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EVALUATION OF ENVIRONMENTAL IMPACT OF TRAFFIC CONGESTION USING REMOTE SENSING: BAB AL-MUADHAM ZONE AS A CASE STUDY

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A B S T R A C T

In general, Baghdad city suffers from a principal problem which is traffic congestion. It has affected it in particular environmentally, healthily, urban and economically due to many reasons. Some of these reasons are the increase in urban growth of the population and the increase in the number of vehicles in it as a reality to meet the requirements of citizens. However, this growth was not accompanied by any development or modernization in the fact of the current road network, which led to an increase in the volumes of traffic flows for the roads. Consequently, the inability of these roads to meet the level of service for which they were designed to ensure the flow of traffic, thus leaving stifling traffic congestion. Bab Al-Muadham area was chosen as a case study because it suffered for many years from traffic congestion that affected its environmental reality. In this research, the factors causing traffic congestion and the resulting damages are addressed in order to lay hands on effective ways to solve this crisis. Field surveys and statistical studies were conducted to assess the real road performance relative to the actual traffic momentum. The amount of pollutant concentrations in the study area was measured using electronic sensors to assess its environmental and health conditions. Results obtained from empirical data were analyzed and discussed. The suggested solution also had a share in this study to address this region's real problem.

1. INTRODUCTION

The road plays a vital role in the transportation system, and its design and capacity affect vehicle flow and traffic density. Roads are typically categorized by design capacity and their intended function (Garber & Hoel, 1997; Al-Jawari, 2012; Department of Transport and Main Roads, 2014; Ognjenović et al., 2015; Salih, 2012; Atawi, 2003). Traffic jams arise from high vehicle volumes, especially during peak commuting times, leading to congestion on major routes (Al-Rubaie, 2020; Kamouna, 2004; Sabeh, 2016; Bull, 2003). Vehicle speed also influences road capacity; higher speeds can alleviate congestion, while slower speeds worsen it (Boitor et al., 2013; Tang & Hu).

Bab Al-Muadham area is located in the heart of Baghdad, Iraq. It is a key urban hub, featuring commercial shops,

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restaurants, an open market, educational institutions, and government offices, resulting in heavy foot and vehicle traffic (Kamouna, 2004; Alsayed, 2011). This congestion exacerbates pollution issues, particularly air quality concerns linked to vehicle emissions (Warlina et al., 2019; Soegoto et al., 2019). Thus, Bab Al-Muadham has been chosen for a study examining traffic congestion and its environmental impacts on public health, exploring potential solutions to these challenges.

2. RESEARCH METHODOLOGY

The research methodology includes a traffic survey and air quality assessment in the Bab Al-Muadham area. Data collection occurred on February 17, 2020, just before the COVID-19 pandemic, with hourly surveys from 7:30 AM to 2:20 PM. The study area encompasses several key intersections: from the Mustansiriya district intersection to Bab Al-Muadham Bridge, from the Muhammad Al-Qasim Expressway intersection to Sarafiya Bridge, from Amin Square intersection to Al-Talieaa Theater intersection, and from Maidan Square to Al-Maghrib Street intersection, as illustrated in Figure 1.

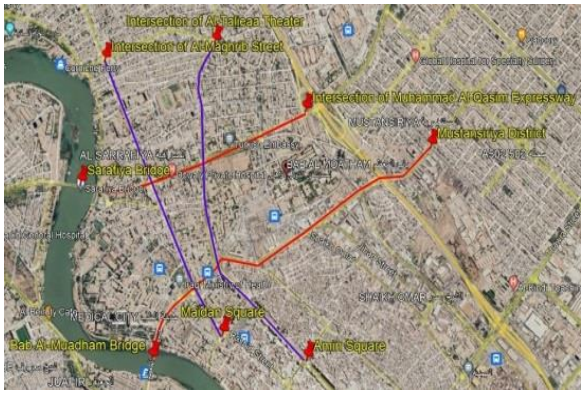

Figure 1. Study area boundaries

The numerous intersections (main and secondary ones) in the study area are illustrated in Figure 2. They all experience severe traffic congestion.

Figure 2. Main and secondary intersections in the study area

The traffic survey was conducted in the Bab Al-Muadham area, focusing on four major and three secondary intersections: Amin Square, Fadhil Square, and Muhammad Al-Qasim Expressway. Figure 3 illustrates the various paths where the traffic survey was conducted.

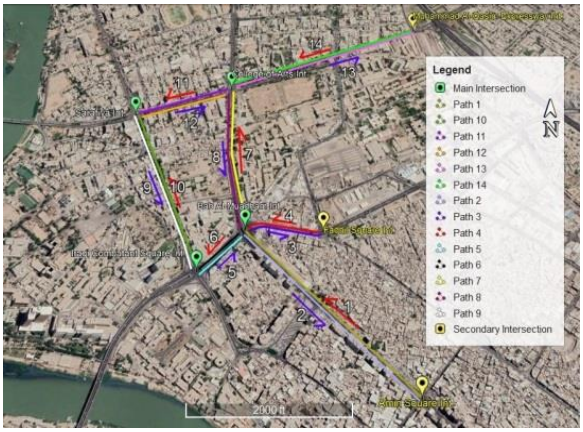

Figure 3. Paths used for traffic survey in the study area

Daily traffic volume and annual average daily traffic (AADT) were calculated for each path. The daily traffic volume indicates the number of vehicles passing along a specific road during a one-hour period, measured in (vehicles/hour). Manual counting was used to gather data, where a team recorded vehicle numbers at specific locations to ensure accuracy (Findley, 2015). The goal was to assess traffic volume and Level of Service (LOS) on these streets and evaluate air quality by measuring pollutant levels. Electronic detectors, produced in China, were installed at two main intersections: Bab Al-Muadham and the College of Arts to measure: lead (Pb), carbon monoxide (CO), carbon dioxide (CO_2), and sulfur dioxide (SO_2).

3. RESULTS AND DISCUSSION

3.1 Traffic Volume Analysis

Average Annual Daily Traffic (AADT) measures total vehicular traffic on a road over a year, averaged over 365 days, and is expressed in (vehicles/day). It serves as an indicator of road usage and can be calculated using the formula provided in (1) (Findley, 2015; Al-Shafiei, 2009).

$$AADT = DHV \div K \quad (1)$$

DHV: design hourly traffic volume.
K: coefficient (10-15)% depending on the type of road, for urban roads 12%. With this study using K=14%.

Level of Service (LOS) assesses transportation efficiency from the passenger's perspective, reflecting traffic flow relative to road capacity. A ratio near 1 indicates congestion, while lower ratios signify improved service levels, ranging from A (optimal) to F (poor). Highway

Capacity Software (HCS) is used to determine these levels (Findley, 2015). Traffic survey results from seven intersections during peak hours (7:30-8:30 AM and 1:30-2:30 PM) are presented in Tables 1 and 2. These results were compared to international standards, which expect traffic volume to be 1100 veh/h per lane and the AADT should be 15800 veh/day. All tested roads had two lanes in each direction.

Table 1. Obtained traffic volume in the study area at 7:30-8:30 am

Path	Daily traffic volume (veh/h)	Evaluation	LOS	AADT (veh/day)	Evaluation
1	1630	More	C	11643	Less
2	2520	More	D	18000	More
3	2040	More	C	14571	Less
4	2610	More	D	18643	More
5	2410	More	D	17214	More
6	1620	More	C	11571	Less
7	2130	More	D	15214	Less
8	2910	More	E	20786	More
9	930	Less	A	6643	Less
10	780	Less	A	5571	Less
11	2860	More	E	20429	More
12	3010	More	E	21500	More
13	2600	More	D	18571	More
14	3500	More	E	25000	More

Table 2. Obtained traffic volume in the study area at 1:30-2:30 pm

Path	Daily traffic volume (veh/h)	Evaluation	LOS	AADT (veh/day)	Evaluation
1	1540	More	C	11000	Less
2	1810	More	C	12929	Less
3	2200	More	D	15714	Less
4	1720	More	C	12286	Less
5	1830	More	C	13071	Less
6	1910	More	C	13643	Less
7	2720	More	D	19429	More
8	2510	More	D	17929	More
9	840	Less	A	6000	Less
10	1320	More	B	9429	Less
11	2950	More	E	21071	More
12	2800	More	E	20000	More
13	3350	More	E	23929	More
14	2510	More	D	17929	More

Tables 1 and 2 indicate that most roads exceed their design capacity, leading to decreased service levels, vehicle accumulation, and heavy traffic jams. The intersections of Bab Al-Muadham and the College of Arts have the highest traffic volumes, correlating with severe congestion in them. This issue stems from a rise in car numbers, reaching 2.1 million in Baghdad by 2017 (Central Organization of Statistics, 2017), alongside a lack of modernization in the road network to accommodate population growth and increased vehicle imports. The insufficient activation of public transport has led to a surge in private transport options like Kia vehicles (11 passengers), rickshaws (Tuk-Tuks), and taxis, further intensifying traffic flow. Additionally, the improper use of sidewalks by shop owners and street vendors narrows roadways, while intermittent parking of vehicles disrupts traffic. The lack of new bridges, tunnels, and roads has exacerbated jams, particularly at intersections like the Iraqi Combatant Tunnel, which does not facilitate bypassing and contributes to collisions. To tackle these issues, tunnels should extend beyond intersections.

To address the problem that has puzzled those seeking solutions, this study proposes several possible approaches as below, see Figure 4.

- Construction of a tunnel (proposal 1) to reduce congestion at the intersection of the College of Arts.
- Construction of a bridge (proposal 2) to reduce traffic congestion at both the College of Arts and Sarafiya intersection.
- Extension of the Iraqi Combatant Tunnel (proposal 3) to reduce traffic congestion at Bab Al-Muadham intersection.
- Construction of a one-way loop road (proposal 4) to reduce traffic congestion at both Bab Al-Muadham and the Iraqi Combatant Square intersection.
- Activating the traffic lights using the solar energy cells as clean energy to ensure the continuity of work of traffic light systems. In addition to ensure the respect and the compliance with traffic laws.
- Activating the public transport system by utilizing double-decker buses which can accommodate up to 90 passengers. This means that one bus can replace approximately 9 Kia cars, significantly reducing congestion on the roads.
- Preventing street vendors and shop owners from using sidewalks and their approaches is essential to avoid obstructing pedestrian traffic. This will help prevent traffic jams and ensure that traffic rules and regulations are enforced, with penalties for those who do not comply.

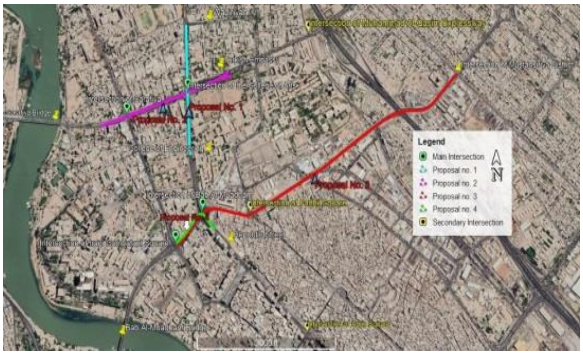

Figure 4. Proposals to reduce the congestion in the study area

3.2 Air Quality Analysis

Air pollution is a significant environmental issue linked to traffic congestion. Incomplete fuel combustion releases harmful gases that affect both the environment and human health, including lead (Pb), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOx), hydrocarbons (HC), and sulfur dioxide (SO_2) (Ruslinda et al., 2016). To measure these pollutants, electronic detectors were installed at 0m above the curbstone at two main intersections (Bab Al-Muadham and the College of Arts) where the highest traffic flow and congestion were observed. The study focused on four key pollutants: CO, CO_2, SO_2, and Pb, with data collected at 1:30 PM during peak traffic. The concentrations were then compared to international standards to assess their acceptability, as summarized in Table 3.

Table 3. Concentrations of polluting gases at 0 m altitude in the study area.

Pollutant	Bab Al-Muadham Intersection	College of Arts Intersection	International allowable limits	Evaluation
Pb ($\mu g/m^3$)	12	14	2	More
CO (ppm)	9.1	9.3	9	More
CO_2 (ppm)	480	540	250	More
SO_2 (ppm)	0.03	0.05	0.14	Less

The results in Table 3 show that all polluting gases, except SO_2, exceed international standards at both intersections. CO levels slightly exceed permissible limits, while CO_2 levels are nearly double the limit, primarily due to heavy traffic and nearby car parks at Republic Square and the College of Engineering. In addition, there are insufficient regulations from the Ministry of Environment and General Traffic Directorate concerning vehicle inspections.

Soil pollution from lead exceeds allowable limits by 6 times at the Bab Al-Muadham intersection and 7 times at the College of Arts intersection, with concentration reaching 420 µg/g of soil in Bab Al-Muadham, linked to leaded gasoline use in Iraq. Overall, the study area shows significant environmental pollution.

4. CONCLUSIONS

This study focused on traffic congestion in Bab Al-Muadham, Baghdad, and its environmental impact. Peak hour measurements revealed severe congestion due to different factors such as vital location, street vendors, lack of parking, closed roads for security, and outdated infrastructure. Even with the construction of new bridges and tunnels, traffic jams persisted. Proposed solutions include building more tunnels and bridges, using solar-powered traffic lights, reactivating of public transport and replacing Kia cars with double-decker buses to reduce the number of vehicles on the road. The study concluded that air pollution is closely linked to traffic congestion, with high levels of harmful gases from vehicle emissions and lead contamination in the soil, posing serious health risks.

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