Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 48, S. 34-39, Şubat 2023

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 48, pp. 34-39, February 2023

Research Article

Baghdad Vehicle Traffic Congestion: Case Study

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(1st International Conference on Frontiers in Academic Research ICFAR, February 18-21, 2023)

(**DOI:** 10.31590/ejosat.)

ATIF/REFERENCE: Ali, S. A. M. & Al-Hemiary, E. H. (2023). Baghdad Vehicle Traffic Congestion: Case Study. *European Journal of Science and Technology*, (48), 34-39.

Abstract

Vehicles contribute a considerable amount of green gas emission to the environment. Methods of calculating such emission using conventional measuring tools do not give an accurate future estimation as the number of vehicles increases, since there are many factors that affect the estimation such as traffic delays. Therefore, a different approach is should be considered in measuring road networks traffic capacity for a specific region, especially when the numbers of vehicles change dramatically during rush hours. Furthermore, the amount of fuel consumption wastage during traffic delays cannot be easily calculated based of on the number of vehicles solely. In this paper, a comprehensive study is made to examine and to calculate the effect of traffic congestion in Baghdad city of Iraq in terms of: pollution, fuel consumption, and time cost, using the road network simulator of SUMO. Several scenarios are considered with randomly selected paths for each vehicle. In this study, several empirical equations are extracted from the simulation test results. As a result, an aberration is observed in fuel consumption and traffic delays while exceeding 100 thousand vehicle capacity for the whole city of Baghdad. However, the interpolated equations can be used to approximately measure the traffic metrics for higher number of vehicles for the same city.

Keywords: Congestion, Road Traffic, SUMO, V2X, Gas Emission.

Bağdat Araç Trafiği Sıkışıklığı: Vaka Çalışması

Öz

Taşıtlar çevreye önemli miktarda yeşil gaz emisyonuna katkıda bulunur. Geleneksel ölçüm araçları kullanılarak bu tür emisyonları hesaplama yöntemleri, trafik gecikmeleri gibi tahmini etkileyen birçok faktör olduğundan, araç sayısı arttıkça doğru bir gelecek tahmini vermemektedir. Bu nedenle, özellikle trafiğin yoğun olduğu saatlerde araç sayısı önemli ölçüde değiştiğinde, belirli bir bölge için karayolu ağlarının trafik kapasitesinin ölçülmesinde farklı bir yaklaşım düşünülmelidir. Ayrıca, trafik gecikmelerinde yakıt sarfiyatı israfının miktarı sadece araç sayısına göre kolayca hesaplanamamaktadır. Bu bildiride, Irak'ın Bağdat şehrinde trafik sıkışıklığının kirlilik, yakıt tüketimi ve zaman maliyeti açısından etkisini SUMO'nun yol ağı simülatörü kullanılarak incelemek ve hesaplamak için kapsamlı bir çalışma yapılmıştır. Her araç için rastgele seçilen yollarla çeşitli senaryolar dikkate alınır. Bu çalışmada, simülasyon testi sonuçlarından çeşitli ampirik denklemler çıkarılmıştır. Sonuç olarak, Bağdat şehrinin tamamı için 100 bin araç kapasitesi aşılırken, yakıt tüketiminde ve trafik gecikmelerinde bir sapma gözleniyor. Bununla birlikte, enterpolasyonlu denklemler, aynı şehir için daha fazla sayıda araç için trafik ölçümlerini yaklaşık olarak ölçmek için kullanılabilir.

Anahtar Kelimeler: Sıkışıklık, Karayolu Trafiği, SUMO, V2X, Gaz Emisyonu.

1. Introduction

Many metropolitan cities around the world have issues of traffic congestion in specific hours of a day, rush hours, as a result of huge number of vehicles operating at the same time. To pinpoint the congestion reasons, complete traffic studies are made to collect useful information about the behavior of such congestions. These studies will be useful to find appropriate solutions to reduce the amount of traffic congestion such as: efficient traffic management system, new road planning, intelligent traffic systems, especially V2X (Vehicle-to-Everything) world is blooming (Ali & Al-Hemiary, 2021).

In this paper, a study is made to give useful information about how traffic congestion is variant as the number of vehicles are increasing, and how vehicle trip numbers increment will increase the greenhouse gas emissions exponentially, plus the amount of unneeded fuel consumption due to traffic flow congestions. Baghdad city is chosen because it is considered one of the largest urban cities in the region with population exceeds 8 million capita (WP, 2023), with number of vehicles registered in the city above 2.7 million (COSIT, 2023), (see Fig. 1). Sumo simulation tool is used to conduct the road simulations. Other tools used to extract the road information, build vehicle networks, and finding the best routes.

Thus, future traffic congestion effects can be speculated and how new technologies, V2X applications and services can be beneficial to overcome and reduce the issues produced by traffic congestions (Ali & Al-Hemiary, 2020). The following section include the main objectives of the study, then followed by similar studies for other cities around the world. After then, the main study metrics are explained, followed by study results and observations..

The main objective of this study can be summarized in the following list:

- To justify the purpose of the paper, as the problem statement states how vehicles contribute a significant amount of world greenhouse gas pollution.

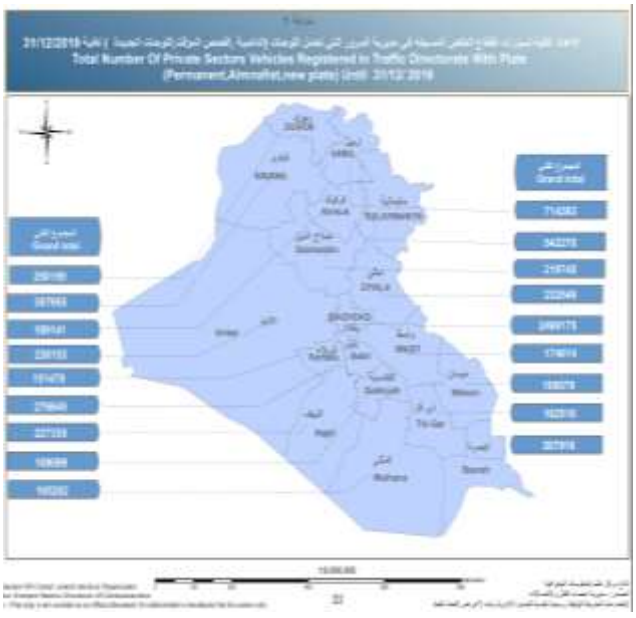

Fig. 1. Vehicles numbers in Iraq governorates till 2020

- To measure the capacity of the road network of the city and when it will be congested at most.
- To produce approximate evaluation and mathematical equations that describes the behavior of the road network as the tremendous increasing of vehicles inside the city (Baghdad City, specifically speaking). Thus that, future speculation can be easily computed.
- The study results will be beneficiary to vehicular network planning and identify the mobile network capacity in terms of latency, data rate, and number of telecommunication towers.
- The study will evaluate the economic cost and loss of revenue due to the inefficient use of roads and excessive use of fuel that if utilized properly a significant amount will be saved.

Several associated studies were adopted around the world to study the urban traffic network congestions for planning and evaluations. In (Alshaya et al., 2019), the paper emphases on the various road traffic simulation software including (Sumo) that are used by many researchers to find useful statistics of studying traffic of the city of Rome. In (Schweizer et al., 2021), a large-scale simulation has been made for the city of Bologna (Italy). The simulation covers pedestrians, bikes, scooters, and other vehicles in rush hours using (Sumo) simulation tool. In (Khumara, 2018), similar simulation has been conducted to build the smart city concept, through devising intelligent traffic systems (ITS). Similar simulation tools used to determine road congestion bottlenecks, and measure the optimum vehicle speeds to present better traffic configurations.

The rest of the paper includes the study metrics, followed by tools used in the study, and then the study steps that had been carried out. The results and discussion in the following section, and the last section concludes the paper.

2. Material and Method

2.1. Lıterature Revıew

Baghdad is the capital of Iraq, and it considered as one with the largest population of the country. Thus, Baghdad is a good example that suffers from excessive traffic congestion compared to other cities in the region. Likewise, the researcher in (Alshaya et al., 2019) worked extensively to reduce the traffic congestion in Rome, which suffers from traffic congestion distinctively by analyzing the source of the congestion through several experiments and simulations. Other related research works conducted by (Barrachina et al. , 2014) and (Benner et al., 1993), which is basically exploiting computer tools to perform accurate simulations. In (Fontaras et al., 2015) some work done to evaluate the source of CO2 emission from vehicles by plotting a model for it. Also, through using specific junction simulation, (Strohmandl et al., 2015) have presented a method of light controlling of the traffic.

As the part of solving problems of traffic congestions. Some researchers were successful to develop simulation scenarios by using objective analysis, i.e., conducting manual survey, and collecting real data by monitoring and observing. In this way, a direct approach is taken to identify the problems and finding the perfect solution for it. In (Ma et al., 2014), they integrate some road network metrics to build a calibration model to deliver some measurements that cannot be taken from direct management. In (Bieker-Walz et al., 2015), they have used a similar approach of

what we perform in this paper for the city of Bologna, Italy. Similarly, (Vent, 2015) have conducted similar approaches to build a simulation package for the city of Dublin, Ireland by using real data of the past few years. In (Huang et al., 2014), a simulation study is conducted for vehicles that are accessing highways by using variate speed limits, so they can analyse vehicle crash rates

2.2. Study Metrıcs

In this section, road traffic metrics that are essential to the simulation are presented and explained. These metrics identifies the main problems and issues of traffic networks that can be mitigated or avoided through using more efficient traffic controls and configurations. The following traffic metrics are used in this study:

- Trip Duration (seconds): each vehicle trip has a starting point and destination point within the map. This metric defines the amount of time required the vehicle to reach its destination through following the roads in a simulated map. The trip duration measures all the delays that might the vehicle faces during the trip such as, traffic light waiting (planned waiting), slow traffic motion (lower speed than usual), traffic congestion time loss. This metric is very important in measuring the traffic flow rates in a specific area.

- Route Length (meters): This metric measures the distance the vehicle travelled to reach its destination. The route is pre-calculated by another tool, which uses the shortest path to accomplish the route.

- Time Loss (seconds): This metric measures the time lost due to driving under the speed limit. In other words, the value of time loss should be equal to zero if normal traffic flow is considered.

- Emissions (mg): the mass of the various gases is emitted while driving the vehicle. Types of emission include the following gases: CO2, CO, NOx, PMx, and HC.

- Fuel (ml): the amount of fuel consumed while finishing the trip in (letter). Hence, all vehicles are considered to be using the same fuel, which gasoline.

2.3. Study Steps

In this section, the previous metrics are applied for the city of Baghdad (Iraq), such that, the whole map with all streets and road networks included are extracted from Open Street Map (OSM) website, which an open-source websites that provides geographical areas in XML format with road networks for researches. The road network of the city is shown in the Fig. 2.

The second step is to generate traffic networks of trips. Five networks are generated starting with 50 thousand trips and increasing by 50 thousand for bigger networks till reaching 250 thousand trips, which is more than the capacity of the city. The start and end points of trips are selected randomly, so unbiased results can be obtained. NetworkGen tool is used to accomplish this step.

Fig. 2. City of Baghdad (Iraq) map of roads network of most municipalities.

The third step is calculating the best route for each trip, for the start point to the arrival destination. Dijkstra algorithm is used for route calculation. This means all vehicles will take the shortest path with minimal fuel consumption; however, traffic congestion is not considered in the calculation, because it is undetermined, since all trips are generated randomly. Duaroute tool is used to calculate the shortest routes for each trip aside.

The fourth step, is to apply the routes to the map and measure the metrics for each trip alone. Sumo tool is used to accomplish this task. The simulation process is repeated for 5 networks with sizes of: 50K, 100K, 150K, 200K, and 250K trips. In each simulation, all the metrics mentioned previously are measured individually for each vehicle (trip). The following section shows the aggregated results of each trip.

2.4. Study Steps

To prepare for the simulation many tools are used to build simulation environment such as maps, roads, traffic, etc. And then this environment is used for V2X simulation (vehicles sent packets to the nearest base station). The following subsections introduces and explain the purpose of each tool.

- OpenStreetMap

OpenStreetMap (OSM) is an online available database of maps with road networks. It almost covers most cities and urban areas. Researchers and users can download regions of the map as an OSM map format which is in XML format. Large regions such as big cities require to download large amount of information which might exceed the capability of the online tool to download large sized regions. Other 3rd party tools are required to be used to access this information. OSM maps are editable and a user can easily modify the data to achieve specific endeavor. This tool is used to download the full road network map of Baghdad (used for the study of the next section), and small sized region of the city to be use in V2X simulation, since larges maps cannot be handled by mobile network simulators (Anonymous, 2017).

- JOSM

Java OSM is a helpful tool build by Java programming language, to edit and create OSM maps. Sometimes the download maps are outdated and streets or bridges are missing because of recent construction. This tool is used to correct the glitches and correct the road sizes in terms of direction (one-way or two-way) and number of lanes (Street width). Most of the roads were correct and modifications are required. Also, the tool is used to convert the OSM map into an accessible format by the other tools such as SUMO (Lopez et al., 2018).

- SUMO

SUMO, stands for Simulation of Urban Mobility, is vehicular traffic simulator developed in 2001 and since then it was upgraded many times to be compatible the world changes such as it is now supporting electrical car mobility. The tool was used to deploy various type of vehicular traffics into a specific map, and the simulator will generate useful output in many aspects. The generated log can be pre-assigned so the simulation will not take long time. Simulations of large maps usually takes a significant amount of time and sometimes the simulation crashes when there are no enough resources such: computer memory (RAM), or processing power (CPU). Therefore, careful measures should be taken before running the simulation.

3. Results and Discussion

3.1. Results

In this section, all the results obtained from the 5 simulations are presented. Each metric is presented separately based on each network size simulation. Fig. 3 shows the total road trips of all vehicles (trips) for the entire simulation. It is obvious from the results the graph appeared linearly, since, all trips are random and the increment of trips are equi-spaced in behavior. The empirical equation generated by the Exel software from the graph is,

$$y = 699724x - 22559 \qquad \text{(eq. 1)}$$

Where (y) represents the total trip length, while (x) represents the number of trips.

The duration of each trip is summed up to obtain the total duration of all trips conducted in each simulation aside. The total duration of all trips will explicitly show the period of time that vehicles were running. Fig. 4 shows the graph of the total duration. It is obvious how the graph has an aberration when the network size increased more than 100K trips, this means that the network capacity cannot handle smooth traffic, and more congestion will be on junctions, plus more wasted waiting time for vehicles.

The generated curve is a second-degree polynomial,

y = 6E+07x2 + 4E+07x - 4E+07 (eq. 2)

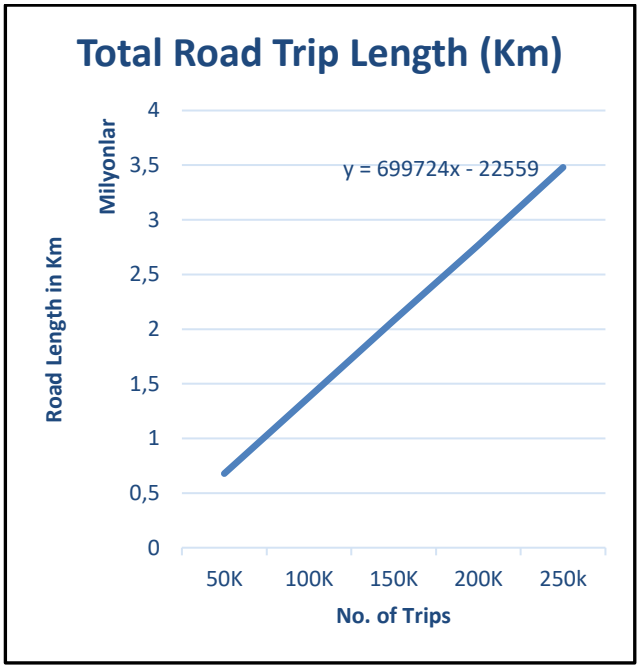

Fig. 3. Total road trips length for each simulation.

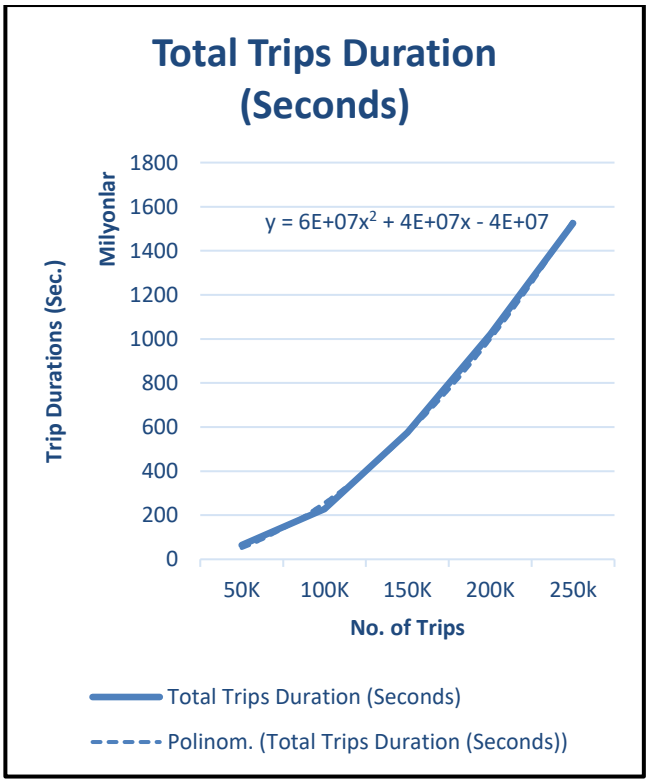

Fig. 4. Total traffic time loss in the network.

The simulation also measured the traffic time loss for each trip, waiting and stop time that is not supposed to be happen, such as heavy traffic congestion; however, waiting at a traffic light in junctions are not included in the measurement, in other words, the time loss is pure wasted time. Fig. 5 shows the graph related to the time loss for all 5 simulations. The generated polynomial from the graph is,

y = 5E+07x2 + 1E+07x - 4E+07 (eq. 3)

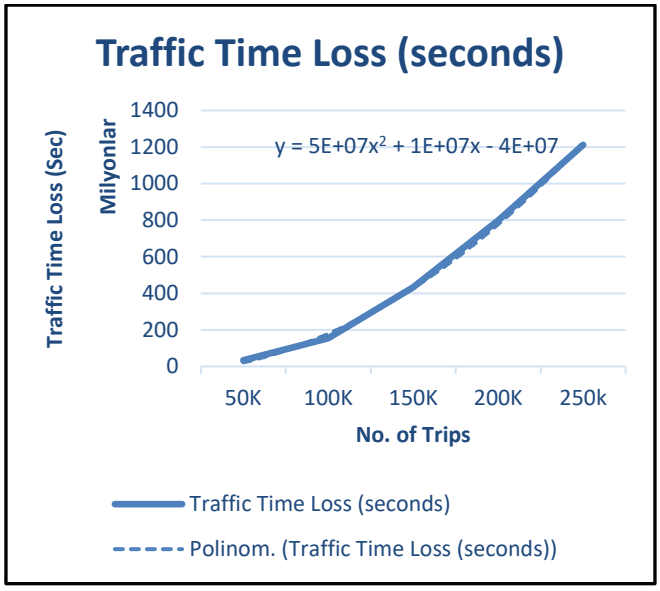

Fig. 6. Total traffic time loss in the network.

The fuel consumption is one of the most important metrics to measure, because it directly related to the total loss of revenue in traffic congestion, plus the amount of unnecessary pollution. Fig. 6 shows the graph of total fuel consumption of all vehicles in all simulations. The generated polynomial from the graph.

$$y = 49354x2 + 73240x - 41814 \quad \text{(eq. 4)}$$

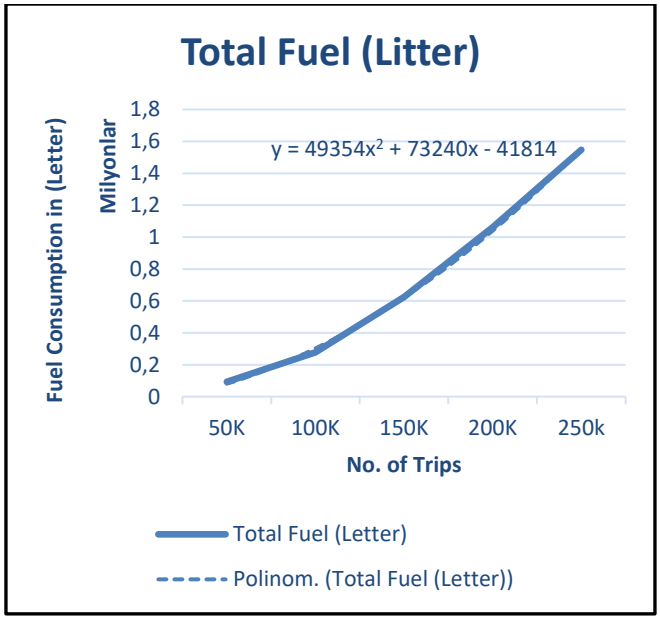

Fig. 5. Total Fuel Consumption in Letters.

The generated gas emission, which is combination of various types of greenhouse gas as shown in Table 1, is considered the amount of pollution being released to the atmosphere, which is the major reason of climate change and global warming. The total emissions of all vehicles within same simulation are aggregated and shown in Fig. 7.

TABLE I. THE AMOUNT OF EACH TYPE OF GAS IN EACH SIMULATIONS.

Trips	CO2(Kg)	CO(Kg)	HC (Kg)	NOx (Kg)	Total Emission (Kg)
50K	215477	6694	35.7	90.95	222298.4
100K	645481	26691	137	280.2	672590.31
150K	1453509	70579	356	643.1	1525087.8
200K	2469900	127777	640	1101.98	2599420.6
250k	3599365	191977	959	1612.58	3793915.3

The generated polynomial for graph is as follows:

$$y = 122160x2 + 174046x - 103236 \quad \text{(eq. 5)}$$

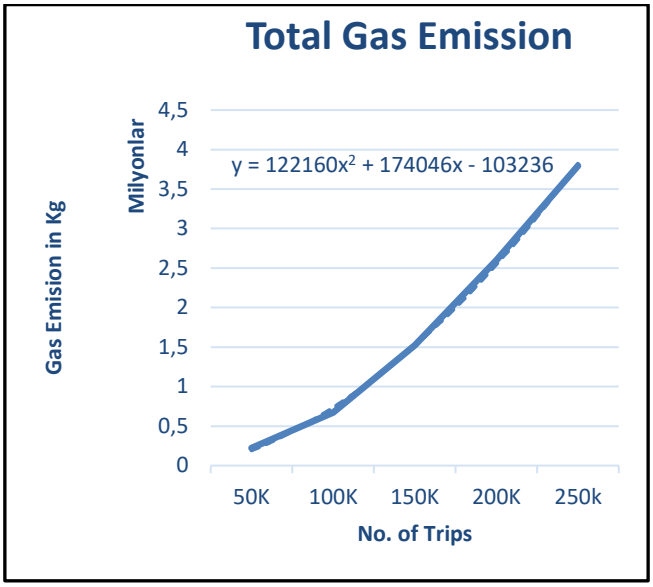

Fig. 7. Total Gas Emission in Kilograms.

3.1. Disscution

As can be seen in the results, the amount of total trips that each traffic metric is tested is between 50 k to 250k. Since the graphs showed a steady-state after 100K trips aberration, there will be no need to increase the number of trips furthermore. The abberation of the curve happens when the number of trips exceeded the 100K limit, which indicates the Baghdad city road networks capacity limit without significant delays in each trip.

4. Conclusions and Recommendations

As a conclusion, a comprehensive study is made to show the effect of increasing number of vehicles to traffic congestion. All the results indicate an aberration as the number of vehicles in the network exceeds 100 thousand. This means the total tolerable capacity of the city is below this number. These results also benefit the design of V2X systems, since it provides the necessary information about the vehicle distribution and network capacity. The same method can be applied to other cities through making proper changes to the simulation parameters.

It is recommended to use the same method to construct data models for crowded cities around the world. These data models can be useful to city road design and future traffic congestion predictions.

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