ÖHÜ Müh. Bilim. Derg. / OHU J. Eng. Sci.

ISSN: 2564-6605
doi: 10.28948/ngumuh.386593
Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi, Cilt 7, Sayı 1, (2018), 217-223
Omer Halisdemir University Journal of Engineering Sciences, Volume 7, Issue 1, (2018), 217-223

Araştırma / Research

COMPARISON OF TRAFFIC DENSITIES AT DIFFERENT SIGNALIZATION TIMINGS IN ROUNDABOUTS

Erinç ULUDAMAR (ORCID ID: 0000-0001-5247-5057)[1*]
Gökhan TÜCCAR (ORCID ID: 0000-0003-3041-299X)[2]

[1] *Otomotiv Mühendisliği Bölümü, Mühendislik ve Doğa Bilimleri Fakültesi, Adana Bilim ve Teknoloji Üniversitesi, Adana, Türkiye*
[2] *Makine Mühendisliği Bölümü, Mühendislik ve Doğa Bilimleri Fakültesi, Adana Bilim ve Teknoloji Üniversitesi, Adana, Türkiye*

Geliş / Received: *06.04.2016*
Kabul / Accepted: *05.10.2017*

ABSTRACT

The increasing number of vehicles triggers traffic jam which is one of the most important problems that occurs in crowded cities. Signalization timing has a crucial role in controlling traffic flow and decreasing loss of time in city traffic. In order to reduce queue length and vehicle delays in traffic, the estimation of traffic concentration at different signalization timings plays an important role. Traffic simulation tools such as RODEL, SIDRA, and VISSIM are used to understand the behavior of vehicles in traffic. In this study, VISSIM program was used to demonstrate queue lengths, vehicle delays and vehicular emission formations in a roundabout at different signalization timings. The study has been evaluated on a real case study to verify the differences between current and proposed states. A roundabout in Adana (Turkey) was selected which is located at the city center with over-saturated traffic density for a case study. The model indicated that increment of the green time period of the south road from 22 seconds to 28 seconds resulted in improved queue lengths, vehicle delays and emission formations of the vehicles which were around the roundabout.

Keywords: Optimization, traffic signalization, VISSIM, emission

DÖNER KAVŞAKLARDA FARKLI SİNYALİZASYON ZAMANLAMASINDAKİ TRAFİK YOĞUNLUĞUNUN KARŞILAŞTIRILMASI

ÖZ

Artan araç sayısı kalabalık şehirlerde oluşan en önemli problemlerden biri olan trafik sıkışıklığını tetiklemektedir. Sinyalizasyon zamanlaması trafik akış kontrolünde ve şehir trafiğinde kaybedilen zamanın azalmasında çok önemli bir rol üstlenmektedir. Kuyruk uzunluğunu ve trafikteki araç gecikmelerini azaltmak için farklı sinyalizasyon zamanlamalarındaki trafik yoğunluğunun tahmini önemli bir rol oynamaktadır. RODEL, SIDRA ve VISSIM gibi trafik simülasyon programları araçların trafikteki davranışlarını anlamak için kullanılmaktadır. Bu çalışmada, VISSIM programı değişik sinyalizasyon zamanlamalarında döner kavşak etrafında oluşan kuyruk uzunluğu, araç gecikmesi ve araç emisyon oluşumunu göstermek için kullanılmıştır. Çalışma, mevcut ve önerilen durum arasındaki farkları doğrulamak için gerçek bir durum çalışması üzerinde değerlendirildi. Durum çalışması için Adana (Türkiye) şehir merkezinde yer alan, aşırı trafik yoğunluğu bulunan bir döner kavşak seçilmiştir. Model, güney yolunun yeşil ışık periyodunun 22 saniyeden 28 saniyeye yükselmesinin, kavşak etrafında yer alan araçların kuyruk uzunluğunu, araçların gecikmesini ve araç emisyon oluşumlarını iyileştirdiğini gösterdi.

Anahtar Kelimeler: Optimizasyon, trafik sinyalizasyonu, VISSIM, emisyon

[*]Corresponding author / Sorumlu yazar. Tel.: +90 532 578 22 16; e-mail / e-posta: euludamar@adanabtu.edu.tr

1. INTRODUCTION

Majority of crowded cities are facing with urban traffic-related problems as their main point of concern [1]. Vehicle density of highways increases dramatically due to insufficient capacity of the street and road networks, as well as highly dynamic changes in road conditions and poor predictability of the behavior of road users [2]. Intersection jam occurs as a result of growing volume of traffic.

Roundabouts are critical points of traffic since vehicles decide their traffic routes at roundabouts where high traffic concentration occurs. Roundabouts can be classified into several different categories based on environment, number of lanes, and size [3]. About 17-35% of total traveling time is spent due to delays at intersections [4]. Simulation models are widely used in analysis of urban traffic and estimation of traffic density since they have specialties of economy, repeatability, and practicability.

The main objective of traffic signalization is to arrange road capacity and decrease queue lengths, while ensuring safe travel at busy intersections. There have been a large number of researches in order to understand traffic flow trend which represents traffic situation in developed countries [5-8]. Researches have shown that optimization of signal timings has positive effects on both vehicular emissions and fuel consumption [9, 10].

Ming [11] evaluated how well different software packages such as RODEL, SIDRA and VISSIM predict capacity, queue length and delay for congested roundabouts, using data from East Dowling Road Roundabouts in Alaska. The authors made the following conclusions: whereas VISSIM had the best estimation; RODEL, SIDRA and VISSIM simulation programs all overestimated the capacities. Nikolic et al. [12] analyzed six different roundabout evaluation tools (AIMSUN, PARAMICS, VISSIM, SIDRA, NCHRP, RODEL and ARCADY) by applying them to five locations and they compared delay estimations with field data. The authors indicated that there was no significant difference between the delay estimation values between the six software packages used at low-moderate traffic volumes, whereas PARAMICS, VISSIM and AIMSUN showed more reasonable prediction results at higher traffic volumes. Among the micro-simulations model analyzed AIMSUN and VISSIM provided the best results. Fernandes et al. [13] were analyzed an urban corridor with roundabout and traffic light with the aid of VISSIM. They found out that roundabout resulted with lower queue length and vehicle emissions than the traffic light control. Lin et al. [8] were also studied with VISSIM. In their study, four different scenarios about Beijing Central Business District were made up to observe the differences between travel time and speed as well as queue length and delay. Lakouari et al. [14] were examined the traffic flow at single-lane traffic circle and roundabout by using a numerical simulation method. The study concluded with the roundabout performed better on short size system and traffic circle performed better on large size system. Meneguzzer et al. [15] used an instrumented vehicle to measure its exhaust emissions at traffic signal and roundabout controlled road intersections. Although the results were not always statistically significant, instead of traffic signal, roundabout tends to lower carbon dioxide emission, whereas traffic light has a better effect on nitrogen oxide emissions.

VISSIM is a microscopic time step and behavior based simulation model that has a variety of usage area in simulating traffic conditions. It is a useful tool in evaluating different traffic management scenarios to decide the best alternative and optimization measures before implementation [8]. It can analyze public and private transport operations making it a useful tool for evaluation of various alternatives for transportation planning [16].

Ilbank roundabout is one of the most jammed areas which is located at the intersection of four main roads in Adana. Each of those roads is combining the city center of Adana to educational campuses such as campus of number of high schools and campus of Cukurova University. The aim of this study was to conduct optimization of signalization timings by comparing effects of varying signalization timings on different parameters such as vehicle delay, queue length and vehicle emissions. Four different signalization timing scenarios were compared in order to explore advantages of advancing of red light for intense traffic flow. VISSIM software was used in order to simulate traffic flow throughout the study.

2. MATERIAL AND METHODS

Traffic intensity in Ilbank roundabout increases dramatically during morning hours since nearly 4000 vehicles enter into that roundabout within 15 minutes between 07:30 and 07:45. Main traffic jam occurs in the south road since the population intensity in south Adana is very high. Those people who live in the south region try to reach their school and university campus by using the south road and the road normally cannot overcome that kind of demand. Long queues form periodically throughout the road. As a result, it takes number of minutes to pass the roundabout.

The queue formed in the south road can be decreased by increasing green time duration for that road since other three roads have not that kind of intensity especially during morning hours. Therefore, special signalization

timing is necessary during morning hours to overcome the traffic jam occurs in the southern road which is the main aim of this study. The satellite image, photograph and screen shot of the model of the intersection is shown in Figures 1 and 2, respectively.

Figure 1. Satellite image and photograph of modelled intersection

Figure 2. Screen shot of VISSIM simulation model

Vehicle delays are the results of queues formed in traffic. Optimization in traffic signalization is conducted in order to reduce queue lengths and vehicle delays at that roundabout. For the simulation of the roundabout, VISSIM software is selected. VISSIM is a microscopic simulation software that uses the pyscho-physical perception model [15-16]. The program is capable to analyze various type of transportation operations [18].

PTV VISSIM software is designed to model vehicle traffic on the street and road networks. In the present study, this software was used to analyze the traffic signalization of the traffic at the roundabout. The input data were collected by means of video filming at the roundabout of Ilbank roundabout. The roundabout was modeled by considering different signalization times.

In VISSIM, the simulation consists of three modules - the input module, the simulator module and the output module. A Windows based graphical user interface is used in the input module. For the collection of statistical data, simulator module is used. The output module is usually composed of a text file or an animation.

The allowable limit for deviation of field data and simulated values should not exceed 15% for acceptable simulation results. In this study, field delay values were also recorded and compared with the simulation results; in order to ensure that simulation data stay within acceptable limits.

In the simulation of a traffic, some input field data has to be entered to the VISSIM software in order to acquire desired data. Geometries of connectors and links, numbers and compositions of vehicles, priority rules are some of the required data in preparation of model in VISSIM software. Simulation software can compute vehicular emissions, vehicle travel times and queue lengths formed at selected ways by the use of that data. Some inputs and outputs of VISSIM software are shown in Table 1.

Table 1. Some input and output values used in VISSIM

Inputs	Outputs
Geometries of links and connectors	Vehicle Delay Time
Vehicle volumes	Queue Length
Signalization timings	Fuel Consumption
Vehicle compositions	Emission Gases
Road priority rules	Vehicle Travel Times

3. RESULTS AND DISCUSSION

According to field data, the roundabout has total signalization period of 60 seconds. The green time period of south road takes 22 seconds, whereas red time period takes 36 seconds and amber time takes 2 seconds. Since vehicle composition of vehicles in traffic on Ilbank roundabout shows similar characteristics to default vehicle compositions of VISSIM, no particular vehicle compositions were entered into the program. Vehicle volumes were estimated according to data of number of students and employees traveling to university campus during morning time.

The time period of 16 minutes between 07:30 and 07:46 was selected for the analysis. Travel times that are obtained from the field were compared with data obtained from simulation in order to validate the output of VISSIM software. Travel times within different time intervals for 22 seconds green time is shown in Table 2. Travel time taken from the field at 07:34 was 97 seconds which deviates around 5.46% compared to 102.3 seconds obtained from the simulation values.

Table 2. Variation of travel time values between different time intervals

Time Interval	Travel Time (Sec)
07:30-07:32	48.1
07:32-07:34	102.3
07:34-07:36	121.7
07:36-07:38	182.4
07:38-07:40	215.3
07:40-07:42	253.4
07:42-07:44	312.2
07:44-07:46	372.9

The greatest expected benefit of transport improvement projects is time economy since travel time is one of the most important expenditure items of transport costs. Figure 3 shows variation of travel time for different green times. As can be seen from Figure 3, travel times reduced with the increased green times. An average of about 14.7% reduction occurs for 22 sec. green time compared to 28 sec. The value of travel time reduction amount is higher at later stages than that of at earlier periods.

Queue length is considered as an important parameter in traffic engineering since it determines the capacity of traffic volumes of the roads. At signalized roundabouts, queue lengths at the traffic lights are of greatest importance for dimensioning the sizes of the lane. The variation of queue length values for different green time periods is presented in Figure 4. Queue lengths values were reduced by nearly 27.3% for 28 seconds green length compared to 22 seconds green length according to simulation results.

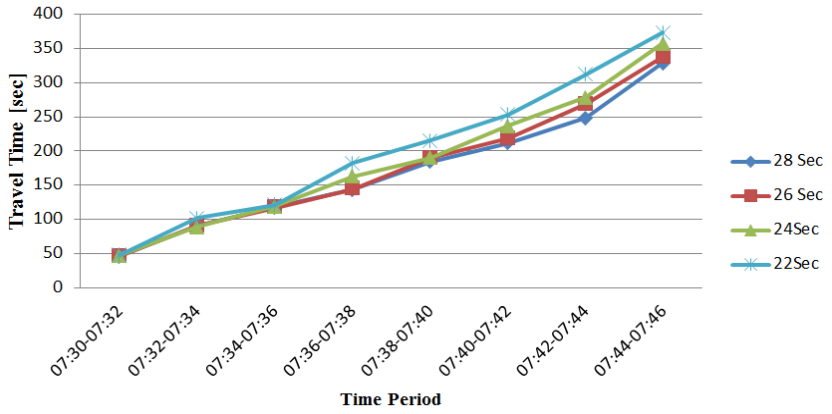

Figure 3. Variation of travel time values for different green times within 2 minutes of time periods

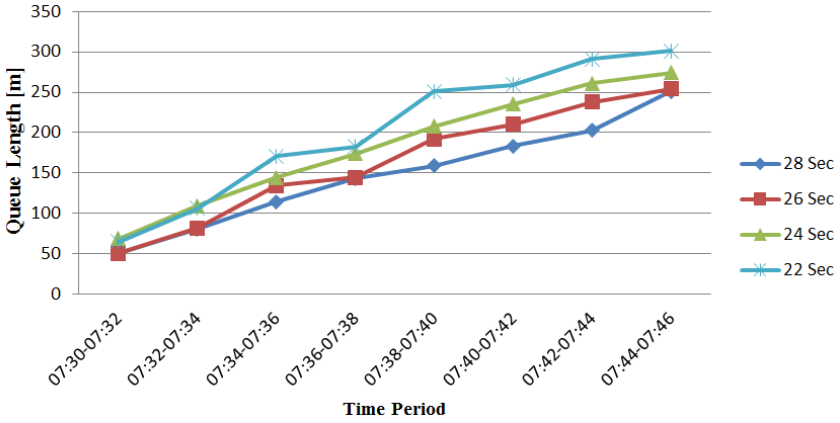

Figure 4. Variation of queue lengths for different green times within 2 minutes of time periods

Carbon (C) present in fossil fuels reacts with oxygen (O_2) molecules present in the atmosphere during combustion. If there are enough O_2 molecules, C atoms combine with O_2 molecules to produce carbon dioxide (CO_2). During incomplete combustion, carbon is not completely oxidized, as a result carbon monoxide (CO) molecules form. Therefore, CO_2 emission is produced by complete combustion of fuel. Figure 5 demonstrates the variation of calculated CO_2 emission values for different green time values. There is an average of 20.64% reduction in total CO_2 emission values when 28 sec green time is used instead of 22 sec.

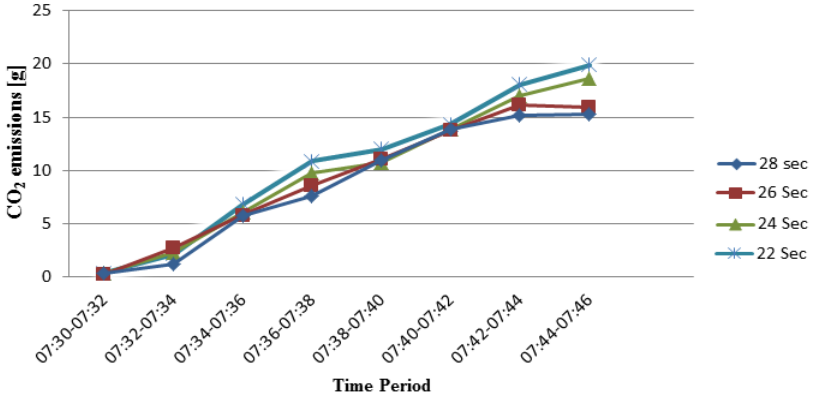

Figure 5. Variation of total CO_2 emissions for different green times within 2 minutes of time periods

Another significant diesel emissions are nitric oxides. Nitrogen is an inert gas at room temperature, however it remains inert up to a certain temperature (1100^{o}C) and above this temperature reacts with O_2 molecules. At the end of combustion, gas temperature inside cylinder arises around 1500^{o}C. At this temperature oxidation of nitrogen takes places in presence of oxygen inside the cylinder, as a result NO_x formation occurs. According to simulation results, NO_x formation within 16 minutes in roundabout is reduced by nearly 5.25% when 28 seconds of green time is arranged instead of 22 seconds.

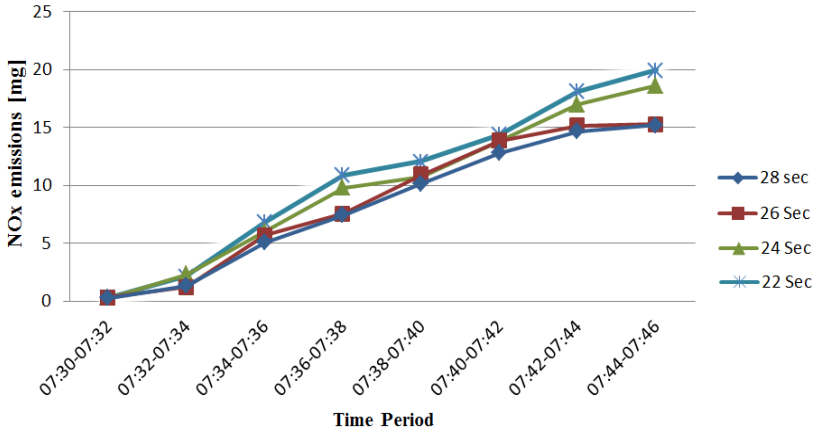

Figure 6. Variation of total NO_x emissions for different green times within 2 minutes of time periods (metin içerisinde atıf yapılmalıdır)

4. CONCLUSIONS

Traffic density near roundabouts triggers exhaust emissions created by the vehicles since emission level is maximum particularly during idling and acceleration period. A model was created for estimation of traffic density and exhaust emissions with different signalization timings in Ilbank roundabout. By the help of this model, some parameters such as travel time spent in traffic, queue length formation and exhaust emissions were discussed under different green time durations. The traffic situation during morning hours in Ilbank roundabout was simulated in order to optimize signalization timing at the intersection.

- According to simulation results, increase in green time for south road has a significant effect on vehicle travel time, queue length and vehicular emissions, since south road intensity is very high during morning hours compared to other roads.
- 28 sec. green time reduced the travel time by 14.7%, queue lengths were shortened by 27.3% and the improvement of vehicle emission was observed as 20.64% and 5.25% for CO_2 and NO_x, respectively compared to 22 sec.
- The traffic signals are advised to be re-arranged that they provide more green time for vehicles try to enter the roundabout from the south. So that, lower traffic jam would occur.

REFERENCES

[1] CUADRA, L., "Technological Forecasting & Social Change Soft-Computing: An Innovative Technological Solution for Urban Traffic-Related Problems in Modern Cities", Technol. Forecast. Soc. Chang., 89, 236–244, 2014.

[2] YUSUPBEKOV, N.R., MARAKHIMOV, A.R., IGAMBERDIEV, H.Z., UMAROV, S.X., "Application of Soft-Computing Technologies to the Traffic Control System Design Problems", Procedia - Procedia Comput. Sci., 102, 540–546, 2016.

[3] GALLELLI, V., VAIANA, R., IUELE, T., "Comparison Between Simulated and Experimental Crossing Speed Profiles on Roundabout with Different Geometric Features", Procedia - Soc. Behav. Sci., 111, 117–126, 2014.

[4] NIELSEN, O.A., FREDERIKSEN, R.D., SIMONSEN, N., "Using Expert System Rules to Establish Data for Intersections and Turns in Road Networks", 5, 569–581, 1998.

[5] YUN, M., JI, J., "Delay Analysis of Stop Sign Intersection and Yield Sign Intersection Based on VISSIM", Procedia - Soc. Behav. Sci., 96, 2024–2031, 2013.
[6] SINGH, M., PONNU, B., ARKATKAR, S.S., "Modeling of Traffic Flow on Indian Expressways Using Simulation Technique", Procedia - Social and Behavioral Sciences, 43, 475–493, 2012.
[7] QUAASSDORFF, C., BORGE, R., PÉREZ, J., LUMBRERAS, J., DE PAZ, D., DE ANDRÉS, J.M., "Science of the Total Environment Microscale Traffic Simulation and Emission Estimation in a Heavily Trafficked Roundabout in Madrid (Spain)", Sci. Total Environ., 567, 416–427, 2016.
[8] LIN, D., YANG, X., GAO, C., "VISSIM-based Simulation Analysis on Road Network of CBD in", Procedia - Soc. Behav. Sci., 96, 461–472, 2013.
[9] MARSDEN, G., BELL, M., REYNOLDS, S., "Towards a Real-Time Microscopic Emissions Model", Transp. Res. Part D Transp. Environ., 6, 37–60, 2001.
[10] RAKHA, H., DING, Y., "Impact of Stops on Vehicle Fuel Consumption and Emissions", Journal of Transportation Engineering, 129, 23-32, 2013.
[11] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.481.7349&rep=rep1&type=pdf (accession date 24.02.2016)
[12] NIKOLIC, G., ENG, P., PRINGLE, R., RANKIN, M., BRAGG, C.K., "Evaluation of Analytical Tools used for the Operational Analysis of Roundabouts", Proceedings of Annual Conference of the Transportation Association of Canada. Halifax Nova Scotia, Canada, 2010.
[13] FERNANDES, P., COELHO, M.C., ROUPHAIL, N.M., "Assessing the Impact of Closely-Spaced Intersections on Traffic Operations and Pollutant Emissions on a Corridor Level", Transp. Res. Part D Transp. Environ., 54, 304–320, 2017.
[14] LAKOUARI, N., EZ-ZAHRAOUY, H., BENYOUSSEF, A., "Traffic Flow Behavior at a Single Lane Roundabout as Compared to Traffic Circle", Phys. Lett. Sect. A Gen. At. Solid State Phys., 378, 3169–3176, 2014.
[15] MENEGUZZER, C., GASTALDI, M., ROSSI, R., GECCHELE, G., PRATI, M.V., "Comparison of Exhaust Emissions at Intersections under Traffic Signal Versus Roundabout Control Using an Instrumented Vehicle", Transp. Res. Procedia, 25, 1597–1612, 2017.
[16] https://tr.scribd.com/document/349536639/Manual-VISSIM-540-e-pdf (accession date 29.09.2017).
[17] HUANG, F., LIU, P., YU, H., WANG, W., "Identifying If VISSIM Simulation Model and SSAM Provide Reasonable Estimates for Field Measured Traffic Conflicts at Signalized Intersections", Accid. Anal. Prev., 50, 1014–1024, 2013.
[18] SIDDHARTH, S.M.P., RAMADURAI, G., "Calibration of VISSIM for Indian Heterogeneous Traffic Conditions", Procedia - Soc. Behav. Sci., 104, 380–389, 2013.