Evaluating the Negative Impact of Traffic Congestion on Air Pollution at Signalized Intersection
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Abstract:
Traffic Congestion is considered as one of the largest contributors to the problem of air pollution at present. A major part of this pollution is due to emissions from vehicles. Intersections are considered as critical elements of road regarding the high level of air pollution which is due to the slow down and stop operations. Thus, the combustion of fuel is increased negatively as intersection compared with other types of road elements. The key focus of this paper is to estimate the negative impact of traffic congestion by calculating the quantities of gases emitted during the traffic congestion at the signaled intersection in Baghdad city. The traffic flow data was obtained by video recording of the study area. From these videos, data was analyzed by using Signalized and Un-signalized Intersection Design and Research Aid (SIDRA 8.0.) software. The selected emissions of HC, CO, NOX, and CO2 in (kg/hr) are based on delay and LOS computation at the signalized intersection. The results of this study will provide suggestions to the transportation and public health officials to reduce the risk of air pollutant by trying different approaches such as eco-routing and eco-signal timing.

Keywords: air pollution, emitted gases, LOS , Sidra ,Traffic delay

1. Introduction
Traffic congestion in urban areas has considerably increased in most developing countries over the past 20 years. The most dominant source of air pollutant emissions is caused by vehicles [1]. As the number of vehicles is expected to double to two and a half times over the next 30 years, congestion will significantly worsen the quality of ambient air [2]. Intersections are commonly considered as high vehicular emissions points within the road network due to the acceleration and deceleration events of vehicles. The more time in congestion, the high percentage of fuel is consumed resulted in high vehicular emissions including carbon monoxide (CO), carbon dioxide (CO2), hydrocarbons (HCS) and nitrogen oxides (NOx) [1]. Emissions and fuel consumption are thought to be related to the decrease in congestion levels. Improvements in traffic congestion may improve the total amount of emissions. It is necessary to study the relation between traffic congestion and emissions by using a useful modeling tool to solve policies development, assessment and optimization problems.
In general, the aim of the study is to evaluate the measures for traffic congestion reduction and its impact on air pollution at the Al-Yarmouk intersection in Baghdad by assessing the impact of congestion on the emission of gases in a study area.

Few studies dealing with evaluating the congestion impact on air pollution. In this section, a short review of such studies is presented regarding the relationship between traffic congestion and vehicular emissions at road intersections. The two basic research approaches are modeling approach, often based on traffic simulation and vehicular emission models, and direct field approach of emission data collected by using Portable Emission Measurement Systems (PEMS). In 1996, a study of the Al-Quds Institute for Applied Research, the pollutant emissions amount was estimated based on the number of vehicles registered and licensed which used roads inside the West Bank. The result of the study suggested
pollution caused by carbon oxides, sulfur oxides, nitrogen oxides, hydrocarbons and lead. The study also reported that if performance is improved Light signals in downtown Nablus, the level of congestion decreases and therefore can reduce consumption Fuel up by about 31% on some streets of the city center, the rate of air pollution resulting from vehicles dropped to a ratio of up to 10% [3].

Another study in 2002, Al-Sahili, K. Abu-Eisheh, S. evaluate the effect of traffic congestion on fuel consumption and the emission of vehicle, estimation was obtained that the average fuel consumption per vehicle was 2.9 km / liter, and the total consumption of vehicles was about 1406 liters of fuel during rush hour. The carbon oxides emission rate per vehicle was about 14.5 g / km, and the amount of gases during the rush hour was about 51.3 kg [4].

Al Haddad et.al (2006), developed a mathematical model based on field measurements for predicting the amount of carbon dioxide pollutants from vehicles in Nablus. They recorded the percentages of 2CO, NO, 2SO, relative humidity and wind speed, simultaneously. The result displayed that the carbon monoxide was the main factor effect the air quality followed by other types of air pollutant with a low percentage of affection [5].

In another study by Adriano, et.al (2012), he developed an eco- driving Technique. The objective of this technique is to decrease the percentages of CO2 emissions from vehicle while driving. An innovative tool has been developed to obtain data and measure fuel consumption of a vehicle. An analytic method also developed to quantify the driving style influence on CO2 emissions. The results showed that if the entire observed car driver had implemented the eco-driving technique, CO2 emissions would have been lower up to 30% than the average typical speed in urban areas [6].

Jabir analyzed the travel time, delay time, degree of saturation, level of service and travel speed in Jordan intersection in Baghdad, Iraq using Sidra software. Data on number of vehicles passing Jordan intersection were recorded by the author from 7am to 3pm for four days. Data were analyzed using Sidra software. The results showed that Jordan intersection needs further developments like using intelligent transportation system application (ITS) to regulate traffic signals, whereby reducing traffic jam, using closed circuit TV (CCTV) might assist traffic office in identifying jam point, hence to reduce traffic jam [7].

Abdul Kareem, 2018 studied the calculation of the percentage of emitted gases from vehicle exhausts. The concentrations of polluting gases resulting from fuel combustion that was calculated for the two types (benzene and gasoline), those gases are namely Carbon Dioxide CO2, Carbon Monoxide CO, and Nitrogen N2. Then, consumption amount of Oxygen gas O2 was calculated. Whereby, the calculating of the total amount of fuel consumption was done by manually counting of the passing vehicles number and that was measured in two main intersections, Al-Sadrin Square and the Airport Square that had been checked starting from April 2017 for and for three months, once a week.The percentage of concentrations of gases emitted was high and its rate in the square of the Al-Sadrin, higher than at the Airport square [8].

Joni and Mohamed, (2016) analyzed the operational traffic flow of Al-Jadryia intersection by conducting field measurements and analyzing the obtained data using SIDRA software. The researchers concluded that SIDRA software performed a good analysis regarding the starting delay, stops, queues, capacities, flows and also phase sequences. Further, the results showed that vehicles emission is reduced after the traffic flow improvement at the intersection and the total Co2 was equal to 747.66 (Kg / h ) and the total fuel (L / h ) was equal to 299.1 [9].

Al-Arkawazi, (2016) studied the effects of delay reduction on the fuel consumption; operation cost, and exhaust emissions at the selected isolated signalized intersections (Bukhari, Sherai Naqib and Shahid Hama). A simulation was applied to evaluate the intersection delay, operation cost, and emissions using the traffic software tool SIDRA 5.1. The simulation results showed that fuel consumption, operation cost, and emissions are high and directly proportional to the intersection delay. He proposed a method to reduce intersection delay by applying a signal timing optimization. The optimization results showed that a significant reduction in in fuel wastage, operation cost, and exhaust emissions was associated with
a reduction in delay [10]. The major output results of the simulation runs are summarized in Table (1) below.

**Table (1): The major output results by using the traffic software tool SIDRA 5.1 [10]**

| Operation Analysis (Simulation Run) | Bukhari Intersection | Sherai Naqib Intersection | Shahid Hama Rash Intersection |
|------------------------------------|----------------------|---------------------------|-------------------------------|
| Intersection Average Control Delay (sec) | 161.7                | 113.2                     | 44.7                          |
| Total Carbon Dioxide (kg/hr)       | 852.8                | 676.1                     | 469.9                         |
| Total Hydrocarbons (kg/hr)         | 1.609                | 1.277                     | 0.82                          |
| Total Carbon Monoxide (kg/hr)      | 54.08                | 44.6                      | 36.14                         |
| Total NOx (kg/hr)                  | 1.62                 | 1.323                     | 1.085                         |
| Intersection Level of Service (LOS)| F                    | F                         | D                             |

2. Methodology

2.1 Area of Study

The study area is a three -leg signalized intersection as shown in Figure (1). The intersection is located in the urban area of Baghdad city in AL-Iraq, connecting Al-Ma'mun district with 14-Ramadhan and Jordan Streets which is considered as a high congested traffic area. The problem is that a large number of vehicles parked illegally near the intersection which causes traffic congestion. Basic geometric characteristics are reported in Table (2).

**Table (2): Basic geometric characteristics of AL-Yarmouk intersection**

| Direction | Approach                  | No. of lane | Width of lane (m) |
|-----------|---------------------------|-------------|-------------------|
| Eastbound | From Jordan int.          | 4           | 3.00              |
| Southbound| From AL-Mansour intersection | 3           | 3.00              |
| Westbound | From AL-Nosoor intersection | 3           | 3.00              |
2.2 Collecting Data
Traffic data are obtained by using videotaping method. This method is preferable for many reasons including the ease of collecting data, a large number of situations can be recorded clearly, the collected data can be revised and analyzed in a more detailed at any time, data including traffic flow, capacity and all the maneuvers can be extracted visually from the videotapes. A number of considerations should be taken into account while recording such as a good weather condition; the video camera should be placed in a roof of high level building located close to the intersection; the camera should be placed to cover all intersection leg.

2.3 Geometric Data
A GIS tool combined with a field measurement is used to collect all the Geometric data including spacing, number of lane and length of segment from map measurements. The GIS data are based on the available satellite images of Baghdad city (last update 2003) with resolution of 0.6m. The field data are based on a site visiting to measure the lane width, storage length and splitter island width.

2.4 Software Selection
SIDRA software (latest Version 8.0.) used for data analysis. This software developed by the Australian Road Research Board (ARRB) to evaluate the traffic performance of signalized intersections [11]. SIDRA was selected due to the advantages that the software model has comparing with other types of software models. The SIDRA software depends on an integrated modeling framework to indicate the performance of roundabouts, sign-controlled, and signalized intersections. The four measures of effectiveness (MOEs) that SIDRA software estimates are as follows:
- Carbon Monoxide (CO)
- Carbon Dioxide (CO2)
- Nitrogen Oxides (NOx)
- Hydrocarbons (HC) or VOCs
Fuel consumption in SIDRA software can be estimated by applying a four-mode elemental model to give an indication of the air quality with an exclusive vehicle drive-cycle model as shown in Figure below [12].

![Figure (2) Driver cycle model [12]](image)

Table (3) below represents the values of vehicle parameters used in the program.

| Vehicle Parameters                                  | Symbol     | The value |
|-----------------------------------------------------|------------|-----------|
| Light Vehicle Mass (average value in kg)            | (MvLV)     | 1400      |
| Heavy Vehicle Mass (average value in kg)            | (MvHV)     | 11000     |
| Heavy Vehicle Maximum Power (KW)                    | (PmaxHV)   | 130       |
| Idling fuel consumption rate for Light Vehicles in millilitres per hour | (fILV)     | 1350      |
2.5 Traffic Data Collection for Signalized Intersection
The traffic volume data did collect for 14 days for intersection by video recording technique for each intersection from 6:30 A.M to 10:30 P.M after several personal observations. Also, personal interviews are made with interested people like traffic policemen at the study area and different road users in order to help in selection the peak hour period for traffic data collection. The peak period of the intersection is (8:15 - 9:15) P.M. It is well known in most of traffic studies for evaluating and enhancement of the existing intersection, the following data are needed:

- Demand volume by movement, V (veh/hr)
- Peak-hour factor, PHF
- Percent heavy vehicles, HV (%)

3. Results and analysis

3.1 Intersection level of service
SIDRA software outputs include level of service and delay results based on the concept described in the US Highway Capacity Manual (HCM) (1), Table (4) below showed the relation between control delay and the level of service (1). After analyzing the signalized intersection by using SIDRA 8.0 software, the results in the Table (5) below showed that delay is (273.9 sec) and the level of service (F).

Table (4) The relation between control delay and the level of service

| LOS | Control Delay per Vehicle (s/veh) |
|-----|----------------------------------|
| A   | ≤ 10                             |
| B   | 10–20                            |
| C   | 20–35                            |
| D   | 35–55                            |
| E   | 55–80                            |
| F   | > 80                             |

Table (5) The traffic characteristics at AL- Yarmouk intersection

| Direction | lane group       | Green Time (sec) | Approach | Intersection |
|-----------|------------------|------------------|----------|-------------|
|           |                  |                  | Delay (sec) | LOS | Delay (sec) | LOS |
| Eastbound | from Jordan int. | 33                | 307       | F  | 273.9       | F   |
| Northbound| from AL-Mansour int. | 26                | 273.2     | F  |            |     |
| westbound | from AL-Nosoor int. | 74                | 235.9     | F  |            |     |

Table (6) The amount of gases was emitted at AL-Yarmouk intersection

| Intersection | CO2 (Kg / h) | CO (Kg / h) | HC (Kg / h) | NOx (Kg / h) |
|--------------|--------------|-------------|-------------|--------------|
| Al-Yarmouk   | 2817.3       | 151.8       | 5.569       | 4.470        |

Carbon monoxide is emitted from incomplete combustion in internal combustion engines, and hydrocarbons are emitted as unburned fuel. Nitrogen oxides are formed by the reaction of oxygen with nitrogen at high temperatures in the combustion chamber.

The release of CO and NOx is the result of complex reactions in the combustion chamber and is directly related to the incomplete combustion process and the chemical equilibrium due to the lack of sufficient time for combustion and obtaining this balance [13].

\[ C_{x}H_{y} + (O_{2} + 3.76N2) \rightarrow (aCO_{2} + b (CO) + d(NOx) + y/2(H2O) + e(H) \]

3.2 Geometric Design Improvement
The improvement that can be proposed for the study area is limited due to the restriction in area and land acquisition. There is a strong objection of widening the available intersection by adding additional lanes to accommodate the high traffic volumes. Traffic congestion in the intersection can be reduced
through constructing Underpass or Overpass. Underpass or tunnel construction is not suitable, and its construction cost considers high compare to Flyover or overpass construction. Specially, small Flyover across the intersection is more convenient and easier to construct which gives excellent result in reducing traffic congestion at intersection.

3.3 Improvement the signalized intersection

Signal timing optimization one of the most common methods for increasing the efficiency of traffic Signals. To calculate the best cycle time using SIDRA 8.0 program. A very important improvement in this intersection is to prevent cars from stopping near the shopping center (Said Alhalib) that is located at the intersection. The application of this procedures and its representation in the SIDRA program has led to a reduction in \(N_b^*\) value from (15 to 5) bus/hr. The decrease in \(N_b\) value leads to a decrease in the value of \(F_{bb}^{**}\) factor. From the SIDRA software, the capacity increased at the intersection based on the number of vehicles (\(N_b\)) and the \(F_{bb}\) factor which lead to reduce the control delay by about 40%. This reduction in delay cause a reduction in the gases emitted from the vehicles.

Table (7) The delay after improvement

| Direction       | lane group                  | Green Time (sec) | Approach | Intersection traffic |
|-----------------|-----------------------------|------------------|----------|----------------------|
| Eastbound       | From Jordan intersection.    | 44               | 104.3    | F                    |
| Northbound      | From al-Mansour int.        | 13               | 221.3    | F                    |
| westbound       | From al-Nusoor int.         | 66               | 191.3    | F                    |

\*\(N_b\) = The number of stopped buses per hour.
\**\(F_{bb}\) = Bus blockage adjustment factor.

Table (8) The amount of gases emitted at AL-Yarmouk intersection after improvement

| Intersection | CO2 (Kg / h ) | CO (Kg / h ) | HC (Kg / h ) | NO\textsubscript{X} (Kg / h ) |
|--------------|---------------|--------------|--------------|----------------------------|
| Al-Yarmouk   | 2205.1        | 139.1        | 4.179        | 4.049                      |

Table (9) Comparison the amount of gases emitted and delay before and after improvements

| Intersection | Before improvement | After improvement | Percentage change |
|--------------|--------------------|-------------------|------------------|
| DELAY (SEC )| 273.9              | 161.9             | 40 %             |
| CO2 (KG / h )| 2817.3             | 2205.1            | 21 %             |
| CO (KG / h ) | 151.8              | 139.1             | 7 %              |
| HC (KG / h ) | 5.569              | 4.179             | 24 %             |
| NO\textsubscript{X} (KG / h ) | 4.470 | 4.049 | 9 % |

The relation between cycle time, travel speed and the emissions (HC, CO, NO\textsubscript{X},CO\textsubscript{2}):
Figure (3) The relation between cycle time, travel speed and (HC)

Figure (4) The relation between cycle time, travel speed and (NOx)
From the above figures we find that when the speed decreases, the amount of gases emitted increases, which is the main cause of high air pollution at the intersections because the speed is too low. The reduction in the emission of each gas depends on the amount and percentage of fuel combustion. This means that the reduction in carbon dioxide emissions after traffic improvements is greater than the reduction in carbon monoxide, because the amounts of carbon dioxide emitted from the fuel combustion process are higher than the amount of carbon monoxide in that process. We also note that the amount of hydrocarbon gas emitted is higher than the amount of sodium monoxide.

4. Conclusions

1- The results of AL-Yarmouk signalized intersection by SIDRA 8.0 computer program showed that level of service (F) for intersection and the delay (273.9 sec).

2- The improvement of the Al-Yarmouk signalized intersection include optimization cycle time, phase time and prevent cars from stopping near intersection lead to reduce the delay (40%) from 273 sec to 161.1 sec.
3- The results showed that congestion has a significant impact on the air pollution at the intersection during the peak hour, where gases are emitted from cars (2817.3 kg / h) of CO2, (151.8 kg / h) of CO, (5.569 kg / h) of HC and (4.470 kg / h) of NOx.

4- After the improvement, the results showed that cars emit gases during peak hour at the intersection (2205.1 kg / h) of CO2, (139.1 kg / h) of CO, (4.179 kg / h) of HC and (4.049 kg / h) of NOx.

5. Recommendations

1- Optimization the traffic signal to reduce the number of vehicle stops, which facilitates the movement of vehicles and reduces the consumption of fuel and thus reduces the pollution resulting from it.

2- Disposal of old cars which Causing significant pollution to the environment.

3- Continuous maintenance of engine vehicles and not allowing vehicles to use the street without obtaining a certificate proving good combustion and high engine efficiency.

4- Encourage the use of public transport by buses and trains by making their services better to reduce the use of private cars.

5- Emphasis on improving the quality of fuel used in different vehicles and using the exhaust assistant which reduces carbon emissions such as carbon monoxide and hydrocarbons.

6- Provide specialized equipment to measure the pollution resulting from exhaust cars.

7- Proper planning of cities so as to reduce the pollution of the environment as one of the main considerations in the planning process in line with the requirements of sustainable development.

8- Provide green areas for air purification and must be landscaped areas in the city especially those adjacent to roads and streets to reduce pollution as it reduces content air from the suspended material and the removal of carbon oxides.

9- The traffic police must prevent stops near the intersection, especially with a shopping center near the intersection.

10- Developing and managing the parking system by locating parking far away from the intersection and away from the sides of the road.

11- Parking spaces must be identified Both sides of the road clearly, away from the intersections at an adequate distance 30 meters or more by International specifications, as well as preventing and accounting the vehicles that exercise the wrong parking leads to reduce congestion at the intersection.

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