American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-9, pp-59-65
www.ajer.org
Research Paper Open Access

Security Optimization of Urban Bus System Based on Automatic Vehicle Location Data (AVL)

*Mahdi Seyrafinejad[1], Sayyed Ali Hashemi[2], Mohsen Ashourian[3]

[1]*MSc. Student – Department of Electrical Engineering, Islamic Azad University, Majlesi Branch, Isfahan, Iran*

[2]*Departmentof Electrical and Computer Engineering, Faculty of Mohajer, Isfahan Branch, Technical and Vocational University, Isfahan, Iran.*

[3]*Associate Professor- Department of Electrical Engineering, Islamic Azad University, Majlesi Branch, Isfahan, Iran*

Corresponding Author: Mahdi Seyrafinejad

Abstract: *Althoughusing of AVL system in comparisonwithtraditionalsystemsis more efficient and itcanimprove bus drivingsystems in terms of cost, time, and so on, it has someproblemssuch as this system has not the ability of optimizing and smarting. Whileitcanbe possible to optimize information extracted of AVL system. Therefore the AVL data weregathered in thisresearch. For this obstacle the parameters affect on passenger'ssafetysuch as number of passengers, average speed, time of travel, stop time, moved distance, and trafficwereconsidered. To acquire the optimal conditions, the fitness functionwasfirstlydetermined for geneticalgorithm. Due to the high correlationbetweenpassenger'ssafety and movedpassengernumber, the number of passengermovedwasselected as dependent variable y(xi) and itwasmodeledusingresponse surface methodologyaccording to the average of stop time xi , average speed x2, time of travel x3, station distances x4, and traffic coefficients x5 in thispaper. Different relation wereconsidered and full quadraticequationwasselected as the best model because of the high R2 (=0.86) and AR2 (=0.73). By usingthis relation as fitness function and appropriateselection of geneticalgorithmparameters, the best stop time, average speed, time of travel, station distances, and traffic coefficients weredetermined as 9.46 min, 24.61 Km/hr, 1.85 min, 60.85 m, and 3.36, respectively. Using the best conditions, the mostnumber of passengerscanbemoved and as a result the safety of passengersincrease.*

Keywords: *Passenger's safety, response surface methodology, genetic algorithm, automatic vehicle location system, modeling*

Date of Submission: 16-08-2017 Date of acceptance: 09-09-2017

I. INTRODUCTION

Automatic Vehicle Location Systems (AVL) for Public transit have become readily available in the last several years and have been utilized to track the locations of transit vehicles in real time. They have been promoted as being beneficial to the transit industry by offering transit agencies more flexibility in monitoring and managing their vehicles and by reducing customers' wait time and increasing riders' (perceived) security (Gomez et al., 1998). These systems are being implemented primarily in large transit systems such as bus system where the AVL can provide obvious efficiencies in managing a large fleet of vehicles (Casey et al. 1998).

A survey was conducted of transit users in a Wisconsin community to assess the level of importance that transit users place on features of transit service which AVL can affect. This information was used to identify the costs and benefits of AVL to the transit riders and service providers. This information then provides a framework for conducting benefits costs analysis. The study concludes with suggestions for transit agencies that are considering the adoption of AVL systems.

Many studies in the literature focus on the development of the AVL technology. For example, Cain and Pekilis (1993) in their article on the development history of AVL give a good description of the shift from Loran et al. to the present global position systems (GPS) with enhanced real time location tracking and schedule monitoring. Dana (1997), Okunieff (1997) and Khattak et al. (1998) also provide a good overview of the GPS technology and the role of AVL for bus transit. These studies on AVL systems highlighted the fact that GPS was the most popular technology available in the market at present. A wide variety of features can be added to the basic AVL system. Smart cards, electronic billing, passenger counters, maintenance monitoring system, etc., are some of the examples.

Very limited literature is available on the safety analysis of passenger for the applications of AVL systems in transit agencies. One reason for this could be that it is a relatively new technology, and there is little data available for detailed safety analysis. Therefore the AVL data were gathered on urban bus system in this research based on passenger's safety. On the other hand optimization of urban bus system based on safety of passengers has not been considered until now. Different methods can be used for optimization of conditions. The most popular method is genetic algorithm.

The Genetic Algorithm (GA) have been widely used in civil and transportation engineering (Putha et al., 2012; Ranjitkar et al., 2005). It has been tested for its applicability in traffic engineering (Bagula and Wang, 2005), environmental modeling and soil mechanics; however, not much attention is given to its applicability in public transportation. Recently, Rashidi and Ranjitkar (2015), investigated the application of the GA to model and estimate bus dwell time. They conclude that there is a prospect for improving bus dwell time modelling using their proposed GA approach. Therefor the goal of the present work is to improve the passengers' safety using genetic algorithm based on AVL data acquired from urban bus system of Esfahan town.

II. MATERIALS AND METHOD

2.1 Data selection

The data were gathered in this research from AVL system mounted on line 34. This line was the most complete line equipped by AVL system in Esfahan (Figure 1). Layout of active fleets was done according to high traffic hours of passenger. So that the number of active fleets increased in busy time.

Fig 1: Full transportation plan of Line 34

The number of transferred passenger has high correlation with active fleets in the line. The number of active buses for each line was selected according to number of passenger and on the other hand efficiency of a line related to the number of transferred passengers in that line. While securing passengers in a line related to bus speeds, time of travel and stop. Therefore to increase passenger's safety and fleet efficiency, it should be transferred more passengers in available speed with available travel and stop times. Therefore moving buses in 45 stations was studied in this research. In each station some parameters such as travel time, average of speed, number of passenger, and stop time were determined. These parameters were then used to optimize the safety of passenger. The Benz bus was more used in the line therefore the following researches were done for this type of bus. This type of bus had the least error massage.

The efficiency of a bus affected by different parameters which their consideration needs different necessary equipment mounted on the bus for collecting information. In this research some parameters which affect the passengers' safety were determined as possible. To determine the optimum parameters using genetic algorithm, fitness function should be determined. The fitness function is a function between the passenger's safety and effective parameters (Weidong et al. 2012).

2.2 Fit function

Effective parameters on passenger's safety or number of passengers (according to previous entries the number of transferred passengers shows passenger's safety) determined in this research were average of speed, travel time, stop time, moved distance, and traffic. To determine the fitness function, different methods such as regression and response surface methods (RSM) can be used (DuMouchel and Jones, 1994; Goos and Donev, 2010). The RSM determine a model based on optimization, therefore it was used for modelling the safety of passengers. For this purpose dependent variable y(x), the number of passengers, was modeled according to independent variables xi, or consideration parameters. Repeat the information for modelling was done according to gathered information from 45 stations in line 34. Among considered models, the model with the least error was selected as the fitness function.

III. RESULTS AND DISCUSSION

3.1Information of bus moving

As it was told the transferred passengers were related to different parameters. Some of the most important parameters were traffic, bus speed, stop time, and travel time. The bus travel time was related to path length, bus speed, and traffic. Furthermore the traffic changes during the day. Therefor a traffic coefficient was presented for each part of line among the sequential stations according to expert opinion (Figure 2). Path length between two sequential stations was the other important parameters affect numbers of passengers and passenger's safety. It was shown in figure 3 for all stations.

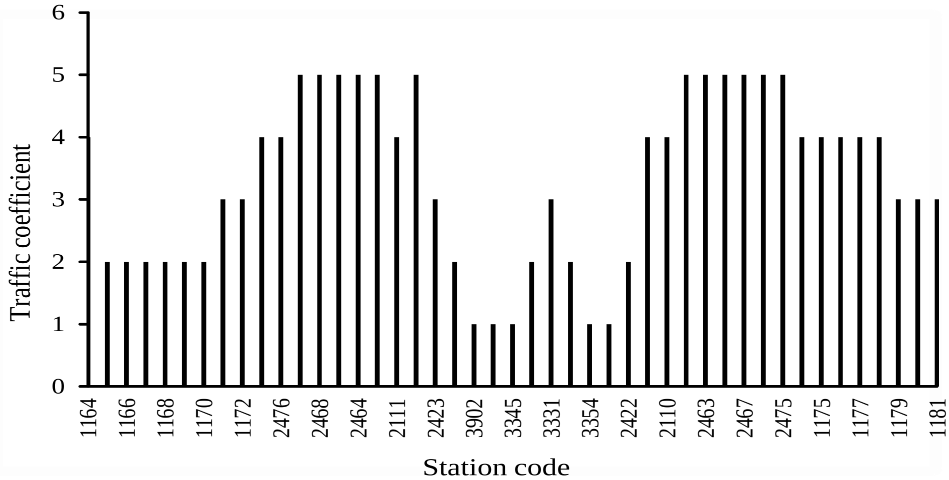


Fig2: Traffic coefficient of each station in Line 34

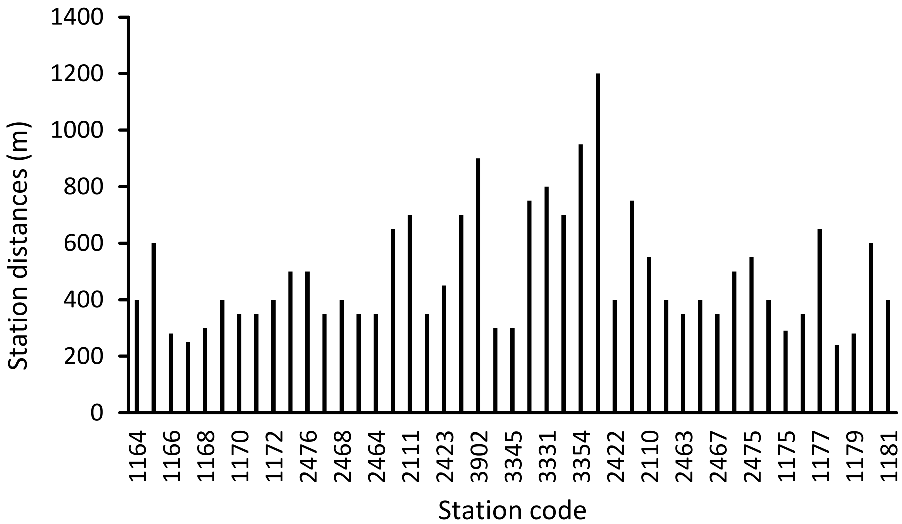


Fig 3: Separate station spacing in Line 34

The length of line was 20327 m, maximum of travel time equaled to 20':27", minimum of travel time equaled to 17', maximum of passengers was 7387, minimum of passengers was 0, maximum of speed equaled to 84.57 Km/h, and minimum of speed equaled to 4.36 Km/h. The number of passengers transferred in different stations was illustrated in figure 4.

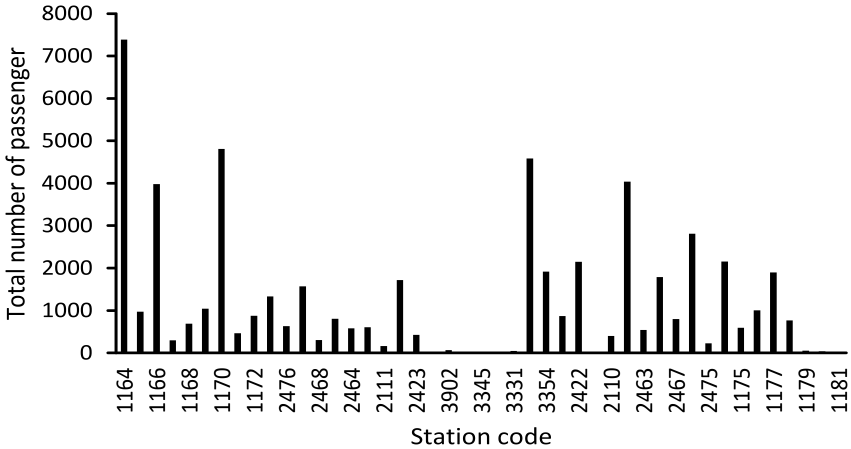


Fig4: Transported passengers by buses in Line 34

3.2Modeling

Four different models, linear and quadratic, were used for modelling transferred passengers based on the effective parameters. The dependent variable was the number of transferred passengers y(x) and independent variables were stop time x1 (min), average of speed x2 (Km/hr), travel time x3 (min), station distances x4 (m), and traffic coefficient x5, respectively. The considered models were linear (Eq. 1), iteration (Eq. 2), pure quadratic (Eq. 3), and full quadratic (Eq. 4) models (Shrivastava and Dhingra, 2002). Totally there were five independent variables and one dependent variable in 45 repetition.

$$y(x) = a_0 + \sum_{i=1}^{5} a_i x_i, i = 1, 2, \ldots, 5 \tag{1}$$

$$y(x) = a_0 + \sum_{i=1}^{5} a_i x_i + \sum \sum_{i<j}^{5} b_{ij} x_i x_j, i = 1, 2, \ldots, 5 \tag{2}$$

$$y(x) = a_0 + \sum_{i=1}^{5} a_i x_i + \sum_{i=1}^{5} b_i x_i^2, i = 1, 2, \ldots, 5 \tag{3}$$

$$y(x) = a_0 + \sum_{i=0}^{5} a_i x_i + \sum_{i=1}^{5} b_i x_i^2 + \sum \sum_{i<j}^{5} c_{ij} x_i x_j, i = 1, 2, \ldots, 5 \tag{4}$$

The result of linear model for estimation the transferred passengers based on independent variables was not very good. As R-squared (R2) between real and estimated values was 0.63 and adjusted R-squared (AR2) was 0.56 which were low values for an estimation (Mao and Iravani, 2014). Therefore this model was not suitable for using as the fitness function. The accuracy of the iteration model was better than linear model as its R2 and AR2 were equaled to 0.73 and 0.57, respectively. Although this model has better accuracy than linear model but it is not very good to use as the fitness function and the other model should be considered. Although the number of model coefficients of pure quadratic model was lower than iteration model, it had better accuracy. As its R2 and AR2 were 0.78 and 0.68, respectively. The estimated passenger number versus real number has been illustrated in Figure 5. As it is shown, this model can accurately estimate the passenger, but it is better to consider the full quadratic model for selection the best model as the fitness function. The full quadratic model was determined from Eq. 4 and the model coefficients were illustrated in table 1.

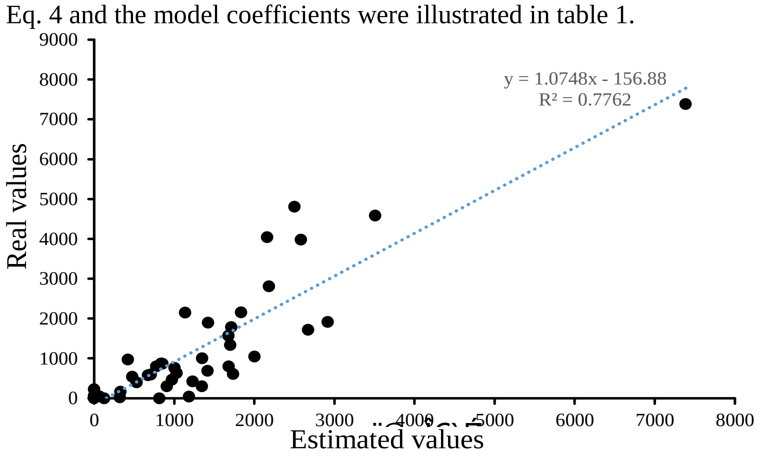


Fig5: Real transported passengers versus their estimated values with pure quadratic model

Table I: Coefficients of full quadratic model

a0	a1	a2	a3	a4	a5	b1
9954.177	7582.387	-321.32	1170.043	0.025167	-3741.96	-145.292
b2	b3	b4	b5	c1	c2	c3
-3188.17	-0.34712	866.6145	15.91483	-0.00244	32.73629	2.009645
c4	c5	c6	c7	c8	c9	c10
-404.146	0.44298	-229.86	3.251677	-63.8236	-0.00468	381.5321

This model has the most accuracy among the models as its R2 and AR2 were 0.86 and 0.73, respectively. The estimated passenger number cross the real passenger number has been illustrated in figure 6. The full quadratic model has the most accuracy among the models and after that pure quadratic was better, therefore the full quadratic model was selected as the fitness function for using in genetic algorithm.

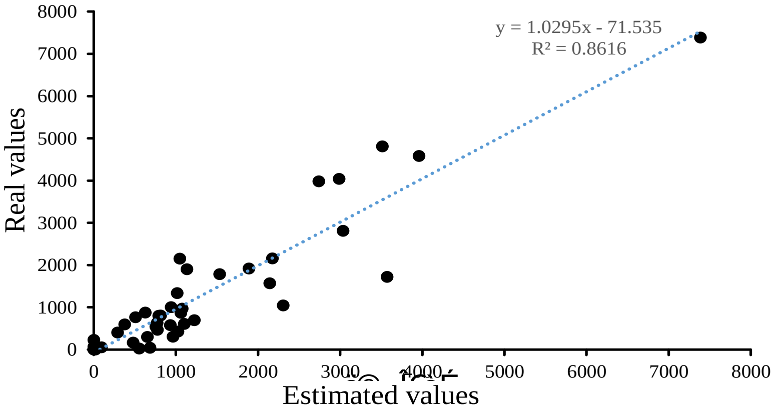
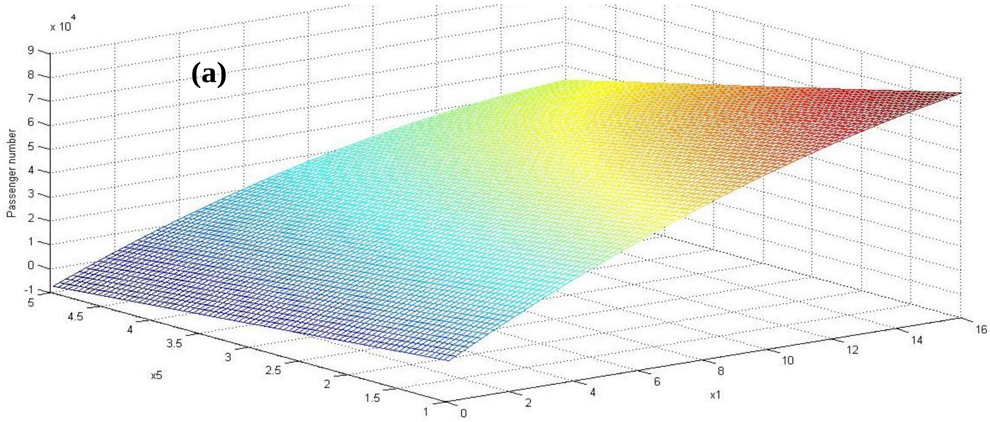


Fig 6: Real transported passengers versus their estimated values with full quadratic model

Different plots were made for illustration the estimated y cross different parameters xi. For example the estimated y cross x1-x5 and x2-x5 has been illustrated in figure 7. As it is shown in the figure 7(a and b), the estimated passengers y reach to the maximum. Therefore the transferred passengers estimated with full quadratic model can be optimized within the range of the study and as a result it can be used as the fitness function very well.

3.3 Determination of optimum conditions

The full quadratic model (Eq. 4) which had the most accuracy for estimation the transferred passengers was used in genetic algorithm as the fitness function. The other genetic algorithm parameters were adjusted as following. The number of independent variables was 5, lower and upper bounds were 0 and 10000, population size equaled to the number of stations, mutation coefficient was 0.2, crossover coefficient was 0.9, and the number of optimized generation was 50. By using the genetic algorithm according to adjusted parameters, the algorithm was running until the fitness function was maximized. Charts related to scores and validation of genetic algorithm are illustrated in figure 8.



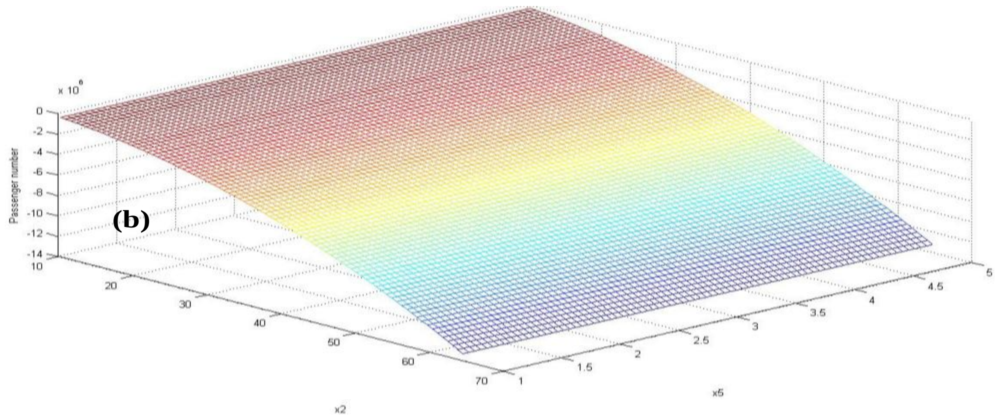


Fig7: The number of estimated passengers using full quadratic model based on changes of x1-x5 and x2-x5

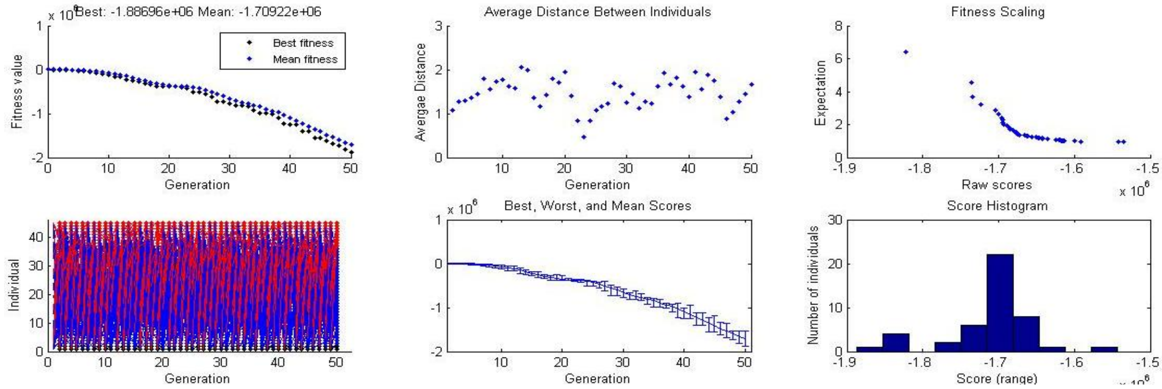


Fig8: Charts related to scores and validation of genetic algorithm for estimation of optimal values of passenger transportation conditions in Line 34

In the figure 8, best fitness plot is the best function value in each generation versus iteration number. Distance plot is the average distance between individuals at each generation. Best individual plot is the vector entries of the individual with the best fitness function value in each generation. Expectation plot is the expected number of children versus the raw scores at each generation. Range plot is the minimum, maximum, and mean fitness function values in each generation. Score diversity plot is a histogram of the scores at each generation. As it is shown the score at sequential generations have been better and the number of children decreased, too. Furthermore the fitness values at sequential generations have decreased which shown available estimation by genetic algorithm. As the figure shown the distances in each generation have decreased and scores in each generation have increased. This conditions shows the genetic algorithm can determine the optimum values of five effective parameters. The optimum values of stop time, average of velocity, travel time, station distance, and traffic coefficient determined with genetic algorithm were 9.46 min, 24.61 Km/hr, 1.85 min, 60.85 m, 3.76, respectively. Furthermore the flag of results reach to zero. With this values for conditions, the most passengers can be transferred. Therefore with control the conditions in this values by drivers, the most passengers can be transferred and as a result the passenger's safety increases. Although we did not find similar researches, there were some researches for optimization the efficiency of buses. Mao and Iravani (2014) analyzed a trend-oriented power system security based on load profile. They make a model based on information of 30 buses and then determine the optimum conditions. Their optimization method is similar to our method. Huang (2016) purpose a new model for estimation of energy consumption by electrical buses. The model related to the parameters of maximum received power, stop time, active buses in line, line length, received energy, and so on. His methods and results were similar to the methods and results in this research. Therefore it can be trust to the results and methods used in this research and by coupling the results with other researches, it can be attached to better methods and results.

IV. CONCLUSION

The number of transferred passengers get effect of different parameters such as bus speed, path length, traffic, stop time, bus moving. By determination the best values of these parameters and supply them in urban bus system, the most passengers can be transferred. As a result the most passenger's safety was made. To determine the best conditions, a relation was made among the number of transferred passengers and the effective parameters. Therefore the RSM was used for modelling the conditions. Four models including linear, iteration, pure quadratic, and full quadratic models were used. By consideration the estimated and real values, it was concluded the full quadratic model had the most accuracy and after that was the pure quadratic. The results of genetic algorithm showed that the best stop time equal to 9.46 min, average of speed equal to 24.61 Km/hr, travel time 1.85 min, station distances equal to 60.85 m, and traffic coefficient was 3.76. With this values for conditions, the most passengers can be transferred. Therefore with control the conditions in this values by drivers, the most passengers can be transferred and as a result the passenger's safety increases.

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Mahdi Seyrafinejad. “Security Optimization of Urban Bus System Based on Automatic Vehicle Location Data (AVL).” American Journal of Engineering Research (AJER), vol. 6, no. 9, 2017, pp. 59–65.