International Journal of
Intelligent Systems and Applications in Engineering

ISSN:2147-6799 www.ijisae.org Original Research Paper

Urban Traffic Optimization with Real Time Intelligence Intersection Traffic Light System

Yuksel CELIK*[1] , Alper Talha KARADENIZ[2]

Accepted : 04/06/2018 Published: 29/09/2018

Abstract: Traffic system is a complex system where a lot of smart components which include signals, vehicles, sensor and pedestrian have communication skills with together on local level and act in a particular manner on high level. Insufficient traffic light control system on intersections brings about unnecessary delays and waste of time, extremely oil firing of engine which run idle mode on lights and increasing greenhouse gas emission. Various systems have been developed in order to overcome these traffic problems. These are the primary developed methods for the traffic optimization systems: fixed time period systems of lighting where time is pre-determined, green wave lighting system and real time optimization system of traffic light. In this paper we suggested a real time intersection traffic optimization system. Real data has been gathered on Karabuk-Safranbolu route to test above systems for different data density. There are 7 lighted junctions on the route and there are traffic congestion in these junctions with the existing fixed time systems . The results of these tests on data show that real time traffic light optimization systems get better results than fixed time period and green wave lighting systems.

Keywords: *Traffic Optimization, Green wave Traffic, Signalization, Fixed time period system of lighting, Simulation of urban mobility (SUMO)*

1. Introduction

Today, one of the biggest problems of the rapidly increasing urbanization is the traffic [1]. As a natural consequence of the poor traffic light control in cities along with increasing number of vehicles, the time lost from delays increases, the idle engine consumes more fuel and at the same time, the emission of greenhouse gases emitted from vehicles to the atmosphere increases. The insufficient number of traffic lights also results in an increase in the rate of accidents that occur at intersections. Optimization systems are developed because of insufficiency in traffic light systems. Traffic light optimization systems are examined in two different ways: online and offline [2].

Commonly used offline systems are fixed-time traffic light systems and green wave traffic light systems [3]. In fixed-time traffic light systems, fixed signal plans can be used that signal cycle time and green light time are determined according to the saturation of approaching currents, and different time schedules can be applied in order to get rid of intersection at times of heavy traffic [4]. Green wave traffic system is the application of uniform traffic lights throughout a traffic route [5]. Throughout the route, the color of the traffic lights at all intersection are seen by the center, while the green light moves across by rolling. This system is called green wave traffic system because these transitions resemble waves [5]. The goal of green wave is based on the principle that majority of cars which pass on green light encounter green light again at the traffic lights on the next intersection [6].

Online traffic systems are the systems that are self-organized, run in real time and are programmed to produce the best results instantly [2]. One of these systems, the Split Cycle Offset Optimization Technique (SCOOT) system, is an adaptive system to traffic demands for not heavy urban traffic systems [7]. The SCOOT system has shown better results than the fixed-time traffic light systems [3]. SCOOT has more than 200 application fields in the world [8]. The other system is SCATS (Sydney Coordinated Adaptive Traffic System), which was developed by roads and traffic committee in Australia at 1970 [9]. In this system, intersection are monitored and the system engineers are notified when an unusual situation occurs or when the equipment at the intersection is in a state of failure [9]. Another system is OPAC (Optimized Policies for Adaptive Control), which was developed in University of Massachusetts in the beginning of 1980s [10]. The OPAC is designed as a system that have the ability to decide a signal to end or to extend in the intersection systems [10]. Another system is RAIN (Real-Time Network-Wide Traffic Signal Optimization) system. It uses strategy level and control level for traffic signal optimization in real time and constantly updates tail weights [11]. In addition to these systems, it is also possible to organize traffic complexity with self-organization in the optimization of traffic light systems [12].

Designed systems need to be implemented and evaluated in a traffic simulation environment before tested in real world with all environmental factors [13]. These simulation environments make it easy to evaluate infrastructure changes together with policy changes before implementation in real roads. They also provide possibility of optimization according to obtained results [13]. These programs provide users with a variety of parameters in real-time traffic control systems, including control strategies, route selection, environment, safety precautions, vehicle and road count [14]. Simulation programs divided into 2 as microscopic and macroscopic in general [14]. Microscopic methods are frequently used for the optimization of city traffic system [15].

Traffic simulation programs including CORISIM (Corridor Simulation), VISSIM (Traffic Simulation Model), AIMSUN (Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks), PARAMICS (Parallel Microscopic Simulation of Road Traffic), TRANSIM Simulation System) and SUMO (Simulation of Urban Mobility) are widely used [16].

In the study, a real-time traffic light optimization system has been designed to respond to changing parameters instantaneously so that the traffic system can operate efficiently. The SUMO traffic simulation program is used to compare and test the real time traffic

[1]*Karabuk University Computer Engineering, Karabuk-Turkey*
[2] *Bolu Abant Izzet Baysal Univ., Bolu Voc. High School, Bolu-Turkey*
* *Corresponding Author: Email: yukselcelik@karabuk.edu.tr*

light system that is created. The flexible testing environment of SUMO is preferred because of its ability to intercept code and its integration into Matlab.

2. Programs Used in The Study and Preparation of Study Environment

As shown in Figure 1, 7 intersections between Karabuk and Safranbolu road, which is about 8.5 km, were selected as study environment. The Karabuk-Safranbolu route from the Open Street Map mapping platform for the selected study environment was downloaded and the data on the map were saved in the xml file.
The Net Editor for SUMO program was used to load the data into the study environment. A screenshot of the Net Editor For SUMO program was given in the Figure 2.

The light system given by Highway administration was strictly applied for the used fixed time traffic system between Karabuk and Safranbolu road. For the green wave traffic light system, the arrival times to the traffic lights on the Karabuk-Safranbolu road are calculated based on the distances between the lights and 70 km/h speed which is the legal speed limit [17].
The communication of the SUMO traffic simulation program with the Matlab Software language, application and testing of

desired traffic light optimization method by coding can be provided. In order to provide the mentioned communication, Traci for Matlab software must be used and the settings for Matlab must be adjusted. As seen in Figure 3, suitable roads and map are tested in the real world environment with desired speeds after uploading them to SUMO traffic simulation software.

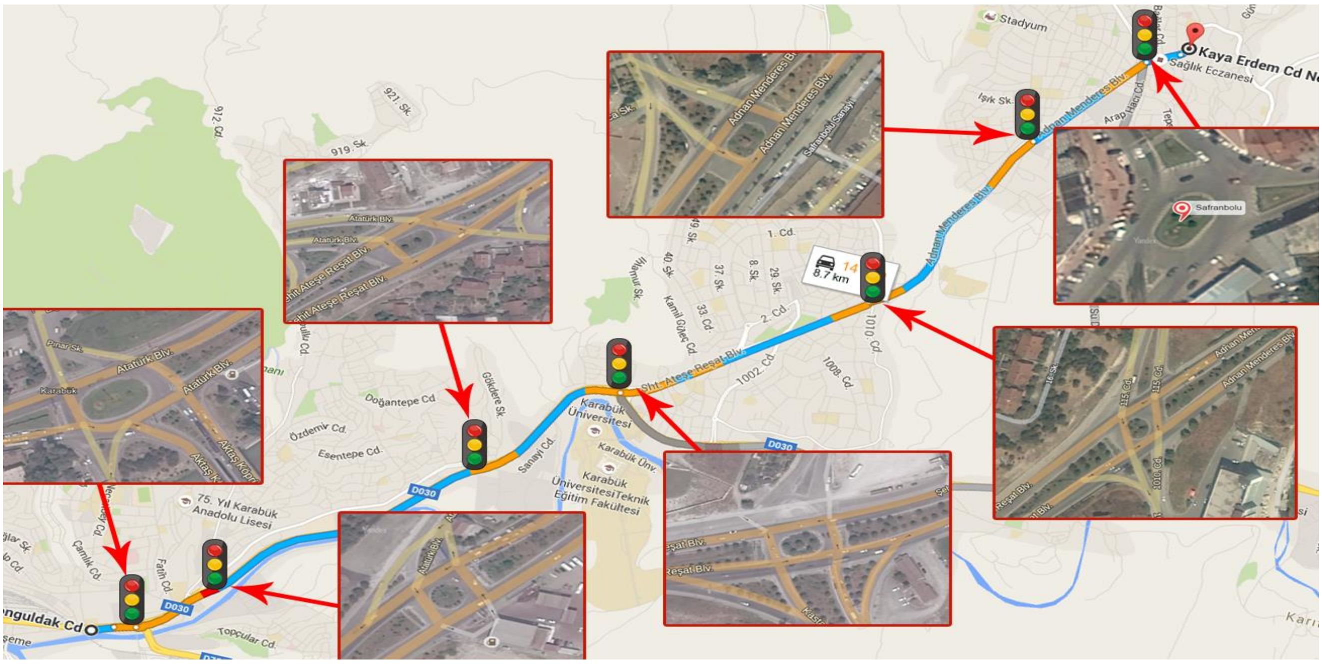

Figure 1. Karabuk-Safranbolu root working area [17].

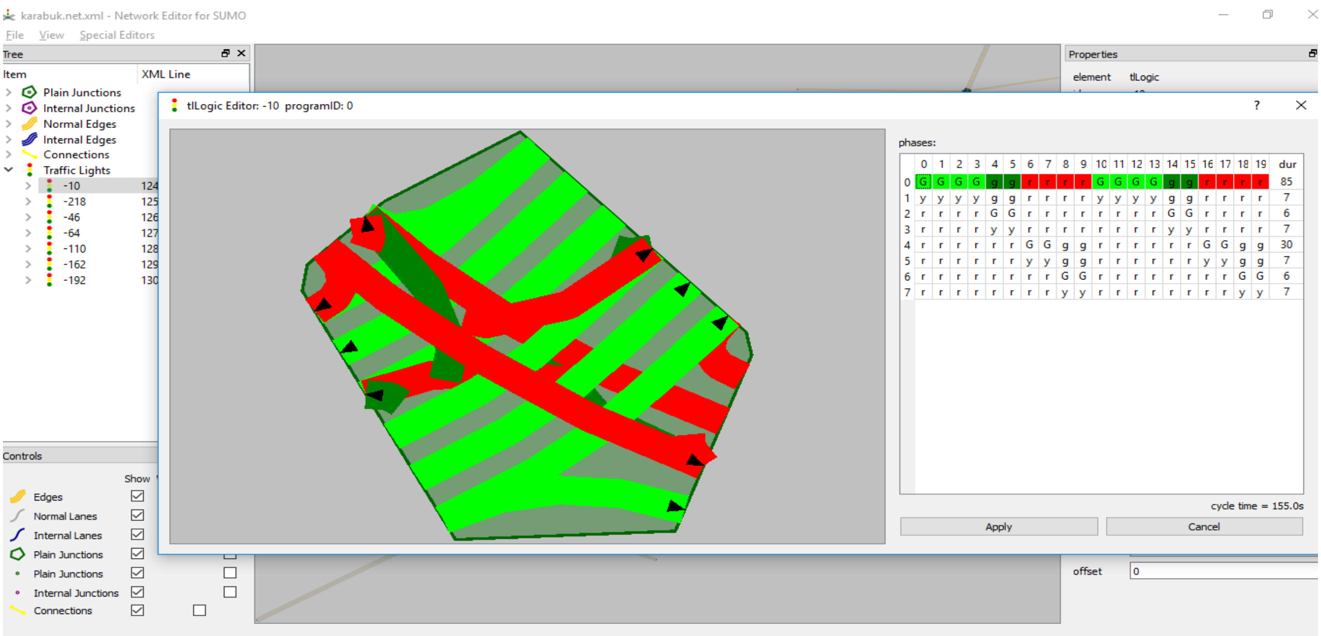

Figure 2. Light duration and phase settings screen display for Net Editor for SUMO program.

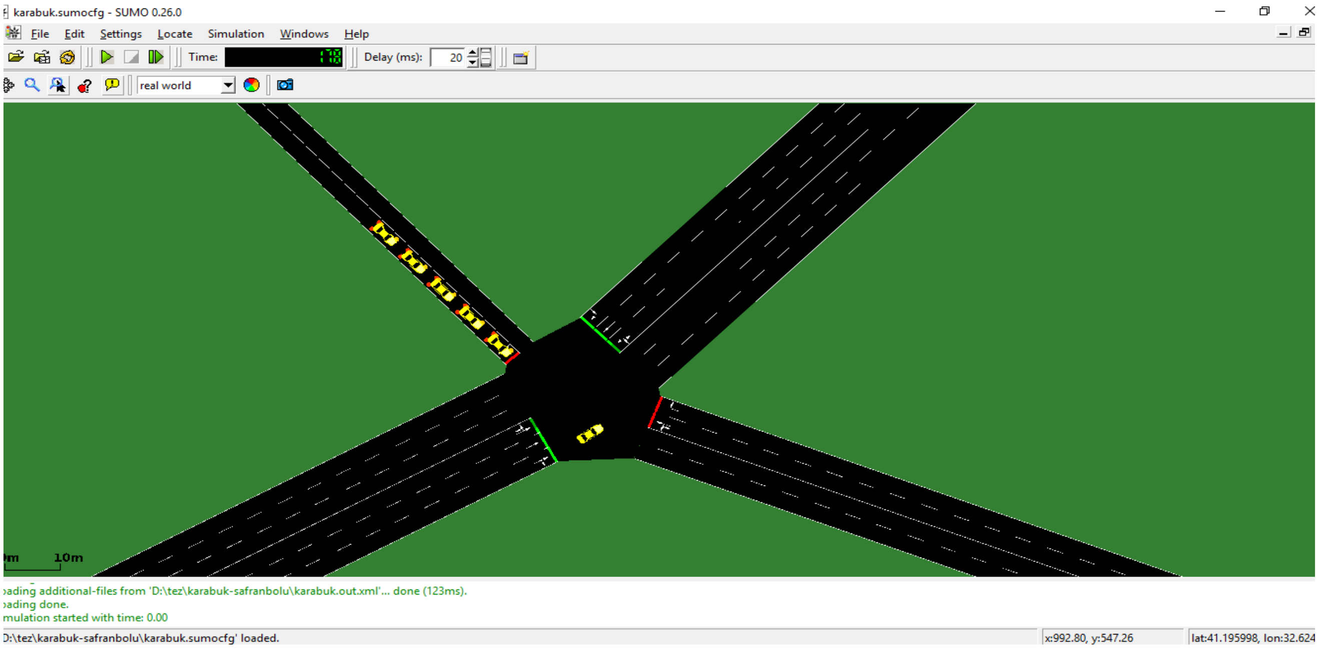

Figure 3. SUMO traffic simulation program working environent.

3. Experimental Tests

In the study, a smart traffic system, which can be self-determined depending on the algorithm applied was designed for the real-time traffic light system. Depending on the traffic density, the intersection examines all the lanes on each side and processes based on the lane where the longest tail is located. The created flow diagram of real-time traffic light system was given in Figure 4.

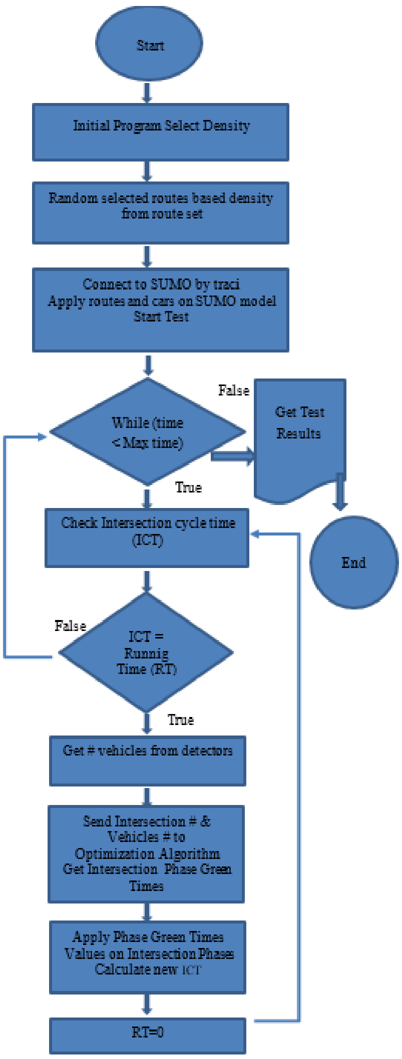

Figure 4. Flow diagram of real-time traffic light signal optimization.

As shown in Figure 5, a smart intersection system has been designed and an 8-step algorithm has been developed for our real-time traffic light optimization system on this smart intersection system.

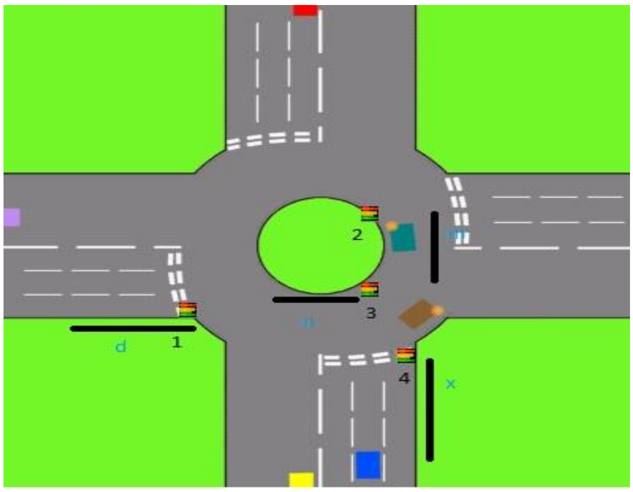

Figure 5. Designed intelligent intersection system.

The algorithm of designed real time traffic light optimization system;

1. Examine the number of vehicles on all lanes, take the longest tail
2. If it exceeds the D threshold value, 1, 3 green and 2, 4 red
3. If it exceeds the M threshold value, article 1 is canceled and 2, 4 green and 1, 3 red
4. If it exceeds the N threshold value article 1 and 2 will be canceled and 1, 3 green and 2, 4 red
5. If the conditions in the first 3 article are not met and there is no vehicle in light 2 and 4, then 1, 3 green

6. If the D threshold value is not met in the lights of number 1 and 3 and a vehicle comes to light 2 or 4 then 2 and 4 will turn green and 1 and 3 will turn red
7. If the M or X threshold values are not exceeded and the lights 1 and 3 is green for more than 90 seconds; 1, 3 turn red and 2, 4 turn green
8. If the D and N threshold values are not exceeded and the lights 2 and 4 are on for more than 90 seconds; 1, 3 turn green and 2, 4 turn red

Six different traffic densities and random five different routes for each density was created using XML codes while calculating in the prepared study environment [17]. The traffic density ratios were obtained by calculating the maximum number of vehicles in the area under test and were selected from 0 to 1. The length of the test area, vehicle length and the safe distance between the two vehicles must be calculated to obtain the maximum number of vehicles. The total length of the road is 8,500 meters which was tested in the study. The average length of a passenger vehicle was taken as 5 meters. The safe distance (m) between two vehicles is the distance calculated by dividing the vehicle speed (km/h) by two. The maximum density in traffic is when the vehicles cannot move or are close to stopping. In the study, the distance between two vehicles is calculated as 2.5 m when the vehicle travels at a maximum speed of 5 km/h. Therefore, a space of 7.5 meters is required for each vehicle on the road. This corresponds to 8500/7.5 = 1,113 vehicle on one lane. Since this route consists of 3 right and 3 left lanes, 1.113x6 = 6.678 vehicles were taken as the maximum number of densities of this route. The number of vehicles to enter the system according to the densities are shown in Table 1.

Table 1. Number of vehicles by density.

Density Number	1	2	3	4	5	6
Density Rate (0-1)	0,15	0,30	0,45	0,60	0,75	0,90
Numberof Vehicle	1002	2003	3005	4007	5009	6010

4. Experimental Results and Discussion

After uploading required data and installing software, fixed time traffic light systems, green wave traffic light systems, and real-time traffic light systems were separately tested in real time environment with different density and different number of vehicles in SUMO traffic simulation software. As a result of the tests, average waiting times, average travel times, the number of vehicles leaving the system and number of vehicles remaining in the system were compared. The average waiting time is the time of vehicles which were inactive in traffic network divided by the number of vehicles (1).

$$\sum_{K=0}^{Number\ of\ \text{vehicles}} \left(Standby\,\frac{time}{Number}\,of\ vehicles\right) \quad (1)$$

The comparison of the average waiting time for the fixed time traffic light system, green wave traffic light system and real-time traffic light system is shown in Table 2 and the graphical representation of obtained experimental data was shown in Figure 6.

Table 2. Comparison of average waiting times.

Density Number	Density Rate	Fixed Time	Green Wave	Real Time
1	0.15	0.68	0.5763	0.4746
2	0.3	0.798	0.6783	0.5586
3	0.45	0.84	0.714	**0.51886**
4	0.6	0.864	0.7344	**0.45842**
5	0.75	0.864	0.7344	0.6048
6	0.9	0.882	0.7497	0.6174

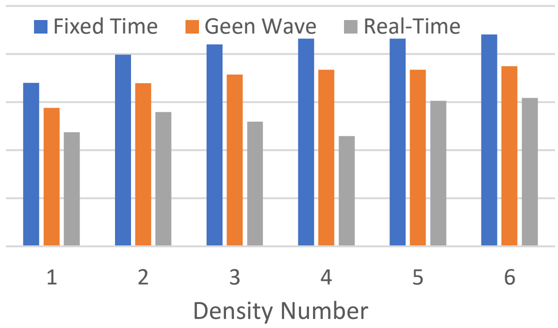

Figure 6. Comparison of average waiting times.

Looking at the results in Table 2 and Figure 6, it is seen that the real-time light system gives better results. It is also seen that in density numbers 3 and 4, which are average densities, the results of the real-time traffic system are much better.

Travel time is the time between the moment the vehicles enter the traffic network and the moment they leave the network. The average travel time is the sum of the travel time of all vehicles divided by the number of vehicle (2).

$$\sum_{K=0}^{Number\ of\ \text{vehicles}} (Travel\,\frac{Time}{Number}\,of\ vehicles) \quad (2)$$

The results which were obtained after comparison of the average travel times for the fixed time traffic light system, green wave traffic light system and real-time traffic light system were given in Table 3 and Figure 7.

Table 3. Comparison of average travel times.

Density Number	Density Rate	Fixed Time	Green Wave	Real Time
1	0.15	297.440	252.8223	**208.2066**
2	0.30	324.488	275.8148	**227.1416**
3	0.45	333.466	283.4461	**223.5566**
4	0.60	338.232	287.4972	**221.2172**
5	0.75	337.374	286.7679	**236.1618**
6	0.90	340.036	289.0306	**238.0252**

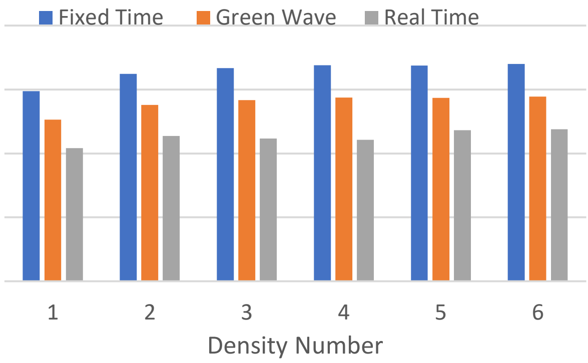

Figure 7. Comparison of average travel times.

According to the test results given in Table 3 and Figure 7, it is seen that the best values are found in the real-time system at all the densities.

In our tests, the number of vehicles which leaves the network is also compared with the number of vehicles which stays in the network. These data are shown in Table 4, Table 5, Figure 8 and Figure 9.

Table 4. Comparison of number of vehicles leaving the system

Density Number	Density Rate	Fixed Time	Green Wave	Real Time
1	0.15	649.20	719.60	754.44
2	0.30	1652.20	1706.40	1756.30
3	0.45	2641.20	2731.80	2748.78
4	0.60	3656.80	3754.20	3759.70
5	0.75	4657.40	4708.67	4759.94
6	0.90	5645.80	5698.84	5751.88

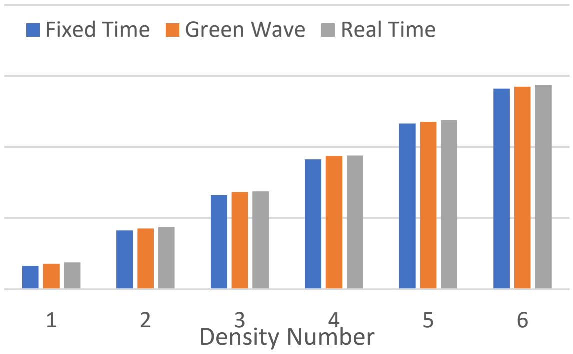

Figure 8. Comparison of number of vehicles leaving the system.

According to Table 4 and figure 8, it is seen that the number of vehicles leaving the system at density 2 is much better in real time traffic system.

Table 5. Comparison of number of vehicles remaining the system.

Density Number	Density Rate	Fixed Time	Green Wave	Real Time
1	0.15	350.8	280.40	245.56
2	0.30	347.0	285.60	242.90
3	0.45	358.6	268.00	251.02
4	0.60	343.0	245.60	240.10
5	0.75	341.8	290.53	**239.26**
6	0.90	353.6	300.56	247.52

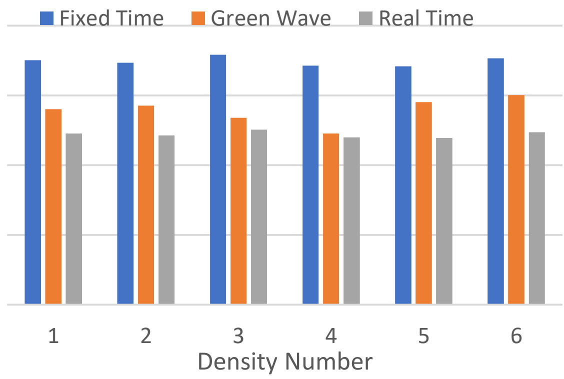

Figure 9. Comparison of number of vehicles remaining the system.

According to Table 5 and Figure 9, it is seen that the number of vehicles remaining in the system at density 5 is much better in the real-time traffic system.

5. Conclusion

Today, one of the biggest problems of the rapidly increasing urbanization is the traffic congestion. Among the factors that cause traffic congestion are the status of roads, the number of vehicles and intersection light systems. However, besides these, additional factors such as human factor, pedestrian traffic, and weather conditions also affect this. In this study, smart intersect light system is suggested for optimization of city traffic flow. The performance of the suggested system will reveal the most realistic and accurate results after testing in a real-world environment. However, testing in the real world is difficult due to time, cost and possibilities. Today, there are computer traffic simulation environments that simulate the traffic system in the real world and can obtain near-realistic results. We tested the smart intersection traffic light system developed in our study using vehicle and road inputs on SUMO City Traffic Simulation System. The simulation was carried out on 7 illuminated intersections along the about 8.5 km road between Karabuk and Safranbolu, modeled as a test area. In order to be close to the actual number and density of the vehicles that will enter the simulation model from the main and secondary routes, the values obtained by performing in-situ counts at certain intervals have already been used. Here, we have tested three different systems as the fixed light system applied to the existing road, green wave light system which we modeled and the smart intersection signal system which we recommend. Experimental tests were carried out with vehicle numbers in 6 different density levels, and test results were obtained. When the results were evaluated, it was seen that the proposed smart traffic light system performed better than both the fixed time light system and the green wave light system. When the model is run, all the roads are empty and depending on the different densities, it is not possible for all of the vehicles (between 1002-6010) to enter the system due to the queues in the main and secondary roads during the test period.

Future studies may improve the entrance of vehicles into the system so that the test environment will be closer to reality. It is also aimed to perform tests with different traffic optimization algorithms on the same system and compare them with the proposed system.

Acknowledgment

This paper is based on master thesis titled "Comparison of Traffic Ligth System Optimization"

References

[1] K. Gyimesi, C. Vincent and N. Lamba, "Frustration Rising IBM 2011 Commuter Pain Survey," IBM, N.Y, USA, 2011.

[2] Pengfei Lia, Pitu Mirchandani and Xuesong Zhou, "Solving simultaneous route guidance and traffic signal optimization problem using space-phase-time hypernetwork," *Transportation Research Part B* , vol. 1, no. 81, 2015.

[3] M.C. Bell, R.D. Bretherton, "Ageing of Fixed-Time Trafifc Signal Plans," London, 1986.

[4] D.Robertson, Hunt P, "Estimating the benefits of signal coordination using TRANSYT or SCOOT," London, 1983.

[5] W. Xiaoping, D. Shuai, D. Xiaohong and M. Jing, "Green-Wave Traffıc Theory Optimization," no. 2, 2014.

[6] K. Tobita, T. Nagatani, "Green-Wave Control of an Unbalanced Two-Route Traffic System with Signals," *Physica A: Statistical Mechanics and its Applications,* 2013.

[7] P. Hunt, D. Robertson, R. Bretherton and R. Winton, "SCOOT: a traffic responsive method of coordinating signals," Transport and Road Research Laboratory, Crowthome, 1981.

[8] C. Mingjin, X. Huizhong, J. Zhilin, F. Yun and X. Jiangping, "An Overview of the Usage of Adaptive Signal Control System in the United States of America," *Applied Mechanics and Materials,* no. 178-181, pp. 2591-2598, 2012.

[9] P.R. Lowrie, "The Sydney Coordinated Adaptive Traffic System," in *Engineering Foundation Conference on Research Directions in Computer Control of Urban Traffic Systems,* California, 1979.

[10] Inchul Yang, R. Jayakrishnan, "Real-Time Network-Wide Traffic Signal Optimization Considering Long-Term Green Ratios Based on Expected Route Flows," *Transportation Research Part C,* vol. sayı 60, 2015.

[11] L. Liao, "A Review of the Optimized Policies for Adaptive Control Strategy (OPAC)," California Path Program Institute of Transportation Studies University of California, Berkeley, 1998.

[12] D. Zubillaga, G. Cruz, L. D. Aguilar,J. Zapotecatl,, N. Fernandez,J. Aguilar,D.A. Rosenblueth and C. Gershenson, "Measuring the Complexity of Self-organizing Traffic Lights," *Entropy,* vol. 16, no. 5, pp. 2384-2407, 2014.

[13] Institute of Transportation Systems , "DLR," Institute of Transportation Systems , [Online]. Available: http://www.dlr.de/ts/en/desktopdefault.aspx/tabid-9883/16931_read-41000/. [Accessed Kasım 2017]

[14] L. S. Jones, M. D. Anderson, D. Malave and A. J. Sullivan, "Traffic Simulation Software Comparison Study," University of Alabama, Birmingham, 2004.

[15] S. Algers, E. Bernauer, M. Boero, L. Breheret, C. D. Taranto, M. Dougherty, K. Fox and J.F. Gabard, *Review of Micro-Simulation Models,* Leeds: SMARTEST, 1997.

[16] L. José, E. Pereira,J. Rosaldo and F. Rossetti, "An Integrated Architecture for Autonomous Vehicles Simulation," in *Proceedings of the 27th Annual ACM Symposium on Applied Computing,* Porto, 2011.

[17] A. T. Karadeniz, *Trafik Optimizasyon Sistemlerinin Karşılaştırılması,* Karabük: Karabük Üniversitesi Fen Bilimleri Enstitüsü Bilgisayar Mühendisliği Ana Bilim Dalı, 2016.