

Effects of checkpoints on urban travel time

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Abstract. Increases in traffic volumes along urban roads leads to congestion. This study aims to evaluate the level of service (LOS) along Al-Masafi Street in Al-Dora. The study is comprised of two stages. First, data was collected by means of a field survey, with the data collection procedure including a count of the hourly traffic volume from 6:00 a.m. to 8:00 p.m. for workdays, Sunday to Thursday, during the spring break at six checkpoints. The data collected by calculating the volume of traffic, travel time, and queue length of vehicles at each checkpoint allowed calculation of the travel time index (TTI), vehicle/capacity ratio, and the speed in each direction. The travel time and queue length were calculated for passing vehicles for a 100 meter scale before each checkpoint, and the volume represents the number of vehicles passing through each checkpoint in a 15-minute time interval. The second stage of this research included the analysis and evaluation of Al-Masafi Street by computing its LOS based on the TTI, V/C Ratio, and Queue measurements. The conclusion is that the average TTI for all checkpoints in this study was 9.331, and the LOS for all studied roads was F, suggesting that checkpoints have a considerable negative effect on LOS.

1. General Introduction

Checkpoints are one of the most obvious lines of defence against terrorism, and are believed to help prevent breaches of people or goods that may present a threat to Baghdad. In line with an increase of terrorism worldwide, an increase in the number of checkpoints is a part of the ongoing efforts to better secure Baghdad; unfortunately, a problem has surfaced in the form of an increase in congestion levels in the streets of the city.

Everyday congestion is common in many Iraqi provinces, and most travellers expect and plan for some delay because of this, particularly during peak driving times such as the rush hour. However, where travellers must take more time to get from one place to another, this may cause more severe issues such as people losing their lives because they are not able to get to the hospital on time. It can also cause businessmen and traders to lose money on shipping; so it takes more time to deliver goods to consumers in Basra, Anbar, or the Kurdish region from markets in other provinces.

2. Problem Statement

Congestion is relatively easy to recognise: roads filled with cars, trucks, and buses, in addition to pavements filled with pedestrians. In terms of transportation, congestion is often related to checkpoints on a road section at a specific time, which leads to speed reductions.

Congestion levels are never the same from day-to-day on a given road because of the congestion unreliability of travel conditions. These problems must be taken into consideration by travellers, who will begin travelling earlier in order to prevent late arrival. As a result, every traveller must dedicate additional time to travel, which may mean arriving early in some cases, time which could have been used for other work. Travellers who do not do this maybe late for their appointments and meetings. Moreover, extra charges may be payable for not delivering goods at the required time.



3. Travel Time

A travel time study specifies the required time amount to travel from an origin to a destination on a given road. In order to conduct such a study, the locations and durations of potential delay causes must also be collected. The study then becomes known as a travel time and delay study. Travel time and delay studies can indicate the level of service of the studied road section, and such data are useful for traffic engineers seeking to identify the location of problems or instances where special attention may be required so as to enhance road traffic flow. Travel time is the time consumed to travel by vehicle on a specific portion of a road; delay is the time lost by a vehicle for reasons beyond driver control [1]. In this research, the recorded time was that required by the vehicle to pass a distance of 100 meters immediately preceding the checkpoint.

4. Queue Studies

Queue studies are of two types, classified by how they identify a queue:

1. A line of stopped vehicles creates a stop line because of some traffic control device, such as a stop sign or light signal, or due to restriction of movement, such as a queue forming behind a vehicle waiting for a gap to make a turn to the left.
2. A number of cars moving as a platoon or a group moving at a speed less than free flow speed because of congestion or traffic streams and/or a roadway abnormality such as congestion induced shock waves, or queues formed upstream of bumps, potholes, lane drops, and stalled vehicles [1].

5. Queue Data Collection

Data was collected by observers placed within eye line of the queue; the observers recorded queue lengths at specific intervals. For intersection delays, an interval of 15 seconds may be used, but as the cycle is not an even multiple, a 13-second interval is preferred. For more accurate counting, 30-second intervals can be used for long queues [2]. For very long queues, the number of vehicles is discounted back to a specific known point, counting only the remainder or "tail" at each interval when vehicles are backed up beyond that known point. The length of the tail of vehicles is then added back to the known point to find the length of the queue. This is useful where queues are generally constant, such as at ramp meters [2]. In this research, the highest number of vehicles waiting in the lane in checkpoint congestion was considered to be the queue length.

6. Travel Time Index (TTI)

The Travel Time Index (TTI) is a comparison between travel conditions at peak period time and travel in free-flow or posted speed limit conditions. For example, a TTI of 1.20 means that a trip that takes 20 minutes in the off-peak period will take 24 minutes in the peak period time, 20 percent longer [3].

$$\text{The Travel Time Index} = \frac{(\text{Peak Period Travel Time})}{(\text{Free Flow Travel Time})} \quad (1)$$

Table (1): Travel Time Index Based Level of Service Boundaries (1)

Level of Service	Travel Time Index	
A	<1.18	
B	1.18	1.5
C	1.5	2.0
D	2.0	2.5
E	2.5	3.3
F	>3.3	

Source: Highway Capacity Manual 2000.

7. Volume Capacity Ratio (V/C)

The most common parameter used to evaluate traffic conditions in cities is the V/C ratio; V is the total number of vehicles passing a point during an hour, while C is the capacity of the highway, defined as the maximum number of vehicles that can pass a point in prevailing traffic conditions [4].

Table (2): (V/C) Ratio

Level of Service	Definition	Freeways	All Other Roadways
A	Conditions of free flow; speed is controlled by driver's desires, speed limits or physical road way conditions.	0.0-0.34	0.0-0.34
B	Conditions of stable flow, operating speeds beginning to be restricted, little or no restrictions on maneuverability from other vehicles.	0.35-0.54	0.35-0.50
C	Conditions of stable flow, speeds and maneuverability more closely restricted, occasional backups behind left-turning vehicles at intersections.	0.55-0.77	0.51-0.74
D	Conditions approach unstable flow, tolerable speeds can be maintained but temporary restrictions may cause extensive delays, little freedom to maneuver, comfort and convenience low at intersections, some motorists especially those making left turns, may wait through one or more signal changes.	0.78-0.93	0.75-0.89
E	Conditions approach capacity, unstable flow with stoppage of momentary duration, maneuverability severely limited.	0.94-0.99	0.90-0.99
F	Forced flow conditions, stoppage for long periods, low operating speeds.	1.00 or >	1.00 or >

Source: San Joaquin County general plan 2010.

In this research, the capacity used in calculating the volume capacity ratio (V/C) for the two-lane section on which the first, second, third, and fourth checkpoints are located was 1,700 (vehicles), while the capacity for the four-lane section on which the fifth and sixth checkpoints are located was 3,400 (vehicles) [5].

8. Previous Research

Kukadapwar and Parbat studied the level of congestion in real time traffic networks quantitatively and qualitatively. The data was analysed by finding the quantity of congestion using TTI, while the qualitative congestion level was measured by Level of Service (LOS) [6]. Smith studied arterial travel time and reliability. He concluded that the reliability of travel time performance measures showed clear differences in estimation of reliability when compared with planning time indices and travel time indices [1].

John et al. studied the level of congestion in Auckland City on three major arterial routes. An instrumented vehicle equipped with GPS was used to collect travel time data during morning peak times, based on the average car method. Based on the LOS specifications from the Highway Capacity manual 2000, the level of congestion was thus identified. The required sample size for reliable estimation of travel time was determined based on a confidence interval method [7].

Ataiwe et al. investigated traffic speed for parts of Al-Karada Kharij road by identifying the congested segments using GPS techniques. The GPS collected speed data were mapped to the highway route using the Arc Map 10 program. Travel time, speed, and congestion indices were measured on the selected highway segments to assess the traffic conditions of the highway route. The methodology used was thus simple and easy to understand, and the research concluded that speed data derived from GPS and GIS can be effectively used to identify traffic congestion and bottlenecks in highway road networks [8].

Gary and Hui Xiong evaluated and identified parametric models to estimate arterial link travel times. A license plate method was used for 50 arterial samples in the Twin Cities seven country metropolitan areas to measure average travel time. Several models were investigated, including those from the Bureau of Public Roads (BPR) and the Highway Capacity Manual, the Singapore model, Spiess's conical volume delay function, and the Dowling model. The result showed differing percentages of errors in evaluating travel time [9].

Kate Lyman studied the reliability of travel time as an important measure of congestion. Reliability was defined as a measure of how dependable the travel time on a given roadway is. The research used data from Portland, Oregon, as a case study for how to prioritise roadways according to travel time reliability measures, recommending the use of travel time reliability in periodization planning [10].

9. Study Area

The current study is mainly concerned with evaluating the travel time index near six chosen pivotal checkpoints within the Al-Dora district, which is one of the most important and congested areas in Baghdad City. The routes that were chosen in the case study are vital areas, which control the traffic in Al-Dora. The first and second checkpoints are placed on a route that links many places of crucial importance such as several universities, such as Al-Farabi University College and Dijla University College, schools, and the Technical Institute, along with many other institutions, to different neighbourhoods. The third and fourth checkpoints are near the Al-Dora intersection that links the highway to other sections of Baghdad City and the gate to the southern provinces, while the fifth and sixth checkpoints are located on a route connecting Al-Dora with another exit towards other sections of Baghdad city over a two-storey bridge. Figure 1 illustrates a satellite image of the chosen checkpoints in the study area.

10. Data Collection

In this research, the traffic volume in the urban street was determined by counting the hourly traffic volume for 14 hours from 6:00 a.m. to 8:00 p.m. during work days, Sunday to Thursday, for six checkpoints. The periods of volume counting were divided into 15-minute intervals. The data collection procedure included calculating the volume of traffic, travel time, and queue length in vehicles for each checkpoint in order to extract the travel time index, vehicle/capacity ratio, and the speed over the 14 hours in each direction. The travel time and queue length were calculated for passing vehicles on a 100-meter scale prior to the checkpoint. The volume represented the number of vehicles passing through each checkpoint in a 15-minute time interval. The collected data were assembled on an hourly basis to clearly show the variation of parameters during the day.



Figure 1. Satellite image of checkpoint locations

11. Results and discussion

This section presents the results and offers a discussion of the checkpoint effect with regard to congestion near the checkpoints and the implications of the travel time index. The results obtained from the data near collected the checkpoints are focused on travel time index, speed, and v/c ratio.

11.1 First Checkpoint

The highest volume of vehicles occurred from 1 p.m. to 2 p.m., which represents the rush hour in Baghdad. The dusk hours 6 p.m. to 8 p.m. also showed high vehicle capacity, while the lowest traffic volumes occurred during the dawn 6 a.m. morning hours. The relationships between time and volume, queue length, travel time, speed and v/c ration are given in Figures 2 to 4, respectively, for the first check point. In Figure 2, the peak (rush) hour is between 01:00 pm and 02:00 pm. The highest volume is 2,097 vehicles, with the longest queue being 17 vehicles. The lowest volume was between 06:00 am and 07:00 am, with the lowest queue of vehicles being just 2 vehicles.

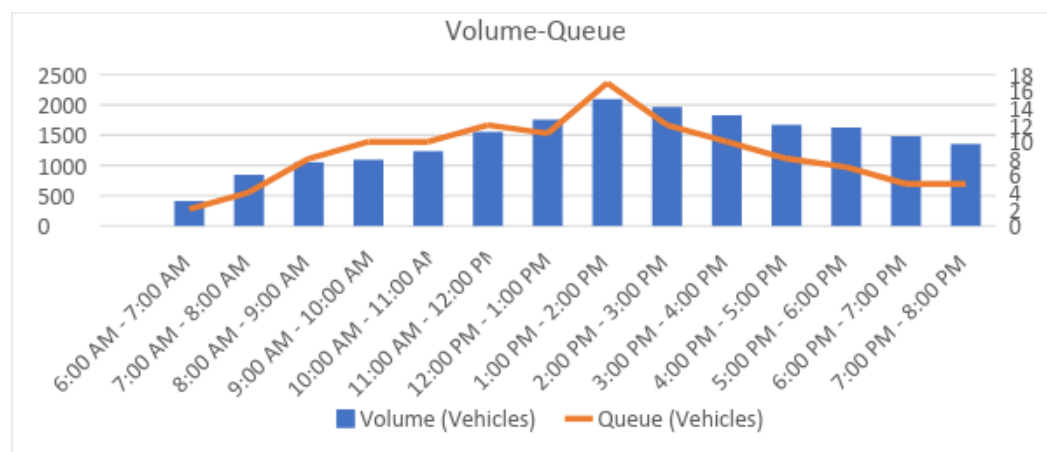


Figure 2. Relationship between Volumes and Queue with Time Intervals

Figure 3 shows that the peak (rush) hour was also between 01:00 pm and 02:00 pm. The highest travel time (123 sec) was associated with the highest vehicle volume and the slowest speed (2.91 km/hr). The lowest travel time was between 06:00 am and 7:00 am, with the highest speed (35 km/hr).

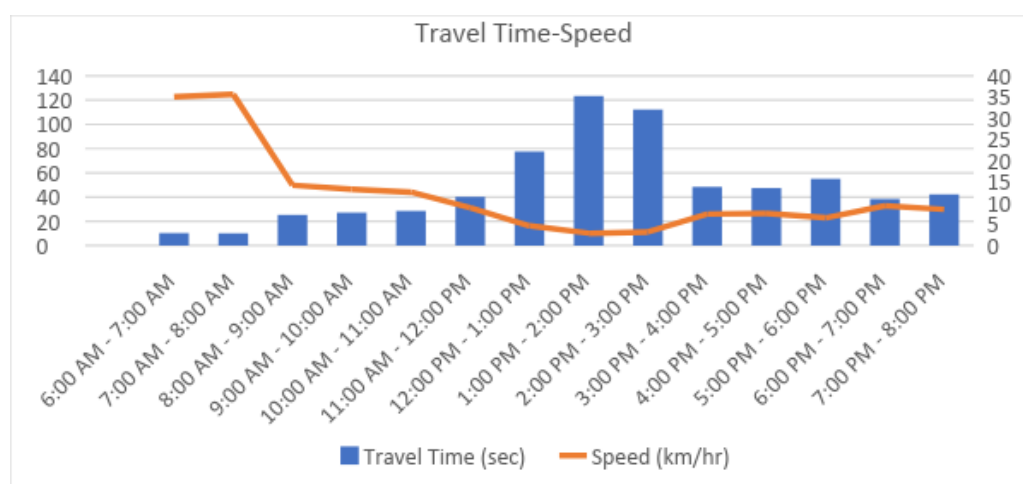


Figure 3. Relationship between Travel Time and Speed with Time Intervals

From Figure 4, the highest V/C ratio in this period was greater than 1.2, which is considered a failure in the route in terms of facilitating all vehicles using it.

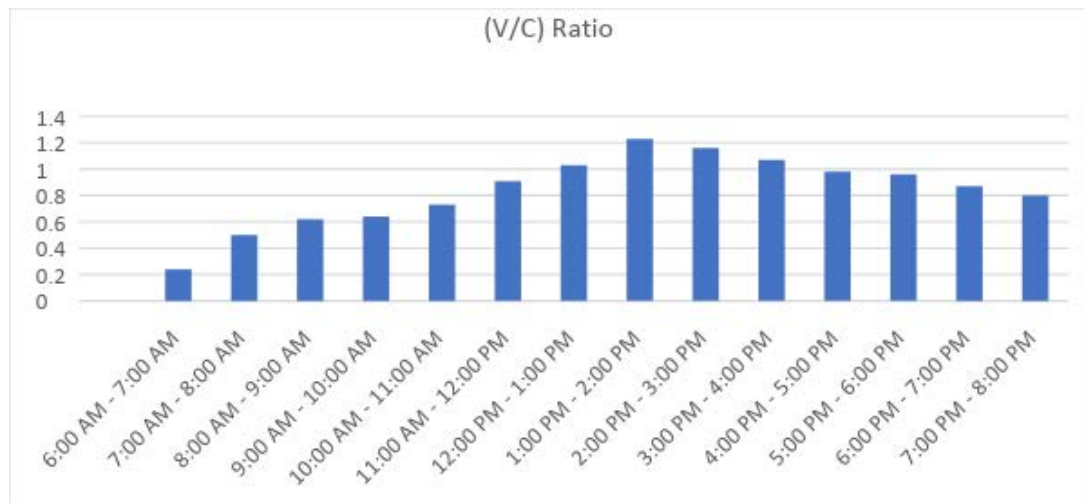


Figure 4. V/C Ratios with Time

The obtained calculations and results show that the LOS of Al-Masafi main street in the study area section is F, which implies forced flow conditions, stoppages for long periods, and low operating speeds. This result is confirmed by all studied parameters, particularly v/c ratio, and TTI.

11.2 Second Checkpoint

The highest volume of vehicles occurred from 7 a.m. to 8 a.m. which represents the rush hour period in Baghdad. Lower traffic volumes occurred during the rest of the day. The relationships between time and volume, queue length, travel time, speed, and v/c ratio are presented in Figures 5 to 7. In Figure 5, the peak (rush) hour is between 07:00 a.m. and 08:00 a.m. The highest volume is 2,034 vehicles with the highest queue being 22 vehicles. The lowest volume was between 7:00 p.m. and 8:00 p.m., with no queue.

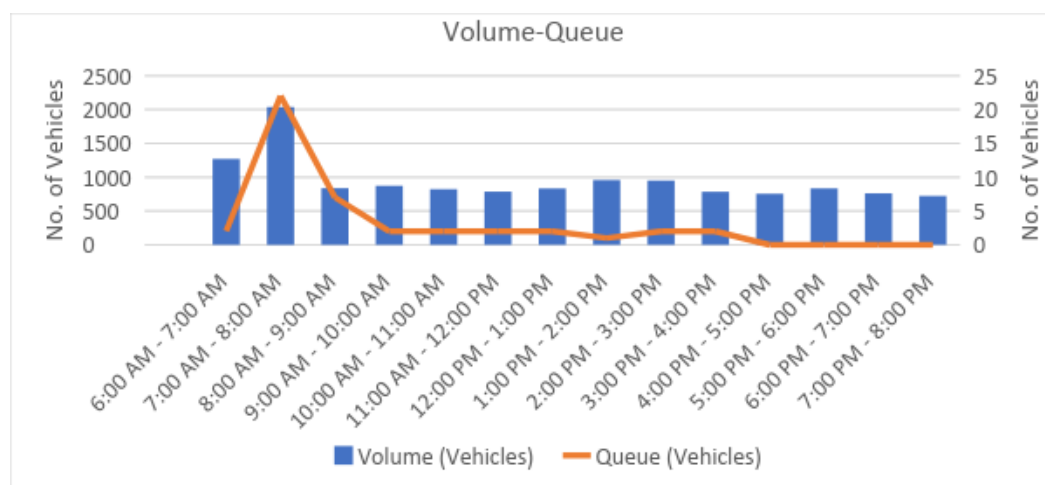


Figure 5. Relationship between Volume and Queue with Time Intervals

From Figure 6, the rush hour was between 07:00 a.m. and 08:00 a.m., with the highest recorded travel time (165 sec). The lowest travel time was between 6:00 and 7:00, with the highest speed (35 km/hr).

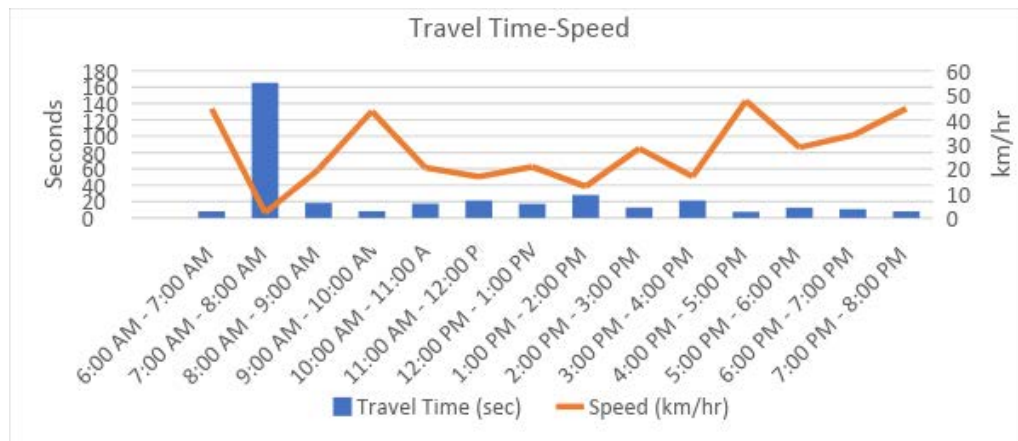


Figure 6. Relationship between Travel Time and Speed with Time Intervals

In Figure 7, the highest V/C was in the rush hour at 1.2, which again implies failure of the route to facilitate all vehicles using it.

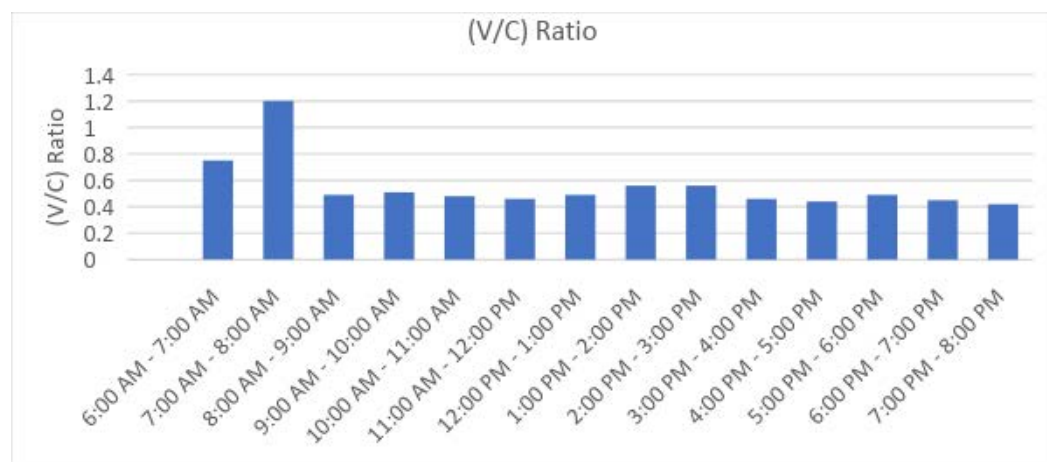


Figure 7. V/C Ratios with Time

11.3 Third Checkpoint

The same trends were observed at this checkpoint. The highest volumes were observed to occur during the rush hour periods of 6 a.m. to 8 a.m. and 12 p.m. to 2 p.m.

The relationships between time and volume, queue length, travel time, speed, and v/c ratio at this checkpoint are illustrated in Figures 8 to 10, respectively. As seen in Figure 8, the highest volume was 2,088 vehicles; the highest queue was 18 vehicles. Both of these were between 01:00 p.m. and 02:00 p.m. The lowest volume was between 10:00 a.m. and 11:00 a.m., with a queue of 11 vehicles.

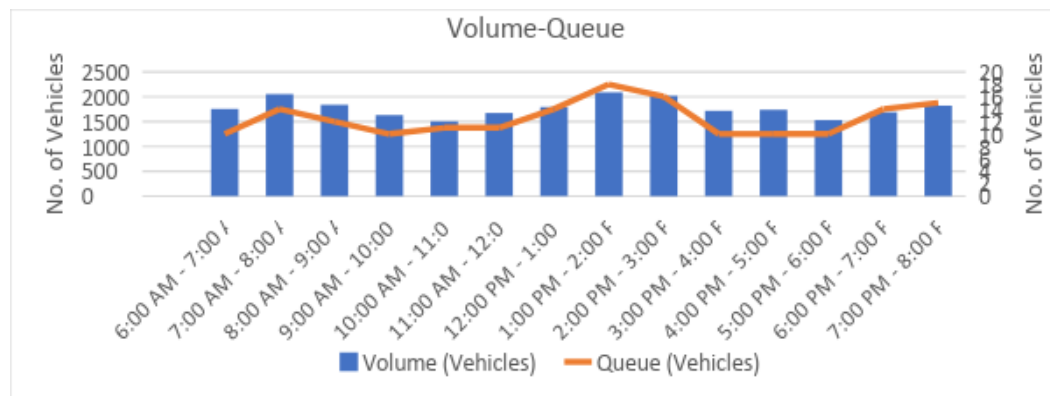


Figure 8. Relationship between Volumes and Queue with Time Intervals

In Figure 9, the rush hour was between 12:00 p.m. and 1:00 p.m., with the highest travel time (145.4sec). The lowest travel time was between 9:00 a.m. and 10:00 a.m. (32.11 sec.), with the highest speed of (11.21 km/hr).

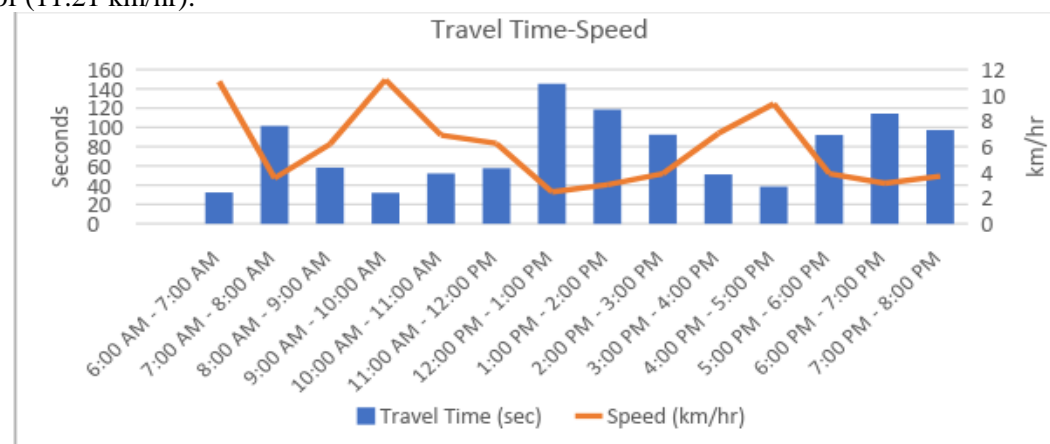


Figure 9. Relationship between Travel Time and Speed with Time Intervals

In Figure 10, the highest V/C is seen to be 1.21, which again suggests the failure of the route to facilitate all vehicles using it.

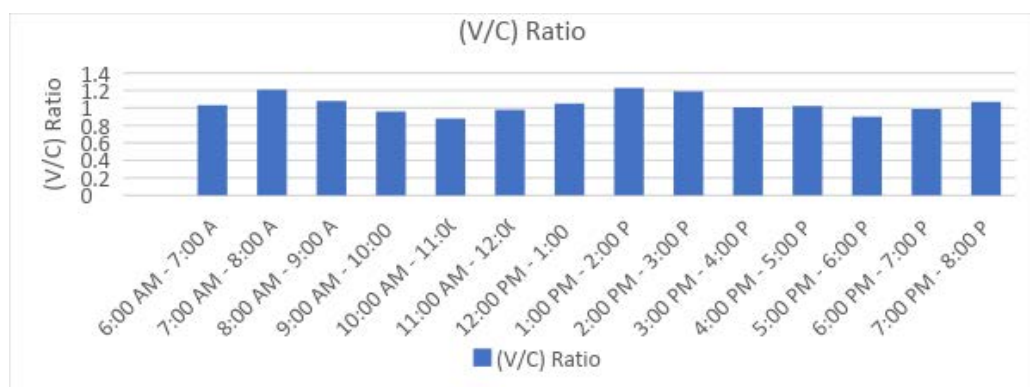


Figure 10. V/C Ratios with Time

11.4 Fourth Checkpoint

Observations are shown in Figures 11 to 13 for the fourth checkpoint. In Figure 11, the highest volume is 1,486 vehicles; the highest queue is 18 vehicles. Both of these occurred between 07:00 a.m. and 08:00 a.m. The second highest records were between 01:00 p.m. and 02:00 p.m. These figures represent the times of the highest volumes in general, while the lowest volume was between 05:00 p.m. and 06:00 p.m., with a queue of 5 vehicles.

In Figure 12, the highest travel time recorded was between 07:00 a.m. and 08:00 a.m., at 58.42 sec, with the lowest speed of 6.16 km/hr. The lowest travel time was between 09:00 a.m. and 10:00 a.m., at 12.14 sec, with the highest speed of 29.65 km/hr.

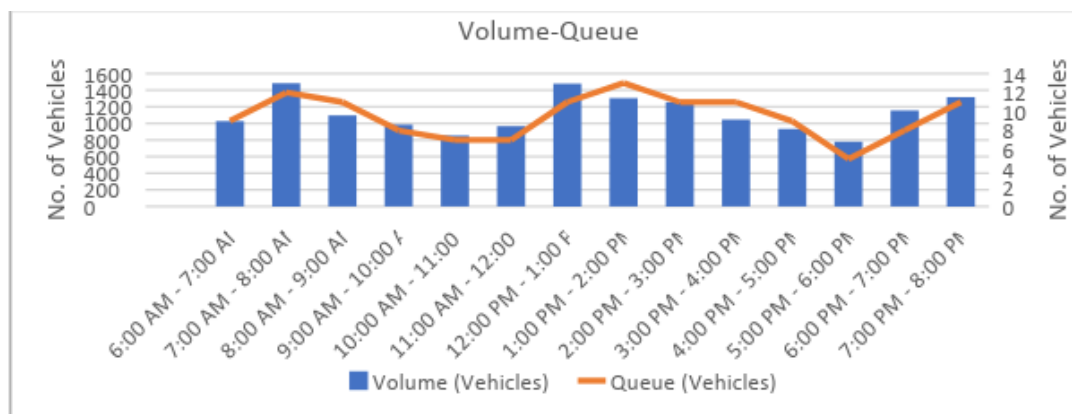


Figure 11. Relationship between Volumes and Queue with Time Intervals

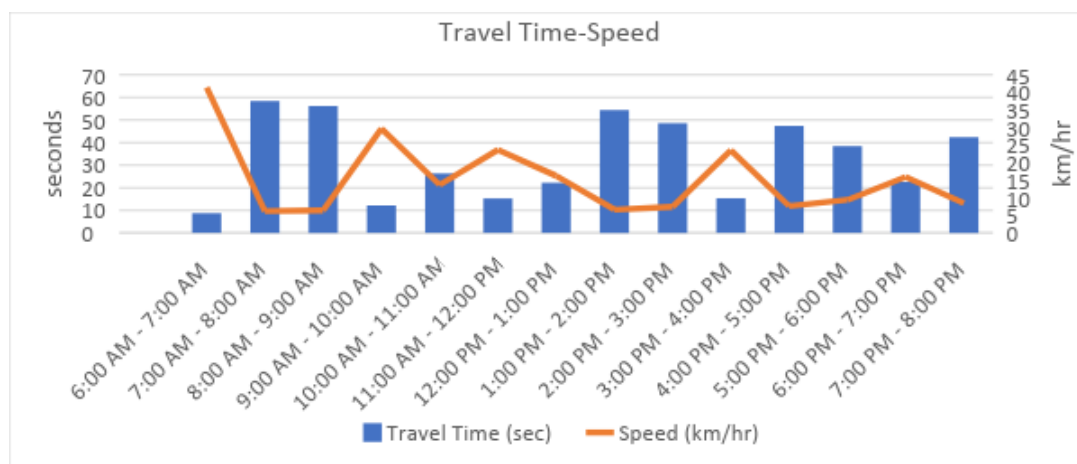


Figure 12. Relationship between Travel Time and Speed with Time Intervals

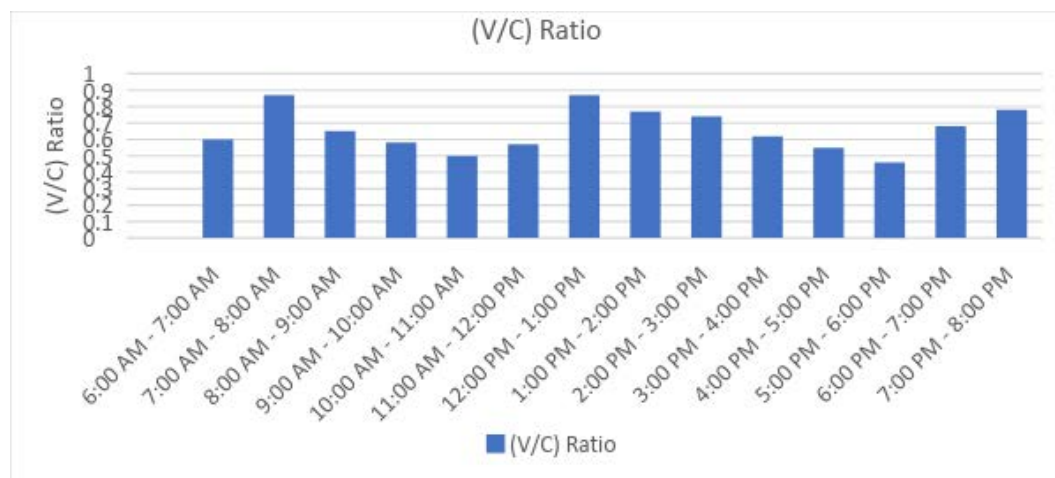


Figure 13. V/C Ratios with Time

As shown in Figure 13, the V/C ratio varied from 0.87 at noon to 0.46 from 05:00 p.m. to 06:00 p.m. This was the first of the study samples to display a ratio that stayed below 1, which is a healthy indicator of the road's traffic flow.

11.5 Fifth Checkpoint

The highest volume of vehicles occurred from 11 a.m. to 2 p.m. and from 6 a.m. to 8 a.m. The dusk hours (6 p.m. to 8 p.m.) also showed relatively high vehicle capacity while the lowest traffic volumes occurred from 8 a.m. to 11 a.m. Figure 14 suggests that the highest volumes occurred from 11:00 a.m. to 02:00 p.m. with an average volume of 2,630 vehicles, and an average queue of 9 vehicles. The lowest volume occurred from 09:00 a.m. to 10:00 a.m., with a volume of 1,320 vehicles and a queue of 4 vehicles.

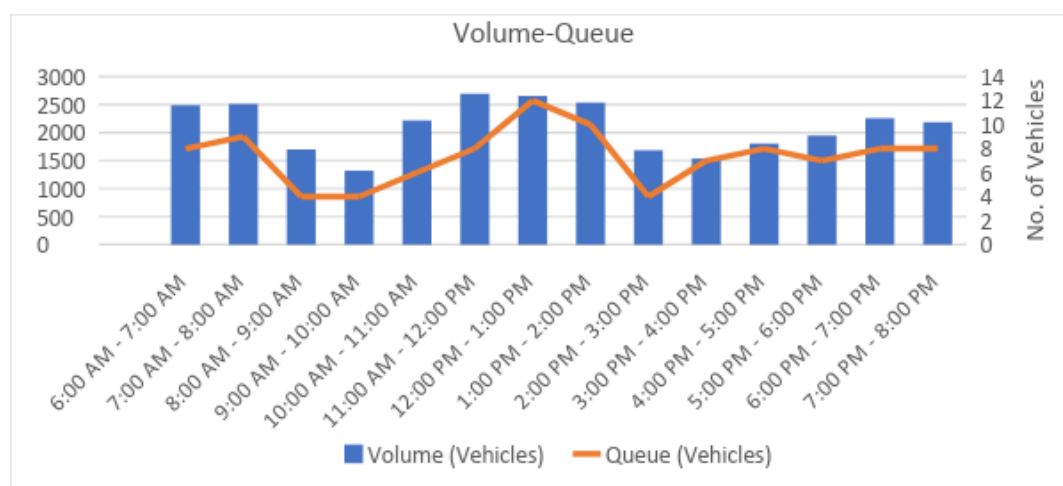


Figure 14. Relationship between Volumes and Queue with Time Intervals

Figure 15 shows that the maximum travel time was 48.32 seconds at the lowest speed of 7.45 km/hr between 01:00 p.m. and 02:00 p.m. It also shows a high travel time between 07:00 a.m. and 08:00 a.m. This emphasises the fact that rush hours in this section and in Baghdad in general, are the times at the

start and the end of standard work hours. The lowest travel time was 14.37 seconds at a highest speed of 25 km/hr, which occurred between 08:00 a.m. and 09:00 a.m.

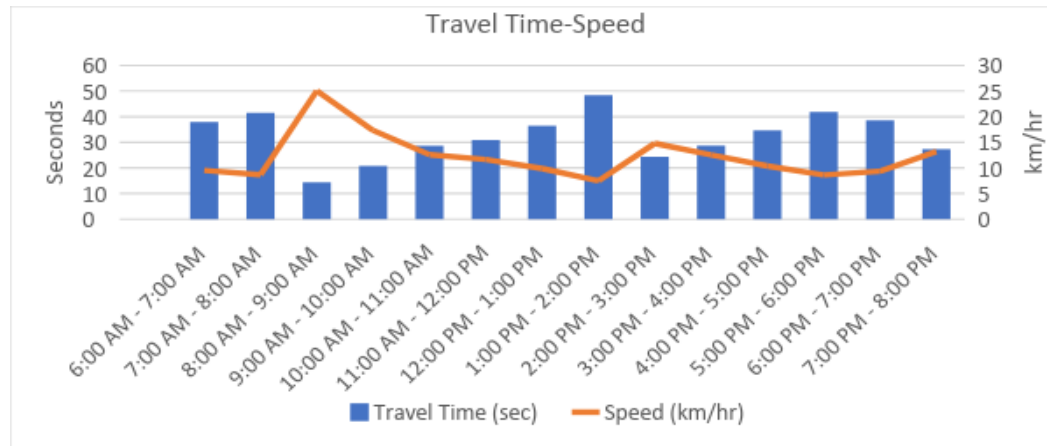


Figure 15. Relationship between Travel Time and Speed with Time Intervals

In Figure 16, it the highest V/C ratio was 0.79, which happened between 11:00 a.m. and 12:00 a.m. It is a good indicator that the V/C ratio did not reach 0.8.

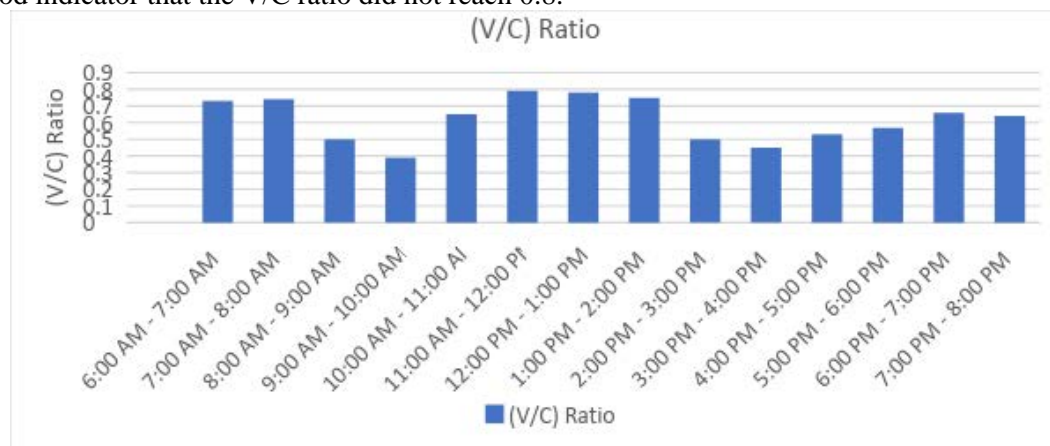


Figure 16. V/C Ratios with Time

11.6 Sixth Checkpoint

The values of the studied parameters are shown in the next three figures; these show further inflation in traffic volume, queues, and travel time in the rush hour periods and dusk hours in Baghdad city. Figure 17 shows that the highest volumes and queue lengths happened from 07:00 a.m. to 08:00 a.m., from 01:00 p.m. to 02:00 p.m., and from 06:00 p.m. to 07:00 p.m., while the lowest volume happened from 09:00 a.m. to 10:00 a.m.

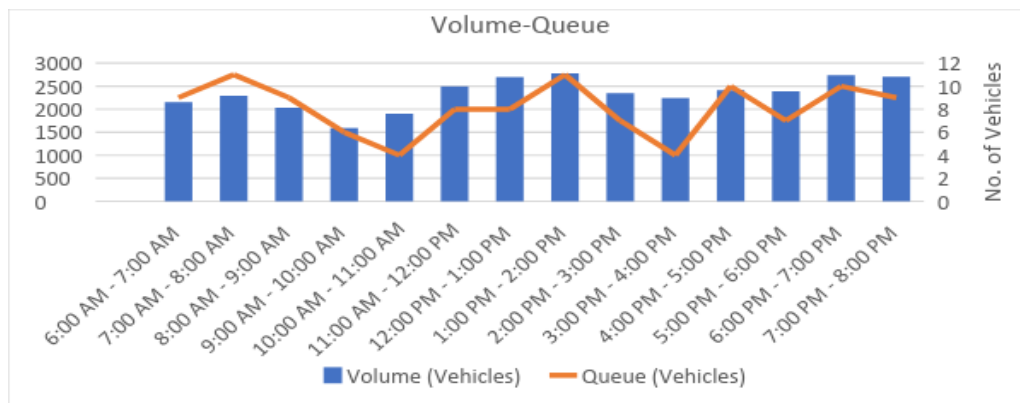


Figure 17. Relationship between Volumes and Queue with Time Intervals

Figure 18 shows the variations of the travel time and speed throughout the day. The highest travel time occurred from 01:00 p.m. to 02:00 p.m., at a lowest speed of 3.91 km/hr. The other observed rush hour also recorded high travel times with low speeds. The fastest time through this section was 12.75 seconds from 09:00 a.m. to 10:00 a.m., with the highest speed of 28 km/hr.



Figure 18. Relationship between Travel Time and Speed with Time Intervals

Figure 19 shows the variations of V/m .

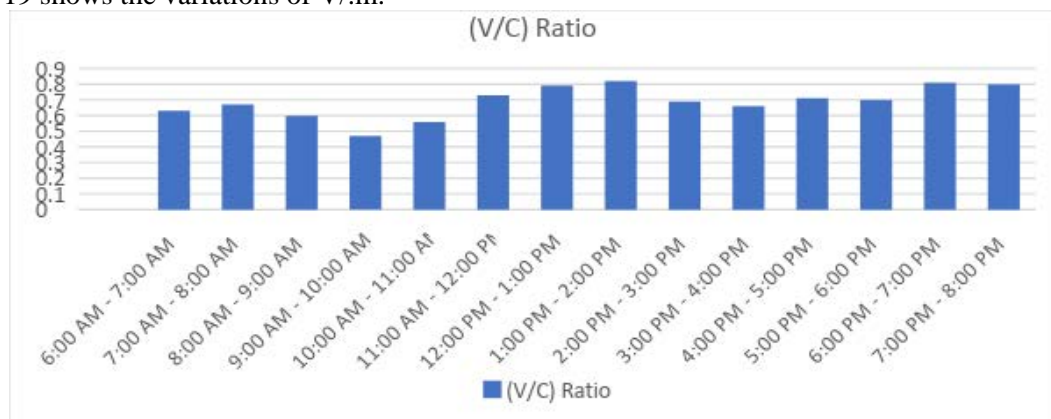


Figure 19. V/C Ratios with Time

12. Conclusions

Based on the results obtained of this research, the following conclusions can be drawn:

1. Average queue length for all checkpoints is 16 vehicles.
2. The average travel time index for all checkpoints in the study area is 9.331.
3. The V/C ratio for the studied road was more than 1.0 for the first three checkpoints (1.2 to 1.21), though less than 1.0 for checkpoints 4 to 6 (0.79 to 0.87).
4. The level of service for all roads where these checkpoints are located (F) which indicates **Forced flow conditions, stoppages for long periods, and low operating speeds**.
5. All roads investigated had no infrastructural defects, and thus it can be concluded that the failure of these roads was because of the negative effects of the checkpoints.

13. Recommendations

1. Removal of checkpoints inside the city, restricting them to major street entrances rather than every road. This solution is already being implemented and is exemplified in the removal of many checkpoints in the city such as at the Al-Zaitoon tunnel, the entrance of Al-Rubae Street, and the entrances of the bridges connecting Karkh and Risafa such as the Al-Ahrar Bridge. This is a successful solution since there have been no negative security setbacks.
2. A new lane can be added to the roads, increasing traffic speed and decreasing delays. Although this solution is complex, it would be beneficial as it could also encompass additional infrastructure renovations in Baghdad, which are necessary if the high rates of vehicle number inflation that took place after 2003 are to be taken into account.
3. There is a need to implement new security measures which ensure the fluidity of traffic flow. This may include the increased use of intelligence in cities, the use of high security cameras, real time road coverage by drones, and other security measures.
4. Improvement is needed to the road network system where checkpoints must exist to reduce the waiting time.

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