The Environmental Impact Reduction of Highway Traffic Congestion using Sustainable Tool

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Abstract. The global environment is mainly affected by the increase in traffic volumes at intersections in terms of air pollution. Serious solutions are needed to avoid air pollution specially in the crowded in congested intersections. Recently, the concept of sustainability and sustainable tools has been found to minimize congestion and excess emissions of the gaseous pollutants problem to some extent. The current study focused on a critical intersection in Baghdad city which is Shaab-Selekh intersection. Shaab-Selekh intersection can be classified as the most congested intersection for its high traffic density, especially in the morning and afternoon peak hours. This study evaluates the level of service, estimating the environmental impact (air pollution) due to traffic congestion, and propose set of sustainable tools to reduce air pollution associated with reduced congestion traffic. In order to reach these objectives, many factors were considered such as traffic volumes and counting time periods (morning and afternoon peak hour) in December 2018 by (video recording technique and manual counting). In addition, SIDRA software version 5.1 was used to evaluate the level of service for the intersection and indicated that it equal to LOS F, and to estimate air pollutants (CO2, HC, CO, NO2). This study will also compare air pollutants for the study area with international standards and the congestion cause negative impacts on the environment.

1. Introduction
According to various information sources, petrol and diesel vehicles have a negative impact on the environment, cause global warming and lead to exceeding the allowable air pollution levels in megacities [1]. The increase of automobilization is one of the most sufficient factors having an impact on the state of the environment. Automobile transport is the main source of pollution in the environment in the urbanized regions [2].

An increase in the number of transport means is accompanied by the increase of traffic intensity in urban road systems, growth of transport delays, increased consumption of fuel and fast wearing-out of vehicle components. The urban population which participates in the traffic is exposed to toxic gases of vehicles, microscopic particles of tires and brake parts of automobiles [3].

High energy is used up when there is traffic congestion; this leads to the emission of high quantities of carbon monoxide (CO) as a result of combustion within the automobile engines. When carbon monoxide...
burns in the presence of oxygen ($O_2$), the product is Carbon dioxide ($CO_2$). Traffic congestion and variations in vehicle speeds impact greatly on the emission of $CO_2$ [4]. The transport sector emits greenhouse gases heavily due to the combustion of diesel and petrol fuels used by automobiles [5]. Almost half of the fossil fuel consumption in the world can be accounted for the transportation sector which also contributes approximately one-quarter of total fossil fuel combustion related $CO_2$ emissions of the world [6]. Sets of sustainable transport tools are available to reduce polluting emissions, including [7]:

- Promotion of public transport mode
- Car restrictions within the cities
- Fuel price can never go down
- Ecological transport tax:
- Co-financing of transport investments
- Sustainable spatial planning policy
- Better telecommunication services
- Better goods transport management

In general, better accessibility and higher attractiveness of public transport modes can be done by the development of high-quality public transport networks such as select public transport vehicles in traffic, design more convenient interchanges, safe and environmentally friendly public transport vehicles and use suitable national passenger information system.

Car restrictions within the cities are another sustainable tool, especially within cities. Car restrictions can be done by high charging of using more cars in a household and limiting their number to one in case of households in parking charging zones. The mentioned tools also related to lowering fuel prices because car restricting makes people choose public transport due to economic reasons. In addition, profit gained when the market fuel price goes down should feed the city or national eco-fund for public transport development.

Each car ride is automatically taxed and the tax amount depends on the city district, journey length, emissions, the noise level and on the day time (the highest during pick-hours). Buying the more expensive hybrid or electric car should be awarded a couple of gains, connected with its purchase (lower VAT and registration fees) and use (entering limited access zones, lower parking fees, etc.).

Baghdad city faces a significant problem with the emission of dangerous gases from vehicle exhausts, as the number of vehicles in Baghdad province is equivalent to 2.1 million vehicles in 2017 and 75% of them are equipped with gasoline engines and are constantly increasing due to the lack of control over the market for private vehicles [8]. Some important factors cause’s greater emissions than the situation where the vehicle is continuous without acceleration or slowdown or restart and warm up and stop with the engine operated [9]. These factors related to traffic congestion in the city, the rapid increase in the number of private vehicles, and stopping the movement with the engines remain in a state of operation (especially at traffic intersections) [10, 11].

The current evaluation methods had critical weakness in the presence of determinants of emissions, methods of measurement and the determination of criteria commensurate with the size of the problem and strict legislation in this direction. At the same time, the problem exacerbated to exceed the global limitations of emissions steadily, which led to the need to move towards sustainable transport tools used to reduce these emissions as addressed in this search the intersection of Shaab-Selekh in Baghdad city.

2. Description of Intersection Site

Shaab – Selekh Intersection is one of the most important intersections of Baghdad city. Because it represents the main arterial that connects the regions of Shaab, Bob AL-Sham, and Husseiniyah and the provinces of Diyala, Kirkuk, and Kurdistan of Iraq on the one hand and the center of Baghdad on the other. It is considered the beginning of the main route that passes through the east of the canal in
Baghdad to Baghdad Alqadyda, as well as the road linking the southern governorates to the regions of Rashidiya and Tagi on the other side. Figure 1 shows the study area (Shaab – Selekh Intersection) location in Baghdad city from the Google Earth website.

![Figure 1. Illustrates the location of Shaab – Selekh Intersection in Baghdad city [Google Earth]](image1)

The intersection of Shaab – Selekh is one of the intersections that deal with heavy traffic volumes and frequent traffic congestion due to its geographical location and a link between the city of Baghdad and other provinces. The study area is surrounded by a range of land uses, mostly residential areas with medium and high residential densities such as areas of Shaab, district of Ur, Benogk, Selekh and Tunis and Cairo districts. One of the most important landmarks in the study area is Al-Sada al-Naim mosque, a military site, and a health center. The path extending to the study area distinguished from Al-Nida mosque to the health interchange in Al-Shaab area using commercial health use as shown in Figure 2.

![Figure 2. Illustrates the land use surrounding the study area [Google Earth]](image2)
3. Air Pollutant Sources
Conducting of Traffic Volume Survey and Environmental Pollutant. The traffic volume counts used in this survey are collected by video recording technique and manual counting for each section in two-hour intervals of observations in December 2018, as illustrated in Table 1.

| Day     | Time    | Demand Flows (veh/h) | Delay (sec) |
|---------|---------|----------------------|-------------|
| Saturday| morning | 3677                 | 4435.42     |
|         | afternoon| 3604                 | 4548.7      |
| Sunday  | morning  | 6018                 | 18171.8     |
|         | afternoon| 7903                 | 30422.5     |
| Monday  | morning  | 6211                 | 36648.65    |
|         | afternoon| 6459                 | 18879.41    |
| Tuesday | morning  | 5942                 | 15905.15    |

The software SIDRA Intersection Version 5.1 (Signalized and unsignalized intersection design research and aid) was used in the assessment of air pollutants and indicators of effectiveness for the intersection. The SIDRA software has been established by the Australian Road Research Board (ARRB), Transport Research Ltd., as mean to design and assess the performance of intersections such as signalized intersections, roundabouts, two-way stop control, and yield-sign control intersections [12]. There are some advantages that the SIDRA has over any other software model in estimating and comparing the efficiency of the signaled junction. [12] indicated that the SIDRA method emphasizes the consistency of capacity and performance analysis methods for roundabouts, sign-controlled, and signalized intersection through the use of an integrated modelling framework [12].

In general, LOS for signalized intersections is based on average stopped delay time per vehicle. As know that the levels of service range from A to F where A being the best when drivers are not influenced by other vehicles, and F being the worst [13]. Also, level of service is a measure by which transportation planners determine the quality of service on transportation devices or transportation infrastructure.

Traffic analysis results showed that the whole intersection works on LOS type (F) as presented in Table 2. Figure 3 shows the LOS for all main approaches of the current intersection.

| Day     | Time    | Delay (sec) |
|---------|---------|-------------|
| Saturday| morning | 4435.42     |
|         | afternoon| 4548.7      |
| Sunday  | morning  | 18171.8     |
|         | afternoon| 30422.5     |
| Monday  | morning  | 36648.65    |
|         | afternoon| 18879.41    |
| Tuesday | morning  | 15905.15    |
| Day     | Time  | Value 1 (kg/h) | Value 2 (kg/h) |
|---------|-------|----------------|----------------|
| Wednesday | morning | 5291           | 24145.32      |
|         | afternoon | 6840           | 19600.78      |
| Thursday | morning  | 4912           | 10494.33      |
|         | afternoon | 6212           | 11624.91      |

**Figure 3. LOS in Study Area by using SIDRA software**

4. **Measurement Methodology**

The software SIDRA Intersection Version 5.1 was used in the assessment of the following air pollutant:
- Carbon dioxide (CO₂)
- Hydrocarbons (HC)
- Carbon monoxide gas (CO)
- Nitrogen Oxides (NOₓ)

SIDRA calculates the above pollutants only and not all air pollutants emitted from vehicles, in kg/h as these units do not resemble the units used in the international standards for measuring air pollutants as volumes of air g/m³ or mg/m³. Therefore, in this research, the size of the road section was calculated by the dimensions of the length of the intersection (556 m) and the width of the intersection (30 m) and the height (3 m) which is the necessary height for the spread of air pollutants so that the volume of the section is (50000 m³). Thus, obtaining the concentration of air pollutants after dividing the results of the SIDRA on the volume of the section and in units of kg/m³ per hour as shown in table (3) (Authors).
5. Results and Discussions

Tables 3 and 4 show the amount of emissions from vehicles at peak hour in the study area after the conversion form unit to another, Fuel Consumption, Cost ($/h).

| Table 3. Emissions from vehicles in the study area using SIDRA software |
|---------------------------------------------------------------|
| **Day** | **Time** | **Carbon Dioxide (CO\textsubscript{2}) (mg/h) ×10\textsuperscript{5}** | **Hydrocarbons (HC) (µg/h) ×10\textsuperscript{5}** | **Carbon Monoxide (CO) (mg/h) ×10\textsuperscript{4}** | **NO\textsubscript{x} (µg/h) ×10\textsuperscript{6}** |
| Sat. | am | 197132 | 384200 | 45358 | 15526 |
| | pm | 204459 | 39117 | 44005 | 15111 |
| Sun. | am | 717057 | 1496820 | 124081 | 45551 |
| | pm | 1195154 | 2491230 | 196407 | 73021 |
| Mon. | am | 1455964 | 2999520 | 238751 | 88331 |
| | pm | 758378 | 1560160 | 133494 | 48684 |
| Tue. | am | 652147 | 1315670 | 113186 | 41321 |
| | pm | 702228 | 1411070 | 122572 | 44715 |
| Wed. | am | 981043 | 1991920 | 170774 | 62100 |
| | pm | 782713 | 1620620 | 139133 | 50604 |
| Thur. | am | 425542 | 874670 | 79609 | 28571 |
| | pm | 47883 | 978280 | 95369 | 33683 |
| Total | | 8550647 | 17515330 | 1502739 | 547218 |

Table 3 shows the highest emissions of gases and consumption of vehicle fuel in the study area were on Monday followed by Sunday and Wednesday, with the lowest emissions and fuel consumption on Saturday as shown in Figure 4.

**Figure 4.** Cost, fuel consumption and emissions in study area according to days

Table (4) shows the most fuel consumer axis is the axis of the Al-Qanna by 51%, followed by the axis of Shaab by 42%, and by 7% of the axis of Selekh as shown in Figure 5.
Table 4. Results of SEDRA software by approaches

| Time | NOx (kg/h) | CO (kg/h) | HC (kg/h) | CO2 (kg/h) | Fuel total (L/h) |
|------|------------|-----------|-----------|------------|-----------------|
| Total | 246.057    | 63915.18  | 1468.351  | 369759.5   | 172700.785      |
| %    | 45%        | 80%       | 54%       | 46%        | 51%             |
| am   | 101.091    | 60144.87  | 1215.849  | 170503     | 75629.48        |
| %    | 41%        | 94%       | 83%       | 46%        | 44%             |
| pm   | 145        | 3,770     | 253       | 199,256    | 97,071          |
| %    | 59%        | 6%        | 17%       | 54%        | 56%             |
| AL QANNA |          |          |          |            |                |
| Total | 77.004     | 8877.278  | 370.599   | 57815.07   | 23785.103       |
| %    | 14%        | 11%       | 14%       | 7%         | 7%              |
| am   | 38.546     | 7637.16   | 246.689   | 25374.81   | 11004.303       |
| %    | 50%        | 86%       | 67%       | 44%        | 46%             |
| pm   | 38         | 1,240     | 124       | 32,440     | 12,781          |
| %    | 50%        | 14%       | 33%       | 56%        | 54%             |
| SELEKH |          |          |          |            |                |
| Total | 863.497    | 7322.046  | 224.5023  | 372333.9   | 141312.67       |
| %    | 32%        | 9%        | 41%       | 47%        | 42%             |
| am   | 392.943    | 4515.882  | 92.031    | 187767.6   | 69380.19        |
| %    | 46%        | 62%       | 41%       | 50%        | 49%             |
| pm   | 471        | 2,806     | 132       | 184,566    | 71,932          |
| %    | 54%        | 38%       | 59%       | 50%        | 51%             |
| SHAAB |          |          |          |            |                |
| Total | 338,303 L/hr |
| %    | 42%        | 51%       | 7%        |            |                |

Figure 5. Fuel consumption in the study area according to approaches

Table 5 shows the total fuel consumption in the study area was 338,303 L/hr. The cost of fuel consumed according to the Iraqi price is 152.236 million Iraqi dinars/hour. Table 5 shows the average morning fuel consumption rate was 46%, and at evening peak time it was 54% as shown in Figure 6.

Table 5. Fuel consumption, cost ($/h) in the study area using SIDRA software

| Day  | Time | Cost ($/h) | Fuel Consumption (L/h) |
|------|------|------------|------------------------|
| Sat. | am   | 128503.1   | 7776.6                 |
|      | pm   | 131928.5   | 8049.9                 |
When comparing data collected from the air pollutant in the study area Table. 6 with the international standards, observed that they exceed the standards for all pollutants (CO\(_2\), HC, CO, NO\(_2\)) excessively. The comparison used with international standards based on the legal text of the Iraqi law of standards, fuel and air pollutants, which allows comparison with international standards, especially the US, if the measurement methods do not match what is in the law [13]. Because the method used for measurement is the use of a SEDRA software rather than the locally adopted measuring instruments. The results of this study were compared with the American and international standards in particular because the Iraqi air pollution standards for mobile sources such as vehicles give measurements of hydrocarbons and carbon monoxide gas only. In Iraq, these gasses were measured by direct methods of single exhaust does not resemble the program used in this research, and because the instructions state that it can be adopted methods of measuring air pollutants based on US EPA standards or equivalent international standards (based on the provisions of item (II) of Article (38) of the Environmental Protection and Improvement Act No. 27 of 2009). The results of this study were compared with the American and international standards in particular, because the Iraqi air pollution standards for mobile sources such as vehicles gives measurements of hydrocarbons and carbon monoxide gas only. The Iraqi standard was measured the polutions by direct methods of single exhaust does not resemble the program used in this research. Based on US EPA standards, the instructions state that it can be adopted methods of measuring air pollutants or equivalent international standards (based on the provisions of item (II) of Article (38) of the Environmental Protection and Improvement Act No. 27 of 2009 (Instructions No. (3) for 2012 were legislated national emission limits for activities and businesses) [13].
Table 6. Comparison of results by SIDRA software with international standards

| Day | Time | Carbon Dioxide (CO₂) (mg/m³) | Hydrocarbons (HC) (µg/m³) | Carbon Monoxide (CO) (mg/m³) | NOx (µg/m³) |
|-----|------|-----------------------------|---------------------------|-----------------------------|-------------|
|     |      | Standards                   | 644400(mg/m³)             | 160(µg/m³)                  | 40 mg/m³    | 660 µg/m³    |
| Sat. | am   | 394,264                     | 768400                    | 9071                        | 310520      |
|      | pm   | 408,918                     | 78234                     | 8801                        | 302220      |
| Sun. | am   | 1,434,114                   | 2993640                   | 24816                       | 911020      |
|      | pm   | 2,390,308                   | 4982460                   | 39281                       | 1460420     |
| Mon. | am   | 2,911,928                   | 5999040                   | 26699                       | 1766620     |
|      | pm   | 1,516,756                   | 3120320                   | 26699                       | 973,680     |
| Tue. | am   | 1,304,294                   | 2631340                   | 22637                       | 826,420     |
|      | pm   | 1,404,456                   | 2822140                   | 24514                       | 894,300     |
| Wed. | am   | 1,962,086                   | 3983840                   | 34155                       | 1,242,000   |
|      | pm   | 1,565,426                   | 3241240                   | 27826.6                     | 1012080     |
| Thur.| am   | 851,084                     | 1749340                   | 15923                       | 571420      |
|      | pm   | 957,660                     | 1956560                   | 19073.8                     | 673660      |
| Total|      | 17101294                    | 34326554                  | 218579                      | 2257333     |

Table 7 and Figure 7 shows that the largest pollutants resulting from car exhaust are carbon dioxide gas by 90.56%, followed by carbon monoxide gas by 9.07%, and HC gas by 0.31%, the largest pollutant cause bad health effects on humans and city Earth's temperature. the distribution of gas volume ratios is not identical to the composition of volumetric air. This large percentage is due to the use of fossil fuels in vehicles as well as the delay of vehicles in the study area, as well as poor quality of fuel used in vehicles in Iraqi cities.

Table 7. Volumetric percentages of air pollutants in the study area [Authors]

| Demand Flows (veh/h) | Fuel total (L/h) | CO₂ (kg/h) | HC (kg/h) | CO (kg/h) | NOx (kg/h) |
|----------------------|------------------|------------|-----------|-----------|------------|
| 69267                | 337798.558       | 799908.5   | 2702.447  | 80114.51  | 547,5633   |
| Percentage of total  |                  | 90.56%     | 0.31%     | 9.07%     | 0.06%      |

Figure 7. Ratio of emission in the study
After analyzing the traffic volume in the study area by comparing the results of the study with the international standards for air pollution, this paper finds that traffic congestion causes delay in travel time and low level of service (F), congestion cause negative impacts on the environment at the study area. Therefore, there is a need to reduce negative environmental impacts due to congestion using the sustainable tools proposed specifically for the study area.

6. Proposals of Sustainable Tools

1) Technological tools:
   - Encouraging the use of cars that operate on clean and environmentally friendly fuel (sustainable fuel), such as the use of electric cars, hybrid cars, cars powered by hydrogen fuels, natural gas and other renewable energy sources.
   - Improve the quality of fuel currently used and reduce vehicles that increase negative emissions to the environment.
   - Encouraging the principle of car-sharing to reduce traffic volumes to the study area by preventing the entry of vehicles used by one or two persons.

2) Economic instruments:
   - Reduction or elimination of taxes for imported vehicles that operate on sustainable fuels.
   - The imposition of fees on private vehicles entering the study area and the center of the city of Baghdad.
   - Providing free parking for cars with sustainable fuel in Baghdad's busy city centers and busy areas.

3) Legal tools:
   - Legislation of laws and regulations that compel road users to acquire vehicles that operate on sustainable fuels.
   - Establish standards for emissions from vehicles operating on fossil fuels for new and used vehicles.
   - Compelling the Traffic Directorate to vehicle owners to maintain and periodically inspect vehicles to reduce emissions through controls and laws.
   - Periodic traffic monitoring to determine the speed of vehicles and their mitigation in line with the speed that reduces vehicle emissions.
   - Monitoring the health effects of transportation and noise emissions in the study area, and applying the Iraqi laws that are concerned with reducing emissions and noise in Iraqi cities.
   - Increase parking fees in the city center and crowded areas in the city of Baghdad passing by the study area to reduce the use of private cars and reduce traffic congestion.
   - Prevent the entry of high-frequency car horns to Baghdad city and other Iraqi cities by preventing them from entering the border crossings.
   - Activation of traffic laws to exceed the standards of voice pollution within cities.

4) Planning tools:
   - Provide special corridors for environmentally friendly cars.
   - Encouraging the use of public transport through improving transport modes, increasing their types and improving the quality of service provided by them.
   - Conducting awareness campaigns for road users to inform them of the importance of the environment and its negative effects on humans, society and the city and the possibility of adopting sustainable ways to reduce polluting emissions from the transport sector.
   - Promote good governance through the implementation of environmental impact assessments of major transport projects to adopt a proactive approach to minimize the negative impacts of the transport sector.
   - Setting stations to measure the level of noise emitted from cars in different parts of the city.
   - Relocation of traffic path and organizing the study area by reducing parked cars with circling engine and increasing the continuity of traffic movement to reduce the contaminants resulting
from the vehicles during parking with circling engine, as shown in Figures 8 through 12. Relocation of traffic path is performed with the following steps:

- Keep the traffic path coming from Al-Shaab towards Al-Selekh and the center of the city continues without any turn left towards Al-Qanna.
- Make the traffic path coming from Al-Selekh area towards the Al-Shaab area continues without any rotation towards Al-Qanna to the left.
- Create rotation on Al-Qanna road near the tunnel in the study area, to achieve the link between the two paths.
- Closing the access leading to the study area from Al-Qanna road.

Figure 8. Proposed Planning Tool in Study Area

Figure 9. Proposed Directions in Study Area (Selekh side)
Figure 10. Detail in Rotation I

Figure 11. Proposed Directions in Study Area (Shaab side)
7. Conclusions
Traffic on roads has significantly increased in the whole world and elsewhere over the past 20 years. In many areas, vehicle emissions have become the dominant source of air pollutants, including Carbon dioxide (CO₂), Hydrocarbons (HC), Carbon monoxide gas (CO), and Nitrogen Oxides (NOₓ). The current work concluded that the study area suffers from jams and congestion traffic; this is shown by calculating the level of service (LOS) in the study area, which indicated that it is at the level (F). Based on the data analysis results, the relationship between fuel consumption and emissions in the morning and evening peak hours is positive in the study area. As fuel consumption increases, emissions increase. Although the Al Qanna approach of the least traffic volumes in the study area, it is the most fuel consumption and emissions due to the slow movement of vehicles towards the study area as a secondary approach, and giving more priority to the Shaab and Selekh approach, thereby increasing the delay times of trips, causing an increase in emissions. Also, this study proved that the SIDERA program can be used in the calculation of environmental pollutants resulting from vehicle exhaust, fuel consumption, and fuel cost.

Some other results related to Shaab approach is the most fuel consuming and emitting pollutant as follows:

- The highest consumption of fuel in Al-Qanna approach by 51%, followed by Shaab approach by 42%.
- The highest CO₂ emission is from Shaab approach at 47% and Al Qanna approach by 46%.
- The highest HC emission is from the Al Qanna approach at 54% and Shaab approach by 32%.
- The highest CO emission is from Al-Qanna approach at 80% and Selekh approach by 11%.
- The highest NOₓ emission is from the Al Qanna approach at 45% and Shaab approach by 41%.
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Author Contributions
Halla conducted the data analysis and wrote the paper draft; Areej proposed the research concept and study plan and revised the paper draft; Abbas provided comments to data analysis and paper draft.