higher possibility of being reduced.

1. Introduction

Today, with the rapid expansion of urbanization, cities as the accumulation place of vital facilities are recognized as the main centers of population attraction. The continuation of this process will result in an ever-increasing population density. On the other hand, one of the significant problems that the big cities and authorities face is traffic. The discussion of intraurban transportation systems has long been beyond the technical and engineering limits. It has become a social and economic issue that could have various impacts on a community [1–3]. Long traffic lines, parking shortages, crowded congestion, traffic restrictions in the downtown, mental impacts, air pollution, and so forth are among the factors that have encouraged transportation managers and planners to develop mass public transportation systems. That is why the necessity of using the public transportation system has been taken into consideration more than ever [4, 5].

The public transportation system, the most important of which is the bus and subway, plays an essential role in the passengers' daily commuting in the cities and includes many benefits that directly and indirectly affect the quality of everyday lives of people [6]. However, the bus system has not been well functioning in many provinces of developing countries, such as Iran. Many management approaches, such as the allocation of bus special lanes and regular bus scheduling, which are necessary for increasing the efficiency of this system, have not been sufficiently considered. However, in the case of the proper use of the bus system's potential capacity, half of the total demand for intraurban transportation can be covered, which yields less use of personal cars.

The most critical problem that Rasht city, one of the metropolises of Iran, is facing today is the high number of official taxis with respect to population density. On the other hand, with such a volume of official taxis, private cars also pick up passengers. Many of the stations and passenger passing axes lack official taxis and urban buses. Despite this, the bus fleet is not responsive to the passage of passengers in different parts of the city due to the low number of its active devices and lack of proper arrangement of the bus lanes and facilities. In addition, neither arrangement nor investigation has been conducted to implement the bus stations and design bus special lanes in different directions of the city so that buses stop by the presence of passengers on some routes. The only bus special lane in Rasht city is the bus lane of Imam Khomeini Street, which does not have excellent performance due to several reasons such as the route inconsistency, distance from the city center, and low bus number fleets and presence of taxis on the bus-only route. All of these factors have caused irregularities in the public transportation system and citizenship of Rasht city, so that, everywhere in Rasht and at any origin and destination of the passenger traveling routes, one can observe personal cars instead of public taxis and bus facilities.

Further to the abovementioned issues, the topics of this research are highly influenced by the policies and economic conditions of society and time, including the following cases [7, 8]:

(i) Rising fuel price (encourages citizens to use the public transportation system),

(ii) Rising car price (encourages citizens to use the public transportation system),

(iii) Increasing immigration from other cities, especially from those with unfavourable weather and cities with water resource shortage towards Guilan province being accompanied by the increasing use of public transportation,

(iv) The growing traffic flow and necessity of paying attention to public transportation.

A review of studies conducted on the bus lanes and public transportation indicates that numerous methods have been presented to analyze and rate these systems. In recent years, due to the diversity of the results and nature of the quality issue of transportation systems as a large-scale problem, the importance of the factors affecting the satisfaction issue has been addressed by researchers. Several factors affect the travel time and number of stations of the public transportation systems, each or a combination of which can be considered as the most desirable topic in this field. O'Sullivan and Morrall presented a model for the traveled distance of passengers by investigating the data collected from 1800 users of the urban train system in Calgary, Canada. By suggesting a relationship between the passengers' distance and their walking time, they concluded that people prefer to travel farther distances (about twice) with the urban train rather than the bus [9]. As passengers tend to reach their destination with the minimum spent time outside the vehicle and transportation agencies tend to reduce their operating costs as much as possible, Saka attempted to balance the demand of bus system users and transportation organizations by the presentation of a mathematical model. By implementing the sensitivity analysis in the presented model, he indicated that the proper location between the stations could simultaneously reduce the time interval between buses and travel time, taking into account the limited capacity of the fleet [10]. Yu et al. attempted to optimize the number of buses on the studied route by presenting a bilevel programming model. This model determined the optimal number of buses intending to minimize the total travel time of passengers, taking into account the overall capacity limitation of the fleet and passengers' route choice behavior [11]. Using the multicriteria decision-making method of the analytic hierarchy process (AHP), Assarzadegan et al. calculated the weight of qualitative indices obtained from the transportation and urban traffic experts. They optimized the bus rapid transit station locations by utilizing the spatial information system and TOPSIS technique. Their goal in this research was to reduce public transportation costs, increase the satisfaction of citizens, and consequently reduce the use of private cars [12]. Asgari in a study proposed the equivalent money cost model for all components of a bus lane system and minimized the sum of them as the final costs. By designing a hypothetical problem, the efficiency of the model was shown in terms of the optimal location of the stations using the proposed method to reduce the final cost, and then the sensitivity analysis was performed for the final cost concerning various parameters such as the cost equivalent to the passengers' time and fuel consumption [13].

Despite the considerable attention paid to the location problem of the public transportation system's stations to determine their optimal number, fewer efforts have been made to solve this problem considering the dynamic nature of the factors influencing the travel time. The researchers recently implemented the metaheuristic methods as novel approaches for solving the problems, as mentioned earlier. These methods have high reliability due to their high accuracy. Combining these methods with the spatial information system can significantly increase the accuracy of proposed models, given that the spatial features are an integral part of the public transportation systems' location. Furth and Rahbee conducted a study to find the stations' optimal location by the use of a simple geographic model for indicating the population distribution in the stations along with a dynamic programming algorithm. Having modeled a street in the city of Boston, USA, they finally concluded that if the optimal distance between the stations in the urban high-traffic areas is closer to the European standards, the model will provide better responses, and this distance should be changed from 200 m to 400 m [14]. Murray investigated access to public transportation and its efficiency in Brisbane, Australia, using spatial analysis techniques. He concluded that the proper strategic analysis using the spatial information system could improve the usage amount of public transportation systems of people [15]. Using the data envelopment analysis and spatial information system, Liu and Lao investigated the functional performance of the bus system and spatial coverage. They first modeled the corridor in the geographic information system (GIS) software and then calculated each of the performance index and spatial coverage of bus lanes using the data envelopment analysis. This method allows researchers to carefully compare the functional and spatial aspects of bus lanes [16]. Combining one of the metaheuristic methods and the geographical information system, Delmelle et al. attempted to simultaneously increase the efficiency and availability of stations, taking into account the reasonable time required to reach them. They tried to find the optimal station location by integrating the space interactive cover (SIC) model and GIS considering the influence of the walking distance between the residence and station and also the location attraction of the public transportation system's station (traffic convenience, destination number of the service provider). Due to the model's nonlinearity, the simulated annealing algorithm was implemented for solving the optimization problem. In their presented model, an interface model was used based on the GIS on which the candidate locations and demand nodes were identified as the applied points for managing the model parameters. This feature enables the decision-making organizations to decide on the removal of the additional consecutive stations or maintenance of the important ones in the network [17]. Hongqin and Yu presented a biobjective model considering the maximum profit of an organization where lower overall cost is imposed on the passengers in the intraurban train system while providing them with top service. Given the dynamic distribution of passengers, they presented a model, which is capable of solving the biobjective programming model by the use of the genetic algorithm. Finally, the utility of the proposed algorithm for the model was indicated by providing a numerical example [18].

Due to the heterogeneous distribution of the passengers at different times, which leads to massive congestion of passengers in parts of the route and stations and reduces the overall service level and benefits of the bus system as a consequence, Haijian et al. proposed a model, which is capable of considering both factors of the dynamic distribution and average environmental passenger allocation ratio of the passengers along the route. Under the strategy of optimizing various goals at different routes and times, the bus station was selected as a critical factor for coordinating the various factors, followed by presenting the interruption model of the average motion with the aim of maximizing the profit margin for the bus fleet. This model can balance the service level at bus stations and improve the profitability of bus service [19]. Otto and Boysen optimized the location of stations to maximize their coverage for the passengers' access using three algorithms: genetic algorithm, simulated annealing, and dynamic programming. Using the available network data, they presented a bilevel dynamic program based upon the heuristic methods proportional to the maximum covering location problem in networks (MCLPN). The results indicated that their heuristic methods yield optimal solutions for 87% of the problems [20]. Barrena et al. conducted a study on the design and optimization of the urban train schedule according to the dynamic demand. They aimed to minimize the waiting time for the passengers at the station, taking into account their satisfaction. For this purpose, they implemented two programmed mathematical formulas capable of converting the nonintermittent nature of the train scheduling issue to the dynamic one. Then, they used an adaptive large neighborhood search metaheuristic algorithm for solving the train scheduling problem. The superiority of this algorithm over the branch-and-cut one was illustrated by solving a large number of hypothetical and real problems. Using the adaptive large neighborhood search metaheuristic algorithm, the travel and algorithm calculation times were reduced by about 26% and 1%, respectively [21]. Tirachini investigated the problem of finding the proper number of bus stops on urban routes in Sydney. In the first step, he estimated the number of stations on the low-demand passenger routes. In the second step, he investigated the issue considering the bus station size interactions, bus speed, distance between the stations, and existing congestion on the roots with high passengers' demand. He indicated that the Poisson models used in locating the bus stations cause the overestimation of their number and inappropriate determination of the optimal number of bus stations. Finally, by presenting the Poisson model, he arrived at the fact that, by fixing the bus speed, the distance between the stations should be reduced in the case of increasing demand. However, if both the bus and the speed of passengers get on the increase, the distance between the bus stations should be taken significant enough even when there is a high demand for passengers. These results are also valid for a rapid bus system where bus speed and distance between stations are high [22]. Varesi et al. conducted the locating problem of the bus stations in Khorramabad city in Iran using the analytic network process (ANP) and fuzzy logic. The ANP model was used to weigh the studied indices, and fuzzy logic was applied to overlap and analyze the data. The research results indicated that the available bus stations of Khorramabad city are not located in more appropriate places than the standard distances between some of the existing stations of the city and need to be organized. Stations in the south and northwest parts of the city are far from the available standards of station distances (600–300 m) and require an optimal location. There are also four stations in the south of

Khorramabad city, which is an inappropriate area, indicating the undesired location of stations in this city [23].

Therefore, by optimizing the delay of a signalized intersection along the bus lane and studying the amounts of use and welcome of citizens from the existing public transportation system, especially the bus lanes, one can provide traffic suggestions and solutions for the better organization of the bus system in order to increase the welfare, urban order, and security of the citizens.

2. Methodology

In this section, firstly, the studied location and route specifications are introduced along with the cross-sectional map and existing status images. Then, the questionnaires used in this research and analysis methods are described.

2.1. Location and Route of the Study. The present study was carried out in Rasht city, one of Iran's metropolises and the center of Guilan province. Among the 34 active buses, 30 are used for the transportation of passengers in the city, and the other four are implemented as alternatives in the case of problem occurrence for each bus. Bus refueling is carried out inside the bus organization, and buses refuel once a day later than 8 pm, and, before this time, refueling is accomplished by different vehicles, which are an income source for the bus service.

Table 1 lists the available buses of the bus fleet of Rasht city with respect to their fabrication year and their quantities. Since each bus is part of the fixed assets of the bus system and the annual depreciation is usually considered for this kind of asset, the useful bus life will be from 5 to 7 years assuming 15–21% annual depreciation for it. For the urban buses of the country, assuming an annual depreciation of 15%, the average life of 7 years is introduced as the desirable index [24]. According to the global benchmark, the average life of the buses is reported as 7.5 years [25]. Increasing the average life of buses increases their maintenance costs and also causes noise and environmental pollutions. Moreover, 50% of the fleet meets an ideal and desirable quality despite the low fleet number.

The bus lane of Imam Khomeini, between Bank Melli and Mosalla Square, was activated with three bus units in March 2016, with a length of 2 km, and it was used for the passengers traveling for about two years. Eventually, it was dismantled under the pressure of the authorities in March 2018. Unfortunately, only 1 km of this route between Farhang and Mosalla Squares is currently available, which is also being used by riding vehicles. This route acts radially within the network structure, facilitating traveling by public transportation lines (bus special lanes) from the center to the south of Rasht city. This path starts from Heshmat Square and reaches the intersection of Shahid Bahonar Street with Imam Khomeini route through passing from Farhang and Mosalla Squares along with that. From the important leading intersections of this route, one can point out to Mikaeil intersection. The studied path area is shown in Figure 1.

Table 1: Available buses of the bus organization of Rasht city with respect to their fabrication year and quality index of the year 2018.

Quality index	Fabrication year	Available quantities
Old and outdated	Before 2006	3
Inefficient and semiactive	2006–2011	10
Desirable active	2011–2014	6
Ideal active	2015–2018	15

2.2. Preparation of Questionnaires. Two types of questionnaires were prepared and distributed. The first questionnaire was prepared for tradespeople located on Imam Khomeini Street along the bus lane and other Rasht city streets. The second one was implemented for passengers using the bus lane. Each questionnaire is designed in two parts. The first part consists of 10 questions, from which the first six are related to the personal profiles of interviewees. The other four questions of the first part are related to the leading indices of the questionnaire. The second part of the questionnaire is dedicated to the subindices considered for each indicator, which includes 30 questions. These questionnaires have been completed via face-to-face interviews with the passengers of the bus special lane. After completing the survey, all the collected forms were reviewed.

2.2.1. First Questionnaire. The first questionnaire was prepared for tradespeople located on Imam Khomeini Street along the bus lane and other Rasht city streets. The questionnaire was designed and adjusted to determine the satisfaction of tradespeople with the performance of the bus lane and with the help of the opinions of experts. The statistical population included 45 shopkeepers working next to the bus lane and 39 ones from other streets. The questionnaire was completed in the form of in-person interviews with shopkeepers.

2.2.2. Second Questionnaire. A questionnaire was designed and prepared to determine the satisfaction of passengers with the performance of the bus lane. This questionnaire was prepared based on the sample questionnaire used by several researchers who have investigated similar subjects and by utilizing the opinions of specialists. The statistical population was considered to be the passengers using these buses. According to the surveys performed from the passengers of the bus special lane, it was found that the number of daily passengers on these buses is 17053. In this way, 376 questionnaires were prepared and distributed among the passengers.

2.3. Data Analysis Tools. After collecting data, the number of 460 questionnaires was analyzed by statistical tests. The statistical tests used in this research include the Kolmogorov-Smirnov (K-S) test and the t-test. These methods are introduced and described in the following. In addition, to optimize the delay of the signalized intersection, machine learning methods were used, which are described below.

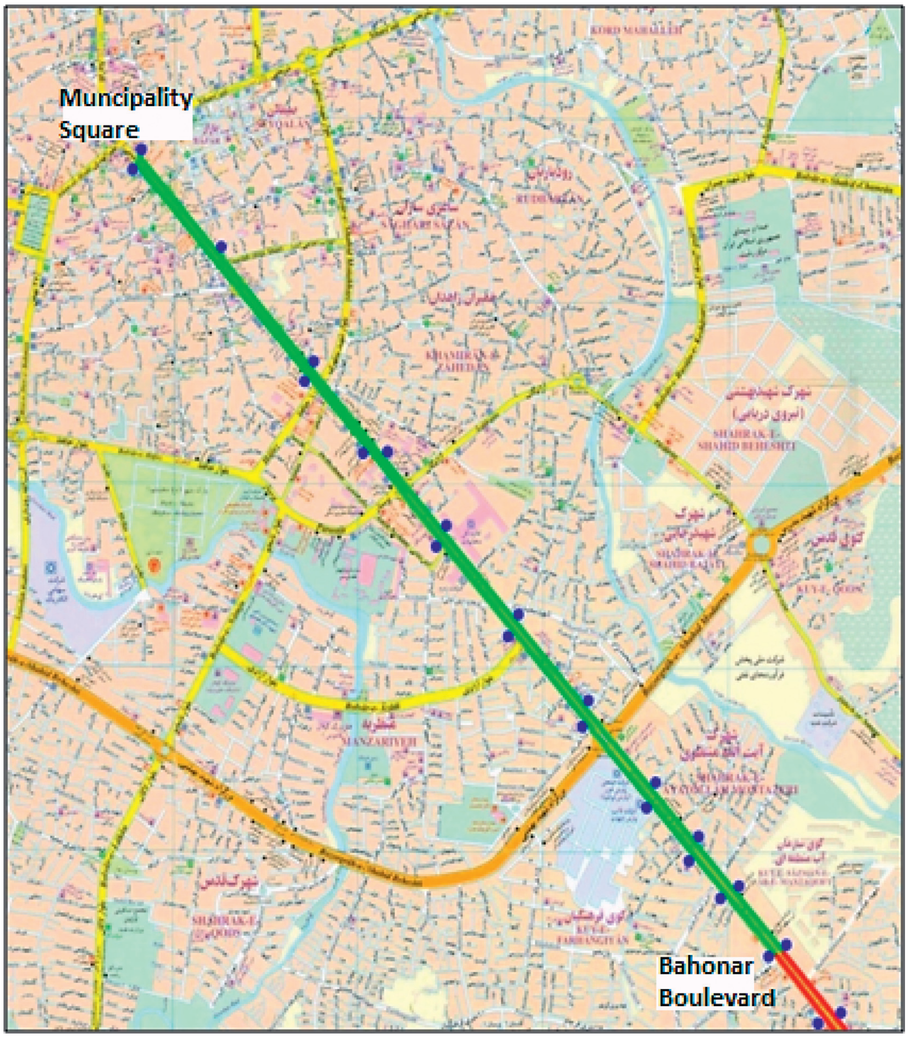

Figure 1: The route plan of Municipality Square-Bahonar Boulevard in the map of Rasht city.

2.3.1. Statistical Analysis Methods

(1) The K-S Test. One of the main assumptions for most of the statistical tests is the normality of the distribution of the observations. The K-S test is implemented for this purpose. This test is a nonparametric one for examining the distribution of observations. The approximate amount of the asymptotic significance of the test can be observed in the output after the test completion; comparing which with α, one is able to perform the test at the significance level of α and decide about the normality of the distribution of the observations. If α is considered to be 0.05 (confidence level of 95%), when p value >0.05, one can assume that the observed distribution is normal. In fact, this test is a distribution matching test for quantitative data. The normality distribution test is one of the most common ones for the samples in which the researcher doubts their normality. The K-S test is an appropriate test for this purpose. This test for the distribution matching compares the cumulative probabilities of the values in the dataset with those of the same values in a particular theoretical distribution. If the difference is great enough, the test will show that the data is not consistent with one of the corresponding theoretical distributions. In this test, if the p value decision criterion is less than 5%, the null hypothesis is rejected [26]. In other words, data cannot be of a certain distribution such as normal, Poisson, exponential, or uniform. The assumptions of this test are given below:

(i) H_0: Data comply with normal distribution.

(ii) H_1: Data do not comply with the normal distribution.

(2) The Independent Sample t-Test. The t-test is a distribution or, in fact, a family of distributions that can be used for examining the assumptions about the sample under the conditions of unknown population distribution. This test's importance is to enable the researcher to acquire information about the community with small samples. This test consists of a family of distributions. It thus assumes that each sample has its distribution, the shape of which is determined by the calculation of degrees of freedom.

On the other hand, the t distribution is a function of the degrees of freedom, and, with more increase, it becomes closer to the natural distribution, and, with more decrease, the dispersion becomes higher. The degrees of freedom themselves are also a function of the size of the selective sample. The more samples, the better. The t-test can be used for the mean analysis in the single-group, bigroup single-variable, and multivariate bigroup studies. This test compares the means and standard deviations of the two samples to determine if there is a significant difference between them. For this aim, the t value should be calculated using equation (1). Then, the estimated t value must be compared with the distribution table of t. For this purpose, the degree of freedom is required, which can be obtained using equation (2) [27].

$$t = \frac{(\overline{x}_1 - \overline{x}_2)}{\sqrt{\left((S_1)^2/n_1\right) + \left((S_2)^2/n_2\right)}}, \tag{1}$$

$$\mathrm{df} = (n_1 + n_2) - 2, \tag{2}$$

in which $\overline{x}_1$ and $\overline{x}_2$, as well as S_1 and S_2, define the means and standard deviations associated with samples 1 and 2, respectively. Also, n_1 and n_2 stand for the quantities in samples 1 and 2, respectively, and df is the degree of freedom.

According to the t value and considering the probability of the first type error ($\alpha = 0.05$) and calculated degree of freedom, the result is interpreted. If the estimated t value is smaller than that of the table, the null hypothesis is accepted; otherwise, it is rejected. The assumptions of the above test are as follows:

$$\begin{cases} H_0: & m_1 = m_2 \\ H_1: & m_1 \neq m_2 \end{cases}. \tag{3}$$

(i) H_0: The variances of the two groups are equal.

(ii) H_1: The variances of the two groups are not equal.

2.3.2. Machine Learning Methods

(1) Fuzzy Logic. Fuzzy logic replaces one of the various inferential methods of humans with simpler machine algorithms. The concept of fuzzy logic was first introduced in the world as a control methodology in the field of artificial intelligence and provided a way to process data based on membership allowing a small group rather than a batch group [28]. Fuzzy logic is a solution by which complex systems that are impossible or very difficult to model using mathematics and classical modeling methods can be modeled with less effort and more flexibility [29]. Being fuzzy means being multivalued instead of the binary logic in which there can be only two answers or states for each question or concept [30].

The foundation of fuzzy logic is based on the theory of fuzzy sets. This theory is a generalization of the classical theory of sets in mathematics. In classical set theory, an element or member is either a member of a set or not. In other words, the membership of the elements follows the 0 and 1 pattern or a binary pattern. However, fuzzy set theory extends this concept and introduces graded membership. In this way, an element can be a member of a set, to some extent, rather than wholly. In this theory, the membership of members of a set is defined by the function $U(x)$, where x represents a definite member, and $U(x)$ is a function that determines the degree of membership of x in the corresponding set; also, its value is between 0 and 1. In fuzzy logic, precise arguments are considered as boundary cases of approximate arguments [31].

(2) Adaptive-Network-Based Fuzzy Inference System (ANFIS). The type of relationship between fuzzy logic and the neural network has given rise to different system types. In other words, neurofuzzy is a combination of neural network and fuzzy inference system in which the neural network is used as a determinant of fuzzy system parameters. The meaning of determining the parameters of the fuzzy system by the neural network is automatically determining the fuzzy parameters such as fuzzy rules or membership functions of fuzzy sets [32–34].

In contrast to neurofuzzy, there is a fuzzy neural network in which fuzzy logic is used to improve neural network function. In this network, fuzzy logic is a subsidiary element and is used only to improve the neural network conditions or add uncertainty to the network. The ANFIS was developed by Young in 1993. This model allows fuzzy systems to use the adaptive error back-propagation learning algorithm in parameter training topics. An ANFIS structure consisting of fuzzy Then-If rules can be used to model and map input-output data [35]. The equivalent structure of ANFIS is as shown in Figure 2.

According to Figure 2, in the first layer, the inputs pass through the membership functions according to equations (4) and (5). Membership functions of each function which are selected Gaussian functions in most cases can be a suitable parameter like the general bell-shaped function, which is defined based on a set of basic parameters in equation (6).

$$Q_{1\cdot i} = \mu A_i(x) \quad \text{for}\, i = 1.2, \tag{4}$$

$$Q_{1\cdot i} = \mu B_i(x) \quad \text{for}\, i = 3.4, \tag{5}$$

$$\mu A(x) = \frac{1}{1 + \left|(x - c_i/a_i)\right|^{2b_i}}. \tag{6}$$

Each node in the second layer is a fixed node called P, the output of which is the product of all the input signals according to equation (7). Also, the third and fourth layers are fixed nodes called N and are calculated with equations (8) and (9), respectively. The i nth node calculates the ith arousal intensity rule ratio for all arousal intensity rules as follows. The output is the previous normalized layer.

$$Q_{2\cdot i} = W_i = \mu A_i(x)\mu B_i(x) \quad i = 1.2, \tag{7}$$

$$Q_{3\cdot i} = \overline{w_i} = \frac{w_i}{w_1 + w_2} \quad i = 1.2, \tag{8}$$

$$Q_{4\cdot i} = \overline{w_i} f_i = \overline{w_i}(p_i x + q_i y + r). \tag{9}$$

The only node of the fifth layer is a fixed node called $\sum$, which calculates all the outputs as the sum of all the input signals by using equation (10). The output of this layer is the total output of the system:

$$Q_{5\cdot i} = \sum \overline{w_i} f_i = \frac{\sum w_i f_i}{\sum w_i}. \tag{10}$$

(3) Criteria for Evaluating Output Models. The purpose of model evaluation is to ensure the model's ability to generalize in the range of training data. In this study, to evaluate the network performance, the criteria of squared correlation coefficient (R^2), root mean square error (RMSE), and coefficient of variation (COV) and the following relationships were used in this research. The R^2 coefficient was used to measure the correlation between the predicted values obtained from the network and the actual values, the RMSE coefficient was applied to measure the model error, and the COV coefficient was utilized to evaluate the data scatter for their mean. In the following relationships, the parameters Y^{mea}, Y^{pre}, and $\overline{Y}$ are observed, predicted, and average observed values, respectively [36].

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} \left(Y^{\text{pre}} - Y^{\text{mea}}\right)^2}{n}}, \tag{11}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n} \left(Y^{\text{mea}} - Y^{\text{pre}}\right)^2}{\sum_{i=1}^{n} \left(Y^{\text{mea}} - \overline{Y}\right)^2}, \tag{12}$$

$$\text{COV} = \frac{\text{RMSE}}{\left|\overline{Y^{\text{mea}}}\right|} \times 100. \tag{13}$$

2.4. Study Standards. The best bus rapid transit (BRT) system is a system with a combination of efficiency, durability, and passengers' convenience. Therefore, to compare the Rasht BRT performance, Institute for Transportation and Development Policy (ITDP) 2012 [37] and ITDP 2016 [38] standards were used.

3. Results and Discussion

Before starting the current study, it was generally thought that the bus lane of Imam Khomeini was ineffective, and tradesmen and citizens each had some positive and negative opinions about this facility; therefore, since the users of Imam Khomeini bus lane were divided into two groups of the facility users and the marginal functions, two types of the questionnaire were created to study the amount of their reception of the bus lane of the Imam Khomeini street in the city of Rasht [39], each of which is described below.

3.1. Results of the First Questionnaire. This section contains general information about the interviewees and the results obtained from the first questionnaire. In order to better assess the satisfaction of tradesmen with the bus special lane performance, it was tried to interview all types of age groups and occupational classes. The number of distributed questionnaires was 84 samples (45 samples for the bus lane tradesmen and 39 samples for tradespeople of other streets), which were randomly selected from the bus lane tradesmen. According to Figure 3,

(i) 2% of interviewees were between 10 and 20 years, 10% between 20 and 30 years, 24% between 30 and 40 years, 26% between 40 and 50 years, and 38% were above 50 years,

(ii) 10% of interviewees were female, and 90% of them were male,

(iii) the last educational level of interviewees was 26% under the diploma, 32% diploma, 13% associate degree, 22% bachelor, and 8% masters and Ph.D.

The results of questions 6 to 9 of the interviewees are illustrated in Figures 4–7. By comparing the results of the questionnaires, it is found that the opinions of the tradesmen near to the bus lane and other streets of Rasht are very close, which indicates that economic recession and decline in the purchasing power of people during 2016 and 2017 are one of the reasons for the decline in the incomes of Imam Khomeini tradesmen and the construction of the bus lane is not the only reason.

In question 10, the interviewees were asked "How much do you score the performance of the bus lane (from Heshmat Square to Mosalla Square) in Rasht city?"; the results obtained are shown in Figure 8, where, unlike Figure 7, tradesman interviewees from other streets gave higher scores to the bus lane in Rasht. In general, the answers were scattered and varied.

3.2. Results of the Second Questionnaire. This section provides general information about the interviewees and the results of the second questionnaire. In order to better assess the satisfaction of passengers with the bus lane performance, all types of age groups and occupational classes were interviewed. These people were randomly selected from passengers of bus special lane. The results of the first six questions in the first part are presented in Figure 9.

3.3. Analysis of the Questionnaire Results. According to surveys, four indexes were designed as the main indexes of the questionnaire, which include the following:

(i) Public transport level of service

(ii) Public transport travel time

(iii) Public transport service quality

(iv) Public transport safety and security

In the eighth question of the first part of the questionnaire, the bus lane performance was asked, the results of which were obtained according to Figure 10.

According to the opinions of interviewees, most of the interviewees are relatively satisfied with the current

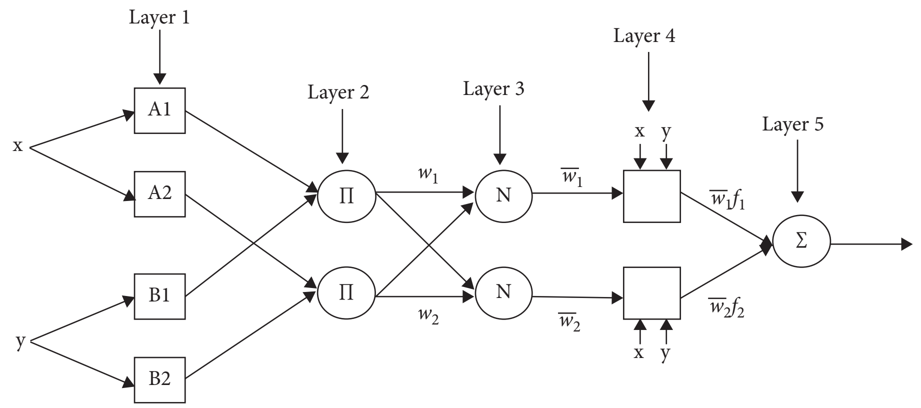

Figure 2: Structure of an ANFIS model.

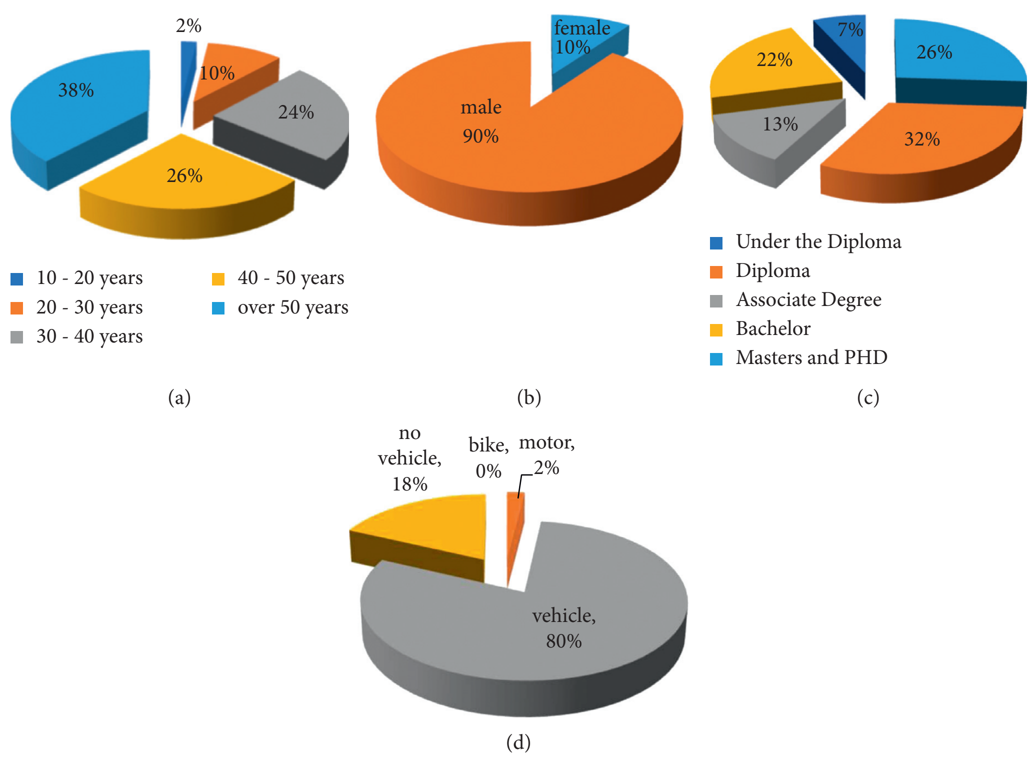

Figure 3: Percentage frequency of interviewees' profiles in the first questionnaire. (a) Percentage frequency by age. (b) Percentage frequency by gender. (c) Percentage frequency by education level. (d) Percentage frequency by in-possession vehicle.

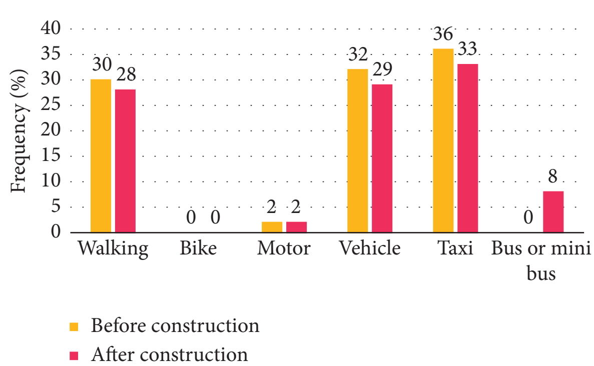

Figure 4: Percentage frequency of interviewees by travel type (the first questionnaire).

performance of the bus lane. In question 9 of the first part of the questionnaire, the reason for the use of public transport of passengers was asked, and the priority order of their opinions is shown in Figure 11. In question 10, the problems of the use of public transportation were asked, and the priority order of their opinions is represented in Figure 12.

According to studies conducted for each of the considered indexes, several subindexes were designed. These subindexes were defined as 30 items in the second part of the questionnaire, and interviewees were surveyed about these items. The analysis of questionnaires has been brought in advance. Subindexes of each of the indexes are presented in Tables 2–5.

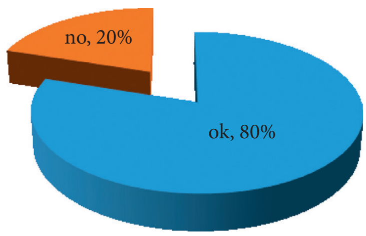

FIGURE 5: Percentage frequency of incomes after the bus lane construction (the first questionnaire).

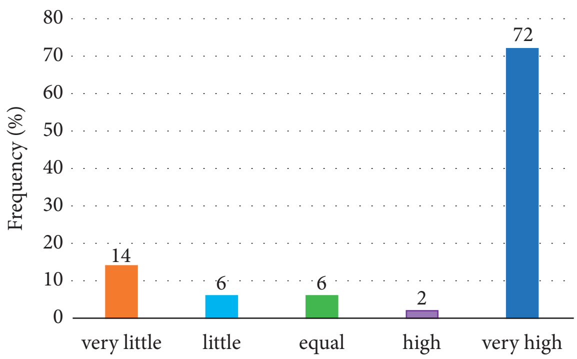

FIGURE 6: Percentage frequency of change in customer access after the bus lane construction.

FIGURE 7: Percentage frequency of change in income after the bus lane construction.

Before the t-test, the normality of the data distribution should be investigated. If the data have a normal distribution, parametric tests are used; otherwise, nonparametric tests are applied. Using the Kolmogorov-Smirnov test, the normality of the data distribution is confirmed, so a single-sample t-test is used to check the question. The result of the Kolmogorov-Smirnov test is presented in Table 6. In this test, the null hypothesis means that the distribution of data is normal, and the opposite assumption indicates that the distribution is not normal.

According to Table 6, since each of the significance levels of research variables is more than 0.05, the null hypothesis is confirmed. As a result, the data have a normal distribution. After determining the normality of the data, the single-sample t parameter is used to estimate the subindex in the amount of citizens' satisfaction. This parameter is variable from the number of 1, which indicates shallow values, to the number of 5, which represents high values. Accordingly, number 3 can be counted as the midpoint. If the average of the variables' status is above 3, it indicates the effectiveness and otherwise shows the field's ineffectiveness. Therefore, citizens' satisfaction with the Imam Khomeini bus lane performance in the city of Rasht will be determined by these numerical data and the single-sample t-test.

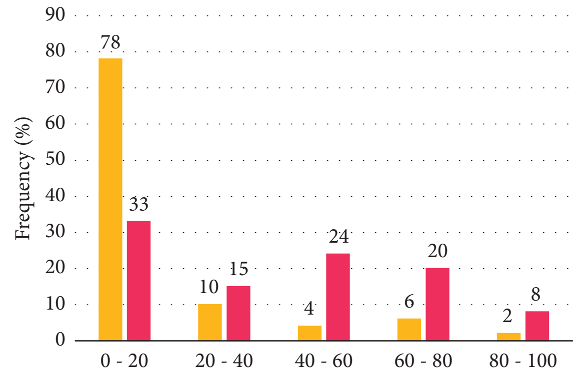

FIGURE 8: Percentage frequency of tradesmen's scores to bus lane route (the first questionnaire).

According to the results of Tables 7–12, despite lack of facilities and poor design of the route, as well as shortage of bus fleet of the Imam Khomeini bus lane system, there is high satisfaction among the citizens.

3.4. Study Standards. In the previous sections, the opinions of citizens and tradespeople were discussed. In this section, the opinions of experts about Rasht BRT performance are investigated.

The BRT Standard Committee includes a group of prominent experts working on the world's best BRT systems. This committee improves road and transportation situations by scoring BRT systems. In 2012, the committee tried to provide the dos and don'ts of transport lines, especially bus by releasing a standard. The Institute for Transportation and Development Policy (ITDP), which published a standard in 2014, is another valid reference for comparing the performance of bus lanes.

3.4.1. Evaluation of the Rasht Bus Special Lane with the 2012 Standard. According to the international standard, the BRT system certificate is graded in gold, silver, and bronze grades. Positive impacts on passengers and the quality of services are among the factors that are critical in scoring. Scores are only attributed to factors that improve overall performance and service quality or minimize the negative environmental impact of traffic. Therefore, by considering the BRT Standard Committee's requirements, the scoring

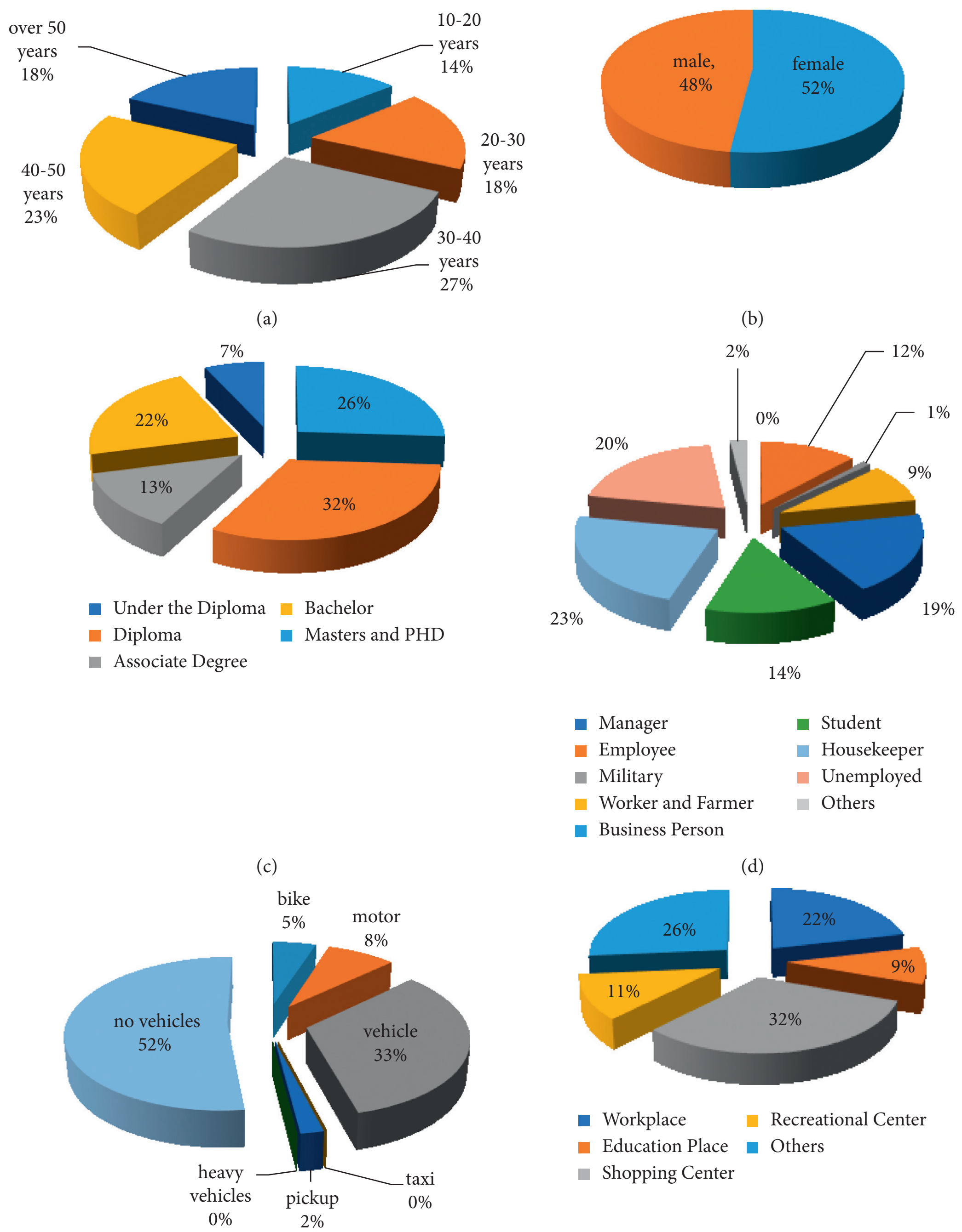

Figure 9: Percentage frequency of interviewees' profiles in the second questionnaire. (a) Percentage frequency by age. (b) Percentage frequency by gender. (c) Percentage frequency by education level. (d) Percentage frequency by occupation type. (e) Percentage frequency by vehicle type. (f) Percentage frequency by travel destination.

of various items of the Rasht bus special lane, according to Table 13, has been investigated. To grade the route, if the score is higher than 85, the grade is golden. If the score is between 70 and 84, the grade is sliver, and if the score is between 50 and 69, the grade is bronze.

According to the obtained results of Table 13, the Imam Khomeini bus lane does not achieve the bronze grade, even without considering items with adverse effects. Therefore, considering the negative items, the Imam Khomeini bus lane score is equal to 27. Some of the reasons for not receiving a good score in the various items are as follows:

(i) Lack of traffic control center

(ii) The bus lane being not connected to other bus lanes or other transport modes except taxi

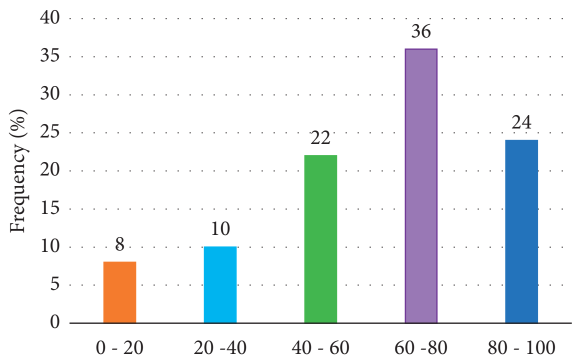

Figure 10: Percentage frequency of interviewees' scores to the bus lane performance.

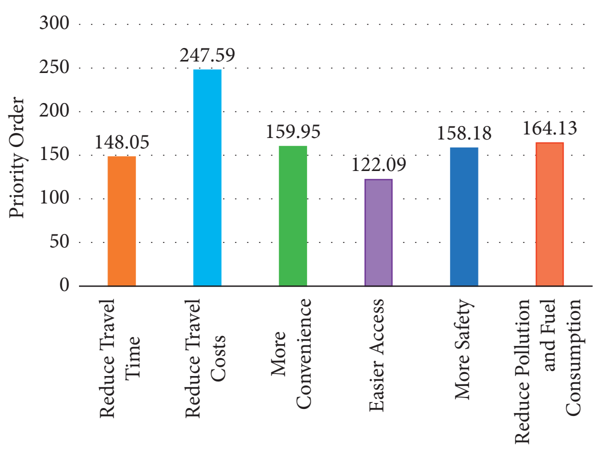

Figure 11: The priorities of passengers in the use of public transportation.

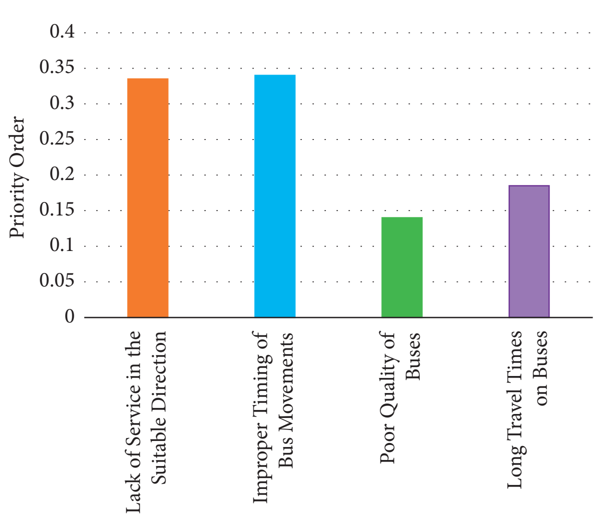

Figure 12: The priorities of passengers in problems of using public transportation.

(iii) The frequency of bus movements at peak hours and off-peak hours being more than the optimal time

(iv) being closed in the late hours of the night and on holidays

(v) In none of the intersections, the buses having the right of way and also other movements being not prohibited

(vi) Taxis and other passenger cars entering the bus lane

(vii) The station not having variable message signs (VMS) equipment and other passenger information smart systems

(viii) The speed of buses at peak hours being less than 15 km/h

(ix) Lack of reinforced concrete pavement at the stations

3.4.2. Evaluation of the Rasht Bus Special Lane with the ITDP Standard. To evaluate the BRT system, indexes are needed since the performance analysis would be performed based on them. In this study, the Rasht bus special lane evaluation is done based on the new version (2014) of the ITDP. The indexes considered in this study are based on the ITDP Institute's standard, and each of the indexes includes several subindexes presented in Table 14.

The importance of each index and subindexes listed in Table 14 has been calculated according to the ITDP standard and experts' judgments. Then, using the Expert Choice software and the AHP method, the weight of each index and subindex was determined. The obtained weights for each index are given in Figure 13. By comparing the calculated weights for the main indexes, it can be understood that the BRT basic principles, service planning, and access and integrity are in the first to the third rank among the main indexes. In Figure 14, the final weights of each of the subindexes are given.

As can be seen, subindexes such as methods of fares collection (3), the exclusive right of way (1), the existence of a special bus route (2), and the circumstance of the line connection at intersections (4) had the lowest weights and therefore the least importance. In Table 15, according to the previous discussions and observations of the BRT line, the score of each index is presented from 100.

As shown in Table 15, the score of Imam Khomeini bus lane of Rasht is 40.01 of 100, which is not a good score for a newly established system and is far from the world's bus special lane standards.

3.5. Delay Optimization of Bus Lane Route Vehicles. According to the obtained results, the delay index has been one of the negative aspects after the construction of the bus lane, which is influenced by parameters such as the number of signalized and unsignalized intersections, the distance between stations, traffic volumes of signalized intersections, stop time at stations, and travel time of the bus lane. The delay index can be obtained from the subtraction between travel time in free-flow speed conditions and travel time during the peak hour. By several visits between 5 and 7 am, the travel time was obtained as 228 seconds. Therefore, by modeling the travel time at peak traffic conditions for the studied bus lane under the influence of signalized

Table 2: Subindexes related to the public transport level of service index.

Index	Subindex
Public transport level of service	The number of public transport vehicles in the city of Rasht is sufficient. The number of public transport stations in the city of Rasht is sufficient. The distance between public transport stations is appropriate. Access to public transport stations (sidewalk to station locations) is appropriate. The service time (opening and closing hours) of public transport is appropriate. The number of passengers in public transport vehicles is high. The number of public transport service routes is appropriate. The level of service is appropriate for the holidays.

Table 3: Subindexes related to the public transport travel time index.

Index	Sub-index
Public transport travel time	The level of service is appropriate at peak traffic hours. The waiting time at public transport stations is high. The stopping time for public transport at stations is high. The travel time for public transport vehicles is higher than that for other vehicles. The travel time at peak traffic hours is reduced by special route construction for public transport.

Table 4: Subindexes related to the public transport safety and security index.

Index	Sub-index
Public transport safety and security	Public transportation is effective in reducing pollutants and protecting the environment. The number of crosswalks on the bus lane is high. The level of security inside public transport vehicles is appropriate. The method of collecting tickets for public transport vehicles is appropriate. The smartization of the public transportation system is effective in promoting their safety.

Table 5: Subindexes related to the public transport service quality index.

Index	Sub-index
Public transport service quality	The quality of public transport stations (in terms of roof, chairs, etc.) is appropriate. The ticket price for public transport is appropriate. The number of ticket offices for public transport is appropriate. The method of collecting tickets for public transport vehicles is appropriate. The number of seats in public transport vehicles is appropriate. The public transport driver's demeanor is appropriate. Heating and cooling systems of public transport vehicles are appropriate. The public transport vehicles are in a good state of cleanliness. The notification system inside public transport vehicles for announcing the next station is appropriate. The way of entering and exiting is appropriate for disabled people. The existence of free internet services inside public transport vehicles increases their usage.

Table 6: Z-value and significance level of indexes.

Variable	Number	Z-value	Significance level
Public transport level of service	376	0.084	0.085
Public transport travel time	376	0.125	0.109
Public transport service quality	376	0.079	0.093
Public transport safety and security	376	0.119	0.205

intersection traffic volumes along the route (Figure 15) and other effective parameters, the final model, according to Table 16, was obtained.

The final model of the travel time and, as a result, the delay of the studied bus lane were obtained according to Table 16. Most of the variables in the study are constant (distance between stations, number of unsignalized intersections), and it is not possible to change them. Additionally, considering that the traffic volumes were counted at the peak hour and are the maximum volumes of this route, and also if the stop time at each station is considered ideal, it is only possible to reduce the delay and increase the travel time by changing the green time. Hence, fuzzy logic algorithms and the ANFIS were used

Table 7: Single-sample t-test of subindexes.

Items	Test value = 3					
	t	Degree of freedom	Significance level	Mean difference	Lower	Upper
Public transportation is effective in reducing pollutants and protecting the environment.	20.623	375	.000	1.15691	1.0466	1.2672
The number of public transport vehicles in the city of Rasht is sufficient.	23.132	375	.000	1.19681	1.0951	1.2985
The number of public transport vehicles in the city of Rasht is sufficient.	19.057	375	.000	1.10372	.9898	1.2176
The number of public transport stations in the city of Rasht is sufficient.	24.514	375	.000	1.24468	1.1448	1.3445
The quality of public transport stations (in terms of roof, chairs, etc.) is appropriate.	28.875	375	.000	1.40691	1.3111	1.5027
The distance between public transport stations is appropriate.	14.555	375	.000	.83777	.7246	.9509
Access to public transport stations (sidewalk to station locations) is appropriate.	14.722	375	.000	.88830	.7697	1.0069
The service time (opening and closing hours) of public transport is appropriate.	26.769	375	.000	1.22606	1.1360	1.3161
The level of service is appropriate at peak traffic hours.	26.886	375	.000	1.22074	1.1315	1.3100
The waiting time at public transport stations is high.	18.653	375	.000	1.09574	.9802	1.2113
The stopping time for public transport at stations is high.	16.660	375	.000	1.00000	.8820	1.1180
The number of crosswalks on the bus lane is high.	14.677	375	.000	.87500	.7578	.9922
The ticket price for public transport is appropriate.	19.282	375	.000	1.06649	.9577	1.1752
The number of ticket offices for public transport is appropriate.	19.661	375	.000	1.05851	.9526	1.1644
The method of collecting tickets for public transport vehicles is appropriate.	17.363	375	.000	1.02128	.9056	1.1369
The number of seats in public transport vehicles is appropriate.	19.987	375	.000	1.09309	.9855	1.2006
The number of passengers in public transport vehicles is high.	13.622	375	.000	.73404	.6281	.8400
The level of security inside public transport vehicles is appropriate.	18.220	375	.000	1.00266	.8945	1.1109
The accidents rate of general transport vehicles is low.	8.297	375	.000	.48404	.3693	.5988
The public transport driver's demeanor is appropriate.	12.843	375	.000	.70745	.5991	.8158
The number of public transport service routes is appropriate.	9.349	375	.000	.51862	.4095	.6277
Heating and cooling systems of public transport vehicles are appropriate.	12.079	375	.000	.65957	.5522	.7669
The public transport vehicles are in a good state of cleanliness.	16.620	375	.000	.92287	.8137	1.0321
The notification system inside public transport vehicles for announcing the next station is appropriate.	18.670	375	.000	.98936	.8852	1.0936
The level of service is appropriate for the holidays.	24.742	375	.000	1.09574	1.0087	1.1828
The way of entering and exiting is appropriate for disabled people.	18.191	375	.000	.97340	.8682	1.0786
The travel time for public transport vehicles is higher than that for other vehicles.	24.899	375	.000	1.09309	1.0068	1.1794
The travel time at peak traffic hours is reduced by special route construction for public transport.	17.108	375	.000	.68883	.6097	.7680
The smartization of the public transportation system is effective in promoting their safety.	21.347	375	.000	.81117	.7365	.8859
The existence of free internet services inside public transport vehicles increases their usage.	19.064	375	.000	.76064	.6822	.8391

to optimize the delay. It should be noted that, in these models, traffic volumes, stop time at stations, distance between stations, green time at the signalized intersection, and number of unsignalized intersections were inputs of the model and the delay was output variable. Moreover, the number of pieces of data used for analysis was 30.

3.5.1. Fuzzy Logic Modeling Results. Figure 16 shows the model for predicting the delay at the signalized intersection based on fuzzy logic. Accordingly, the traffic parameters affecting the delays at the signalized intersection, including right-turn traffic volumes, direct movement traffic volumes at the entrances, green time, and the distance between stations, were considered in the final model. Membership functions are one of the essential pillars in the structure and network of fuzzy logic. Also, the degree of membership indicates the degree of membership of element x to the fuzzy set A. If the membership degree of an element of the set is 0, that member is entirely out of the set, and if the membership of a member is equal to 1, that member is entirely in the set. Now, if a member's membership is between 0 and 1, this number indicates the

Table 8: Descriptive statistics of the subindexes.

Items	Number	Average	Standard deviation
Public transportation is effective in reducing pollutants and protecting the environment.	376	4.1569	1.08780
The number of public transport vehicles in the city of Rasht is sufficient.	376	4.1968	1.00324
The number of public transport vehicles in the city of Rasht is sufficient.	376	4.1037	1.12304
The number of public transport stations in the city of Rasht is sufficient.	376	4.2447	.98453
The quality of public transport stations (in terms of roof, chairs, etc.) is appropriate.	376	4.4069	.94480
The distance between public transport stations is appropriate.	376	3.8378	1.11607
Access to public transport stations (sidewalk to station locations) is appropriate.	376	3.8883	1.16997
The service time (opening and closing hours) of public transport is appropriate.	376	4.2261	.88812
The level of service is appropriate at peak traffic hours.	376	4.2207	.88042
The waiting time at public transport stations is high.	376	4.0957	1.13907
The stopping time for public transport at stations is high.	376	4.0000	1.16390
The number of crosswalks on the bus lane is high.	376	3.8750	1.15600
The ticket price for public transport is appropriate.	376	4.0665	1.07249
The number of ticket offices for public transport is appropriate.	376	4.0585	1.04398
The method of collecting tickets for public transport vehicles is appropriate.	376	4.0213	1.14056
The number of seats in public transport vehicles is appropriate.	376	4.0931	1.06049
The number of passengers in public transport vehicles is high.	376	3.7340	1.04487
The level of security inside public transport vehicles is appropriate.	376	4.0027	1.06708
The accidents rate of general transport vehicles is low.	376	3.4840	1.13126
The public transport driver's demeanor is appropriate.	376	3.7074	1.06811
The number of public transport service routes is appropriate.	376	3.5186	1.07563
Heating and cooling systems of public transport vehicles are appropriate.	376	3.6596	1.05884
The public transport vehicles are in a good state of cleanliness.	376	3.9229	1.07674
The notification system inside public transport vehicles for announcing the next station is appropriate.	376	3.9894	1.02756
The level of service is appropriate for the holidays.	376	4.0957	.85876
The way of entering and exiting is appropriate for disabled people.	376	3.9734	1.03760
The travel time for public transport vehicles is higher than that for other vehicles.	376	4.0931	.85126
The travel time at peak traffic hours is reduced by special route construction for public transport.	376	3.6888	.78076
The smartization of the public transportation system is effective in promoting their safety.	376	3.8112	.73683
The existence of free internet services inside public transport vehicles increases their usage.	376	3.7606	.77366

Table 9: Single-sample t-test of indexes.

Indexes	Test value = 3					
	t	Degree of freedom	Significance level	Mean difference	Lower	Upper
Public transport level of service	33.267	375	.000	.98286	.9248	1.0410
Public transport travel time	35.481	375	.000	1.01968	.9632	1.0762
Public transport service quality	35.757	375	.000	.96905	.9158	1.0223
Public transport safety and security	29.777	375	.000	.86596	.8088	.9231

Table 10: Descriptive statistics of the subindexes.

Indexes	Number	Average	Standard deviation
Public transport level of service	376	3.9829	.57289
Public transport travel time	376	4.0197	.55727
Public transport service quality	376	3.9691	.52550
Public transport safety and security	376	3.8660	.56390

Table 11: Single-sample t-test of the bus lane performance.

	Number	Average	Standard deviation
Bus lane performance in the city of Rasht	376	4.1835	.04691

Table 12: Single-sample t-test of the bus lane performance.

	Test value = 3					
	t	Degree of freedom	Significance level	Mean difference	Lower	Upper
Bus lane performance in the city of Rasht	25.227	375	.000	1.18351	1.0913	1.2758

Table 13: Scores of different items of Imam Khomeini bus lane of Rasht.

Row	Item	Impact	Committee score	Rasht score	Description
1	Fare collection management	+	7	3	Bus drivers receive tickets
2	Number of routes that leave out the corridor	+	4	0	No route leaves out the corridor
3	Frequency of bus movements at peak hours	+	4	0	Is more than 2 minutes
4	Frequency of bus movements at off-peak hours	+	3	0	Is more than 5 minutes
5	Services inside the station	+	3	1	The only service inside the station is a shoe cleaner machine
6	Control center	+	3	0	There is no control center
7	Located on the busiest route	+	2	2	It has the highest demand
8	Service times	+	2	0	It is close at late hours and on holidays
9	Multicorridor network	+	2	0	There is no particular network along the route
10	Set the route of movement	+	7	4	Too many opening sections
11	Route separation	+	7	3	Too many opening sections and the frequent presence of taxis
12	Intersection performance	+	6	0	It does not have the right of way at any intersection
13	Location of bus lanes in stations	+	4	0	Taxis and other vehicles are present
14	Minimizing bus emissions	+	4	4	All buses have passed EURO III standards
15	The station contains several intersections	+	3	2	Mikael, Farhang
16	Central station	+	3	1	Meli Bank and Mosalla
17	The quality of the pavement	+	2	1	Without reinforced concrete at the stations
18	The floor level of the bus stop	+	6	6	All stations are level
19	Comfortable and secure stations	+	3	1	Access to stations is dangerous
20	Number of bus doors	+	3	2	Includes two doors
21	Station sliding doors	+	1	0	There are not at the stations
22	Brand names	+	3	0	There is no brand in this route
23	Passengers information	+	2	0	There is no information
24	Public access	+	3	3	All stations have wheelchair access
25	Integration with other modes of transport	+	3	1	Only taxi has been integrated
26	Pedestrian access possibility	+	3	1	In most stations, pedestrian accesses are not suitable
27	Secure bike parking spaces	+	2	0	There are no bike parking spaces
28	Bike path	+	2	1	A bike path is nearby but does not have any rental bikes
29	Integration of the bike path and the bus lane	+	1	0	There is no integration between these two routes
30	Minimum average speed below 13 km/h	–	10	5	At peak hours, it is 11.7 km/h
31	Number of passengers in each direction below 1000	–	10	0	There are more than 1000 passengers in each direction
32	Not using the right side of the bus lane	–	5	2	In most parts, there are opening sections
33	The gap between bus and station	–	5	0	There is no distance between the bus and the station
34	Bus stop invasion to the sidewalk	–	3	1	There is in Farhang
35	Overcrowding	–	3	1	There is in Meli bank station
36	Poor bus and station maintenance	–	3	0	Bus and station maintenance is desirable
37	Distance between stations is long	–	3	0	Distance between stations is desirable
Total score				27	None of the grades are gained

Table 14: Classification of indexes and subindexes for evaluation of the bus lane and BRT.

Indexes	Sub-indexes
BRT basic principles	The exclusive right of way Existence of a special bus route Methods of fares collection The circumstance of the line connection at intersections Station level compared to the route level Existence of parallel routes Moving or stopping buses at stations
Service planning	Control center Located in one of the main corridors Passenger demand at different hours Service hours A network composed of several corridors Existence of broken center line on the stations' route
Infrastructures	Amount of pollutants emissions Distance between stations in the center of intersections Existence of stations with two-way route Pavement quality Distance between stations
Stations	Convenience and safety of stations The number of bus doors The possibility of entering and leaving two buses side by side in one direction Existence of sliding doors at the station Particular signs and symbols for the station
Notification systems	Passengers informing Access of all people (the disabled) Connection with other modes of public transport
Access and integrity	Pedestrians' access Secure parking space for bicycle Bike paths System connection to bike paths

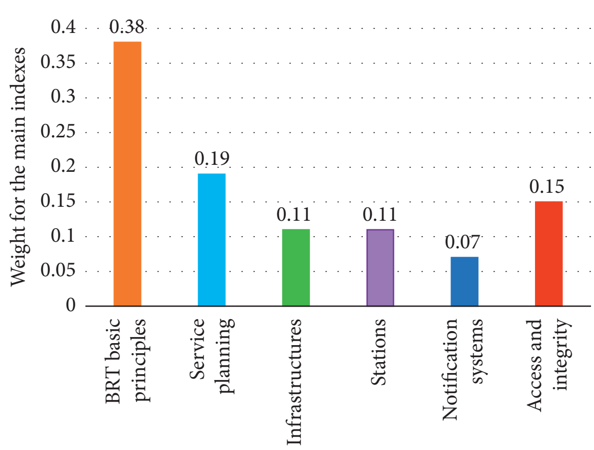

Figure 13: Obtained weights for the main indexes.

gradual membership. The assumed membership functions in this study are shown in Figure 16.

3.5.2. Results of the ANFIS Model. The second model used in this study is the adaptive-network-based fuzzy inference model. With the purpose of predicting the delay in the signalized intersection, which is under the influence of right-turn traffic volumes, direct movement traffic volumes in the entrances, green time of the traffic light, and the distance between stations, the ANFIS model with various structures, based on the number of membership functions, and algorithm of different membership functions were developed and tested. For randomly splitting the dataset, this model was created with 70% of data as the training dataset and its precision was examined according to the rest 30% (test dataset). According to the statistical parameters in Table 17, the results show that the most optimal structure of the ANFIS model for delay modeling at the signalized intersection of the present study with three membership functions for each input is the Gaussian 2 algorithm. Moreover, the number of input membership function was 3. Also, in Figures 17–19, the relationships between delay at the intersection and other variables are shown in the form of three-dimensional diagrams.

3.5.3. Comparison of Output Results. Figure 20 compares the output results of the fuzzy logic model and the ANFIS model, which predict the delay values at the signalized intersection. In this figure, the 1 : 1 line represents the comparison line between the obtained results and the output results of the models. So the closer the results to this line, the more accurate the predicted results. Based on the results, both models used in this study have high accuracy in predicting the amount of delay at the signalized intersection under the influence of traffic parameters. Figure 21 depicts

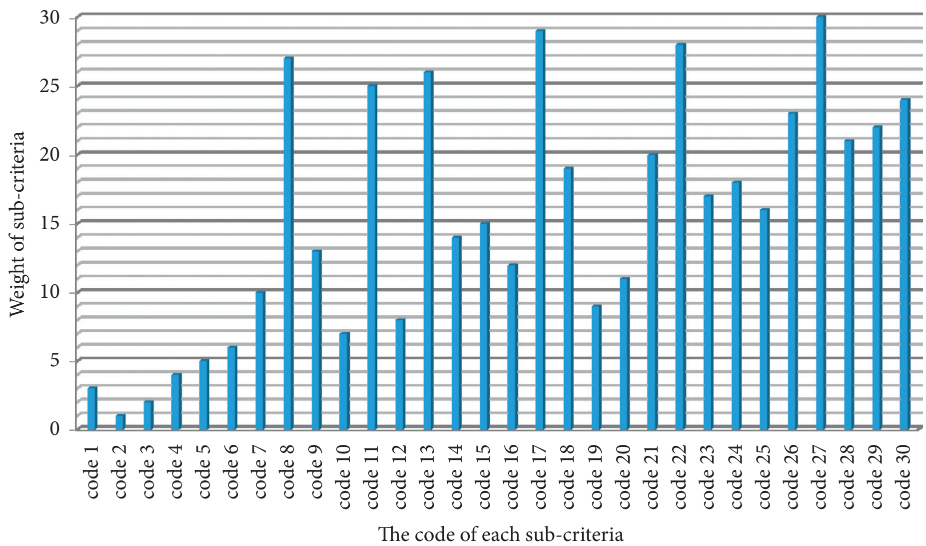

FIGURE 14: Final weights of subindexes (software output).

TABLE 15: Scores obtained for the bus lane of Rasht.

Index	Index weight	Subindex weight	Final weight	Line score	Score × final weight
The exclusive right of way	0.381	0.228	0.087	40	3.47
Existence of a special bus route	0.381	0.22	0.084	60	5.03
Methods of fares collection	0.381	0.234	0.089	30	2.67
The circumstance of the line connection at intersections	0.381	0.205	0.078	30	2.34
Station level compared to the route level	0.381	0.194	0.074	100	7.39
Existence of parallel routes	0.189	0.238	0.045	0	0.00
Moving or stopping buses at stations	0.189	0.175	0.033	0	0.00
Control center	0.189	0.164	0.031	0	0.00
Located in one of the main corridors	0.189	0.116	0.022	80	1.75
Passenger demand at different hours	0.189	0.201	0.038	70	2.66
Service hours	0.189	0.116	0.022	50	1.10
A network composed of several corridors	0.189	0.127	0.024	0	0.00
Existence of broken center line on the stations route	0.107	0.318	0.034	0	0.00
Amount of pollutants emissions	0.107	0.252	0.027	80	2.16
Distance between stations in the center of intersections	0.107	0.234	0.025	40	1.00
Existence of stations with two-way route	0.107	0.15	0.016	0	0.00
Pavement quality	0.107	0.168	0.018	30	0.54
Distance between stations	0.112	0.152	0.017	80	1.36
Convenience and safety of stations	0.112	0.205	0.023	40	0.92
The number of bus doors	0.112	0.196	0.022	60	1.32
The possibility of entering and leaving two buses side by side in one direction	0.112	0.071	0.008	60	0.48
Existence of sliding doors at the station	0.66	0.071	0.047	0	0.00
Particular signs and symbols for the station	0.66	0.182	0.120	0	0.00
Passengers informing	0.145	0.106	0.015	0	0.00
Access of all people (the disabled)	0.145	0.228	0.033	60	1.98
Connection with other modes of public transport	0.145	0.214	0.031	50	1.55
Pedestrians' access	0.145	0.262	0.038	60	2.28
Secure parking space for bicycle	0.145	0.145	0.021	0	0.00
Bike paths	0.145	0.166	0.024	0	0.00
System connection to bike paths	0.145	0.076	0.011	0	0.00
Total			1.00		40.01

the output results of different models; also, the observed results for the delay in the signalized intersection have been compared point by point.

Table 18 shows the error rate results and statistical values for different models of predicting the amount of delay. Based on the results obtained from the fuzzy logic

Figure 15: Traffic volumes of a signalized intersection in the route of the bus lane.

Table 16: The final model of the bus lane travel time.

Final model	Beta	Standard deviation	t-test	Sig.
Traffic volumes	14.743	2.421	4.653	.004
Stop time at stations	1.110	.084	13.265	.000
Distance between stations	.088	.004	24.275	.000
Green time at the signalized intersection	22.801	1.080	21.111	.000
Number of unsignalized intersections	5.068	1.633	3.103	.002
Constant	8.337	2.754	3.027	.003
R^2		.888		

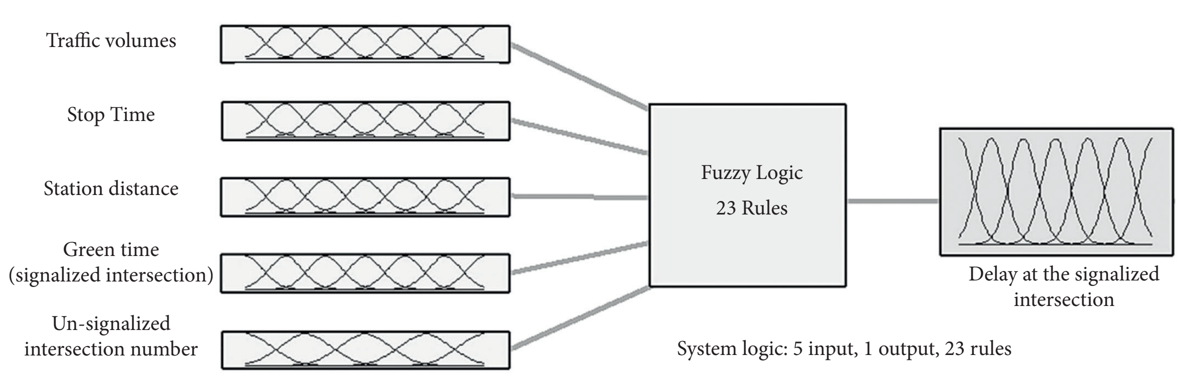

Figure 16: Structure of the used model for the delay prediction at the studied signalized intersection.

Table 17: Statistical results of the ANFIS model for predicting the delay at the signalized intersection.

Algorithm—input membership function	Training			Test			All data		
	RMSE	COV	R^2	RMSE	COV	R^2	RMSE	COV	R^2
2-trimf	4.1322	7.8626	0.9852	28.1477	48.6353	0.8005	11.9697	22.3637	0.9450
3-trimf	0.0044	0.0084	0.9904	48.5948	83.9649	0.3420	20.7209	38.7141	0.8499
4-trimf	0.0003	0.0006	0.9909	37.5285	64.8442	0.6524	15.1418	28.2903	0.9174
2-trapmf	6.8831	13.0967	0.9747	35.1272	61.3576	0.6419	16.4082	31.2607	0.8987
3-trapmf	0.0028	0.0054	0.9904	24.4196	42.6543	0.8222	10.5330	20.0671	0.9529
4-trapmf	1.8748	3.5674	0.9898	37.9973	66.3708	0.5825	16.4398	31.3208	0.8983
2-gbellmf	4.3868	8.3469	0.9844	34.0760	59.5214	0.6625	15.2360	28.4664	0.9165
3-gbellmf	0.0050	0.0095	0.9901	36.3502	63.4936	0.6172	15.6790	29.2940	0.9120
4-gbellmf	0.0004	0.0007	0.9908	32.0985	56.0671	0.6994	13.8451	26.3774	0.9253
2-gaussmf	4.1741	7.9423	0.9851	68.6383	119.8921	0.3420	29.8511	55.7729	0.7048
3-gaussmf	0.0064	0.0123	0.9910	20.1961	35.2771	0.8755	8.7112	16.2757	0.9666
4-gaussmf	0.0005	0.0009	0.9910	50.2771	87.8203	0.2758	21.6861	41.3160	0.8299
2-gauss2mf	4.7970	9.1275	0.9831	44.8612	78.3600	0.4216	19.8416	37.0713	0.8645
3-gauss2mf	**0.0058**	**0.0109**	**0.9907**	**8.8807**	**15.5121**	**0.9887**	**3.0153**	**4.3401**	**0.9905**
4-gauss2mf	0.0011	0.0022	0.9908	28.2451	49.3365	0.7653	12.1830	23.2109	0.9402

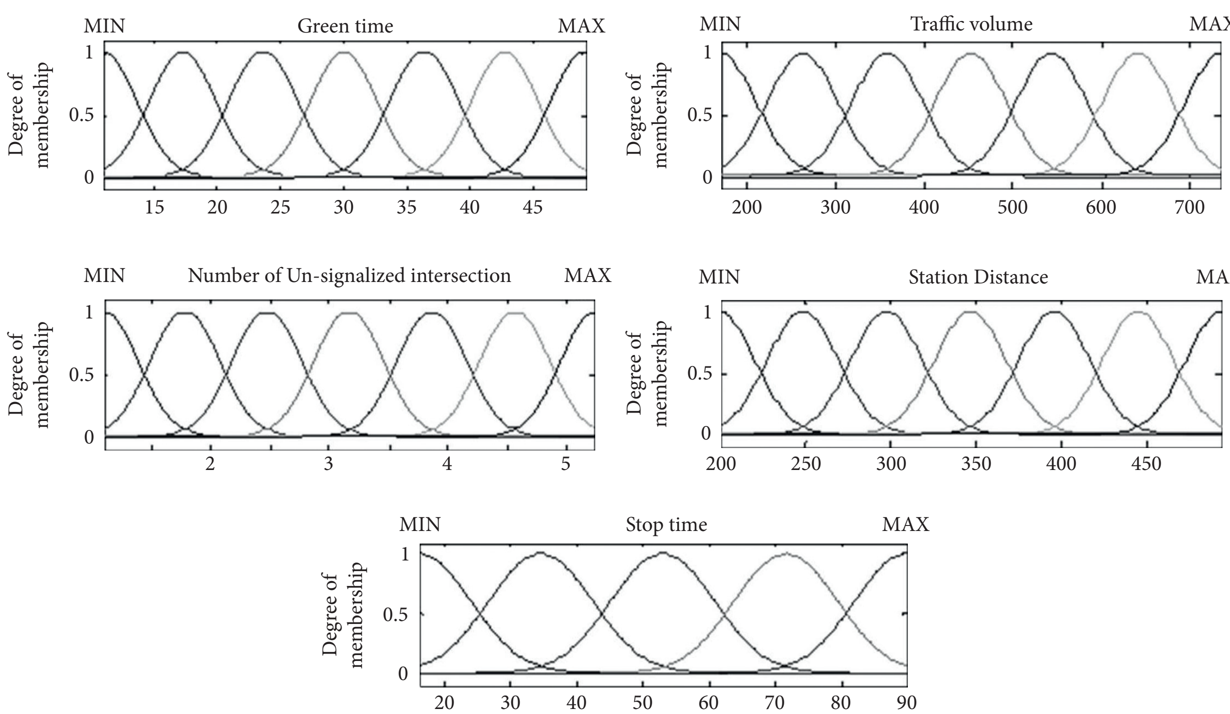

Figure 17: Membership functions of effective traffic parameters in predicting the delay of the signalized intersection in the fuzzy logic model.

model, the maximum absolute error is equal to 31.02, the mean absolute error is 11.35, and the mean percentage error is equal to 29.19 percent. Also, in the ANFIS model (fuzzy-neural), the maximum absolute error is equal to 11.41, the mean absolute error is 0.91, and the mean percentage error is equal to 2.23 percent. Examination of statistical parameters of the different models results shows that the ANFIS model has lower RMS and COV values and a higher R^2 than the other model. In fact, this model has a better situation in terms of statistical parameters in predicting the delay of the signalized intersection under the influence of various traffic variables.

By examining the results of vehicle delay optimization according to Figure 22, the average delay of the present vehicles at the signalized intersection is 56 seconds if the ideal stop time is considered and the distance between stations does not change. The green time of the traffic light is determined according to Table 19.

Therefore, considering the green time of Table 19, the delay value for drivers will be 56 seconds, and if the share of taxi transport is reduced by 30%, better results for the traffic flow on this route can be obtained. In the future, researchers can continue this study with other optimization methods, deep learning, and machine learning techniques [40–42].

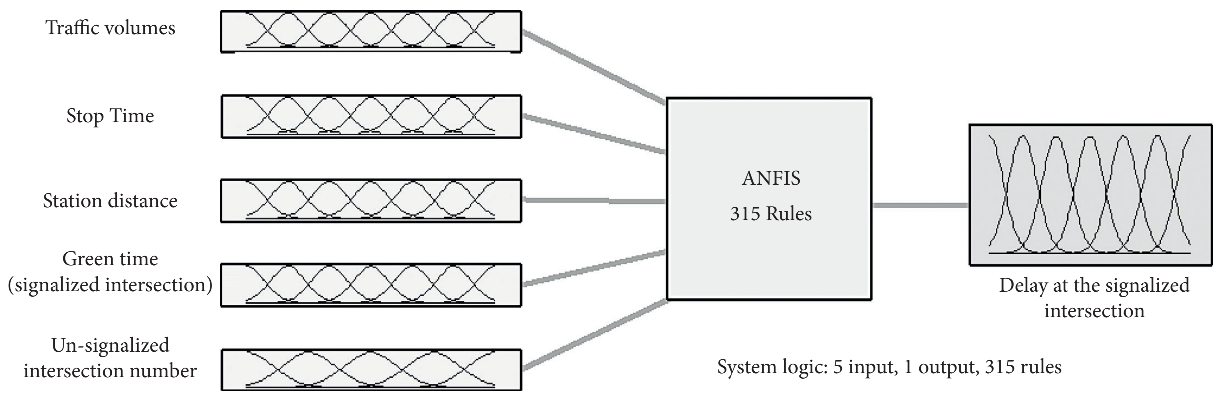

Figure 18: The structure of the model used to predict the delay at the signalized intersection using the ANFIS model.

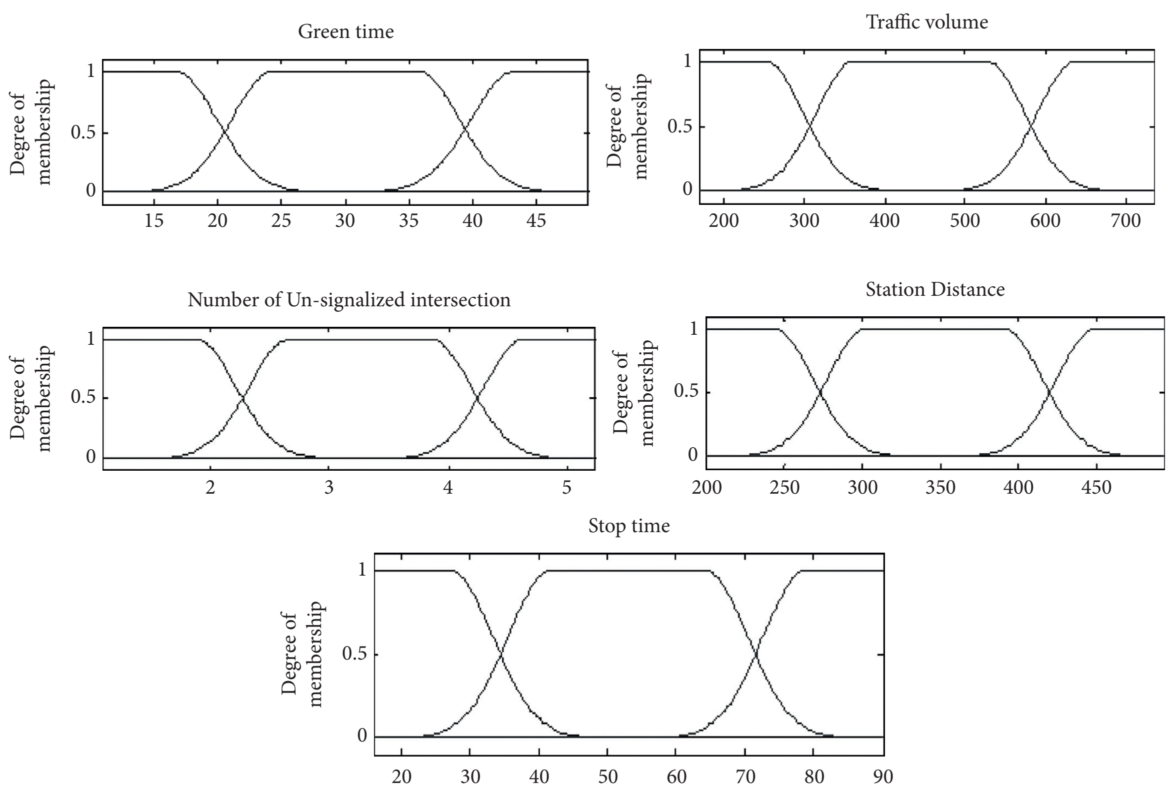

Figure 19: Membership functions of effective traffic parameters in predicting the delay at the signalized intersection in the ANFIS model.

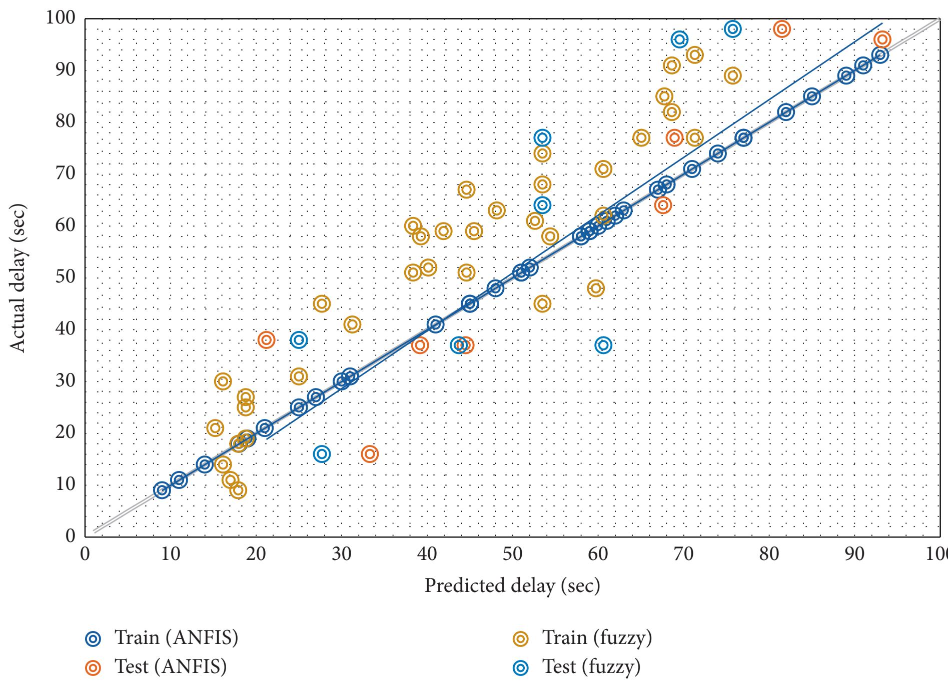

FIGURE 20: Comparison of the predicted and the observed delay values in different models at the signalized intersection.

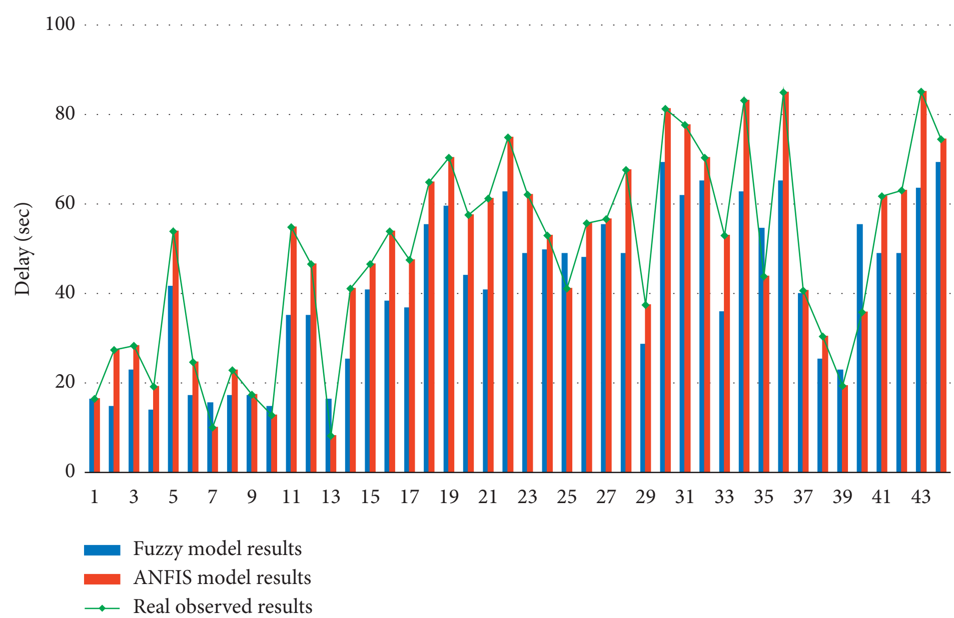

FIGURE 21: Point-by-point comparison of output results from different models and observed results for delay at the signalized intersection.

TABLE 18: Error rate results and statistical values for different models of delay prediction.

Statistical values	Fuzzy logic	ANFIS
Maximum absolute error	31.02	11.41
Mean absolute error (MAE)	11.35	0.91
Mean percentage error (MPE)	29.19	2.23
RMSE	14.17	3.01
COV	19.52	4.34
R^2	0.9121	0.9905

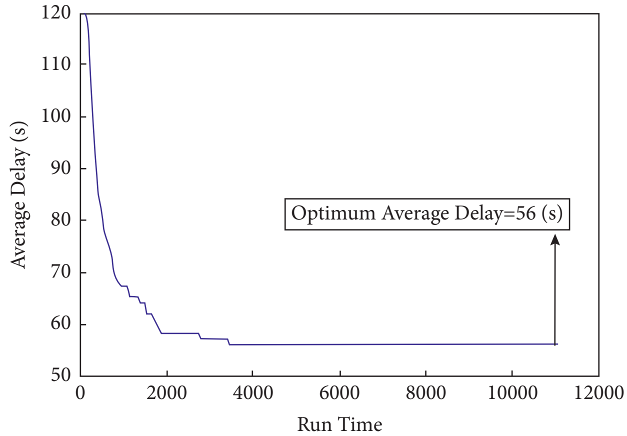

Figure 22: Average delay of the studied signalized intersection after optimization.

Table 19: Green time specifications of the current and optimal situation of the traffic light.

Phase number	Green time of the current status	Green time of the traffic light (seconds)	Yellow time (seconds)
1	40	45	3
2	32	38	3

4. Conclusion

Sweeping conclusions from each study and research, as well as providing practical solutions, can be the source of solving some problems and issues related to the field of research. In this research, after investigating previous studies and introducing the place of research and methods of analysis and modeling, the factors influencing the citizens' use of the bus lane of Imam Khomeini were discussed. According to the results, in comparison with the fuzzy model, ANFIS had a higher ability to predict and optimize the delay based on statistical parameters such as RMSE and R^2. The optimum amount was obtained as 56 seconds, and, by this value, the intersection performance in the delay reduction of bus movement is the best. Also, despite the lack of high-quality amenities and facilities, poor geometric design of this route, and mediocre quality of services, passengers' high satisfaction was obtained. Moreover, according to the descriptive results of subindexes, travel time had the most top priority for citizens in using the bus lane. The negative point of Imam Khomeini bus lane is the nonstandard and numerous open sections along the route, which have created dangerous and hazardous locations that require corrections and putting separator fences on these sections. Given the results of evaluation of the Rasht bus special lane by the standards, the weaknesses should be removed by adopting the following suggested solutions:

(i) Construction of routes that are parallel and radial with the existing bus special lane
(ii) Entering new buses into the system with the same origin and destination points to increase fleet speed
(iii) Establishing a traffic control center for buses
(iv) Completion of other bus special lanes to increase line efficiency
(v) Construction of two-way stations, instead of construction of two stations with one-way capabilities
(vi) Designing a particular symbol for each station to identify it better
(vii) Better naming for stations, for example, the names of Bank Melli and Pardis instead of Dr. Heshmat and Azadi
(viii) Establishing VMS and connecting them throughout the stations to inform passengers of the exact arrival time of the bus and display map of the transportation lines
(ix) Integration of bike paths and the Imam Khomeini bus lane.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Disclosure

In this study, Iranian governmental organizations have not been partners or sponsors, and this study is purely studious.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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