



SOLUTION MODEL FOR URBAN TRAFFIC CONGESTION: EGYPTIAN CASE STUDY

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ABSTRACT

Traffic congestion is a major problem in many cities around the world resulting in massive delays, increased fuel wastage, environmental impact and other negative consequences affecting the daily life of each individual. From a transportation engineering point of view, making the correct decision to eliminate such congestion problems can be very difficult for decision-makers who carry the burden of analyzing large quantities of data which could be vague and conflicting in nature. Therefore, an effective and consistent system is required to simplify the decision-making process of the traffic congestion control. Traffic simulation could be that tool.

The seriousness of traffic congestion in Egypt is the main motive for the study presented herein. The study aims at developing a model that sets guidelines on how to approach an urban congested traffic area, be able to tackle the problem and choose the effective engineering solution in terms of either geometry and/or structure.

Sectors of El Nasr Road, Cairo with a total length of 2.4 km is chosen as a typical example of an urban area with traffic congestion hotspots. It serves as an excellent location to implement the traffic solution model on.

The model is developed and implemented as follows: collection of traffic data, diagnosis of the congestion problems in terms of social, commercial, cultural, and behavioral aspects. The analysis of the data finger points out the flag areas by conducting total and peak traffic volume counts, simulation of the existing traffic conditions to get the delayed travel times of vehicles in that area. The analysis of the output would finally help decide whether such problem would be solved by geometric adjustments of the surface or the problem requires a multi-layered intersection.

Keywords: Traffic Congestion, Solution Model, Total & Peak-Hour Volumes, Traffic Simulation.

1. INTRODUCTION

One of the rapid developing cities in the world in terms of population growth is the capital city of Egypt, Cairo, which would provide accommodations for more than 24 million people by the year 2027 (Yohansin et al 2010). This rapid growth is directly proportional to the increasing pressure on the infrastructure systems available in the capital city, mainly on road networks (Yohansin et al 2010). The average vehicle speed around town is expected to be below 10km/hr per day (Yohansin et al 2010). This pressure will be translated into traffic congestions, which will have dominant and adverse effects on both the quality of the capital city population life and its economy.

A traffic engineering model solution is proposed and presented in this paper. The model should be able to pinpoint the main sources of congestion in an urban area and suggest an engineering sequence of steps to be followed to find the most suitable solution for such problems. The suggested solution would be the most feasible and effective one in terms of traffic control efficiency and congestion solution. The model is, then, applied on one of the traffic congested areas in Egypt, which is thoroughly discussed in the part of the Case Study, to study the model's effectiveness and proposed solution(s).

2. DEVELOPING TRAFFIC SOLUTION MODEL

Figure (1) shows the proposed model that should provide solutions to urban traffic congestions. It all starts with designating the study area and parameters contributing to the traffic problems on the urban artery under investigation. Data relevant to the designated study area will be collected and analyzed thoroughly in order to diagnose the traffic problem. Engineering solutions will be evaluated after using the simulation traffic tool in order to assess the effectiveness of these solutions through the output of the simulation program. If the suggested improvement is not accepted, another solution is proposed and assessed till reaching acceptable performance of traffic flow

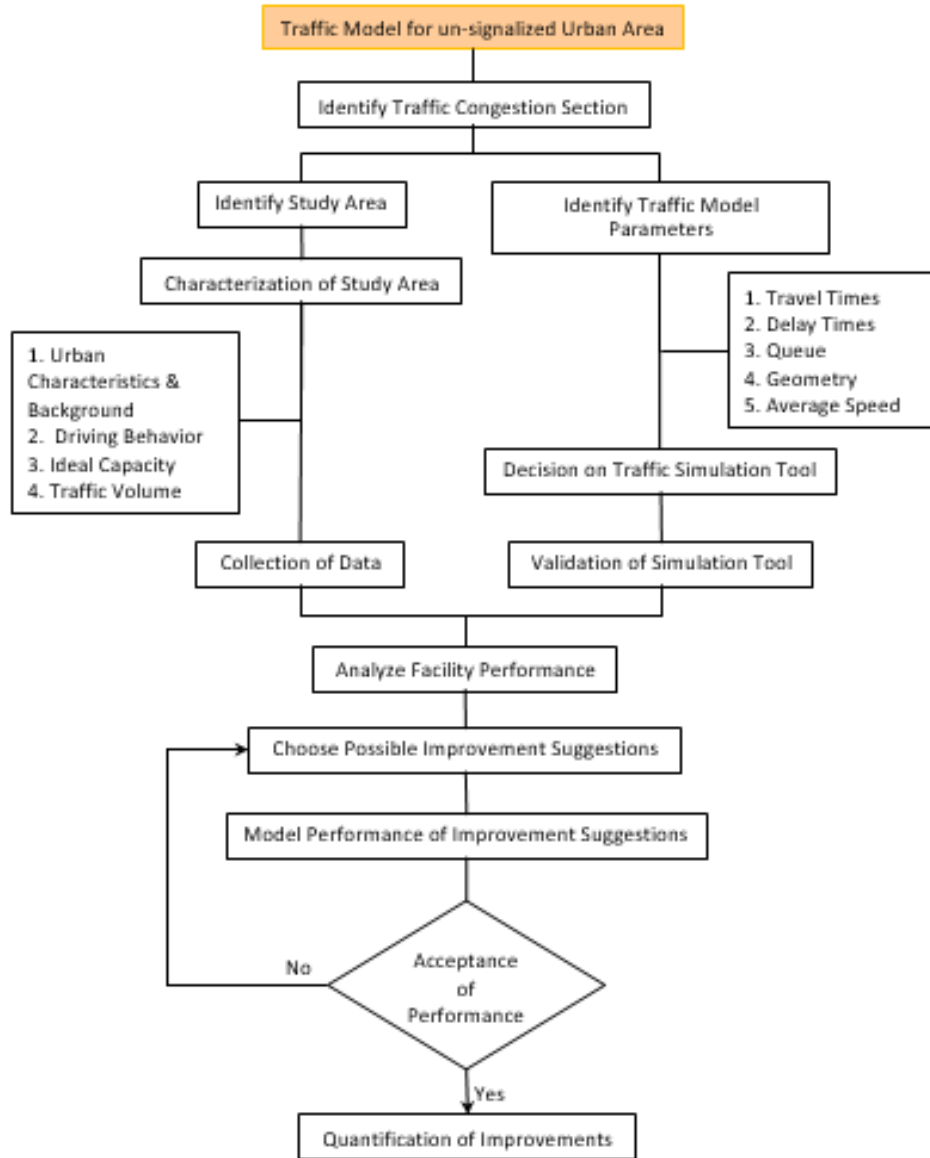


Figure 1: Traffic Solution Model

2.1. Identification of the main influencing Parameters

The process starts by identifying the crucial parameters for the traffic solution model which point out the social, cultural, commercial, urban planning and geometrical design factors that contribute to such a congestion problem and add to the existing pressure on the road network. The identified parameters are analyzed to comprehend their possible direct and/or indirect effects on the congestion problem.

2.2 Information Collection

The most crucial step to guarantee the success of the model and the efficiency of its output is the data collection processes and its analysis including: research about the study area in terms of urban and transportation planning, previous total traffic volume counts and studies, interviews with the transportation authorities, surveys of the drivers and residents, contour maps and soil reports.

2.3 Data Collection

Traffic data collection includes total volume vehicle counts during different hours of the day to determine the peak hour of the study area. Afterwards, detailed, categorized traffic and pedestrian counts are conducted at the chosen peak hour of a typical day at different stations of the area. Such data collection and its analysis will lead to the main basis of all assumptions in the application of the model. Using the traffic volumes and the main geometric features of the study area, the delay time and average speeds are simulated using a traffic simulation tool.

2.4 Traffic Simulation

The model calls for selecting an appropriate simulation technique. There are various simulation programs that are used to model a traffic flow situation. The selection of the suitable tool to simulate the existing traffic flow should be guided by the output parameters needed for the evaluation of simulation model; e.g. travel delay times of the vehicles, Moreover the different tools in the program to optimize the simulation model are important as well (e.g. input collected traffic volumes, option of adjusting for the driving behavior of the vehicle drivers). After choosing the simulation tool/program, different measures of effectiveness (MOE) such as the reduction of delay times of different sections of the study area and the average speed of the vehicles in the whole network are used to evaluate and compare different proposed scenarios with the situation of the study area.

At the end of this step, further solution approaches and scenarios may be considered to optimize the output of the simulation by reducing the travel and delay times of the vehicles and monitor the traffic control of the whole area.

3. APPLICATION OF THE PROPOSED TRAFFIC SOLUTION MODEL: CASE STUDY IN EGYPT

To validate and calibrate the described traffic solution model, it is used to study one of the traffic congested areas in Egypt. Long term and short term solutions are proposed, simulated, analyzed and finally evaluated.

3.1 Identify Study Area

A typical highly congested area in Greater Cairo, Egypt with high impact on the general traffic flow in the capital city is chosen, observed and analyzed. The main arterial road “Nasr Road” in Nasr City, one of Cairo’s largest districts, is selected to demonstrate the validity of the model. Figure (2) shows the Google Earth image of the selected area.

3.2 Characterization of the Study Area

In 1959, the Egyptian President made the decision to plan and execute a new district called “Nasr City” or “The City of Victory” which is located in the east side of Old Cairo, formally a deserted area, to prevent the urban expansion on cultivated land around the Nile valley and delta. The “new” district was planned on a total area of 1200 km² (Cairo Observer, 2015).

The concept of its master plan was based on a grid pattern which consists of different neighbourhoods with “central nucleuses” and contain “superblocks” with several services and activities. The grid pattern consists of main intersecting roads with a width of 50 m which acted as main dividers between the different zones (Cairo Observer, 2015).

Over the last fifty years, land use transformation has started taking place during the built up phase (i.e. before the completion stage of the district) shifting Nasr City to a “mixed use concept (residential-commercial)” instead of “single usage” as per the original plan concepts. The area has experienced drastic population changes, according to the population statistics (Central Agency for Public Mobilization and Statistics, Egypt): Population Count in the year 1996: 291,571 & and in the year 2006: 501,597, in terms of number of inhabitants, socio-cultural background and life styles, which were important factors that led to the land transformation.

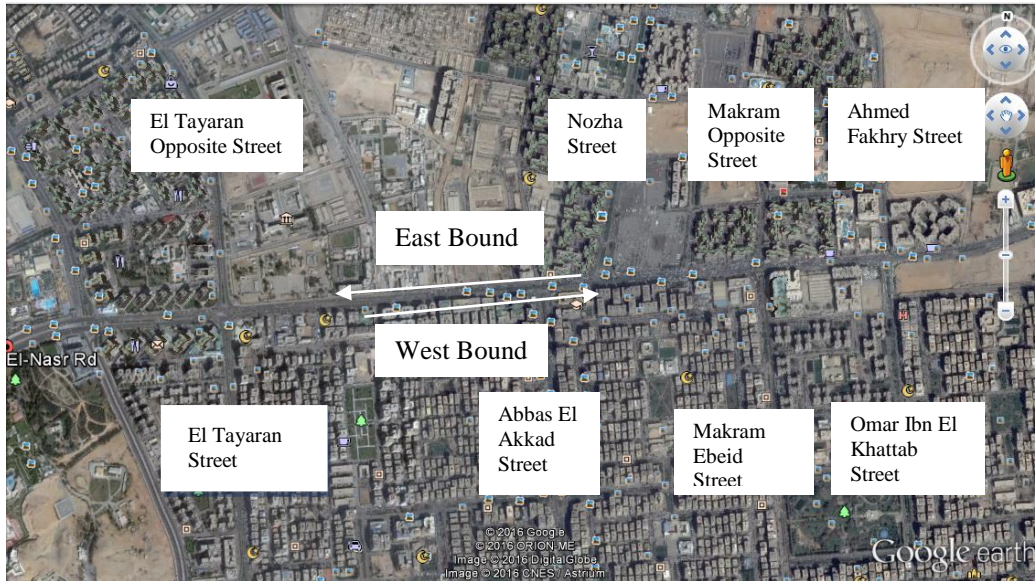


Figure 2: Google Earth Image of the Study Area

3.3 Origin of Traffic Congestion Problem

Nasr City has witnessed a severe deviation from its master plan in terms of urban planning structure and population accommodation. The daily scene in Nasr city is chaotic, very high in vehicular traffic congestions and lacks pedestrian circulation facilities. In addition, the ineffective public transportation networks and increasing population density, the replacement of residential low-rise buildings with multi-story apartment buildings, have escalated the congestion situation in that area noticeably. The originally planned district which should have been composed of residential blocks with its services and activities in the center, has turned to a mix use area with many commercial, educational and residential areas. Most ground floors of the buildings located on the main arterial road of this district have been used for commercial purposes which increase the rate of traffic attraction; such traffic was not taken into account in the original design.

Another significant factor contributing to the congestion problem is the changes in socio-cultural behavior and life style of the citizens. The lack of proper driving behavior, which could be summarized in illegal parking, no respect to the over-taking maneuver and no respect to the general rules of the road, are some of the major factors in causing such traffic congestion. Figure (3) shows an example of the present vehicular congestion at one of the intersections in the selected area.



Figure 3: Chaotic intersection situation

3.5 Traffic Volume Counts

Total volume data collection was conducted using on site and videotaped counts in both directions for an intersection at a typical segment of the road. The preliminary selection of the counting hours were based on the most congested hours of the day.

The segment which was chosen to represent a typical congested section of the road is located at Makram Ebeid Street (check Figure 1). These counts were done by installing cameras at a five storey building at Nasr Road. The recording continued for 24 continuous hours. These videos were filtered and manually counted for the following typical rush hours: 7 to 11 AM and 4 to 10 PM. Based on this count, the peak hour of the typical working day is selected for further analysis. Table 1 shows the results of traffic volume count.

Table 1: Total volume count

Time	Total Volume Count (Wednesday 9-9-2015)		
	Direction: from Tayaran Street to Omar Ibn El Khattab Street		
	West Bound	East Bound	Total Volume (Σ 2 ways)
7am-8am	3063	3840	6903
8am-9am	3841	4935	8776
9am-10am	3550	4525	8075
10am -11am	3250	3682	6932
4pm-5pm	3490	3225	6715
5pm-6pm	4029	3962	7991
6pm-7pm	3377	4242	7619
7pm-8pm	3413	4228	7641
8pm-9pm	3340	3870	7210
9pm-10pm	3750	4005	7755

It was concluded that the peak hour of a typical working day in Nasr Road is from 8 to 9 am. A detailed manual count is then conducted at each intersection to record the traffic volume during that peak hour at each intersection. The count was done partially by videos recorded by the group or by on-street counting using Talley-sheets. The first two intersections were counted at same day at a typical working day between Monday and Wednesday. The two others were counted on the following day and finally the last two intersections at the third day. Figure 4 shows the results of the intersection hourly count.

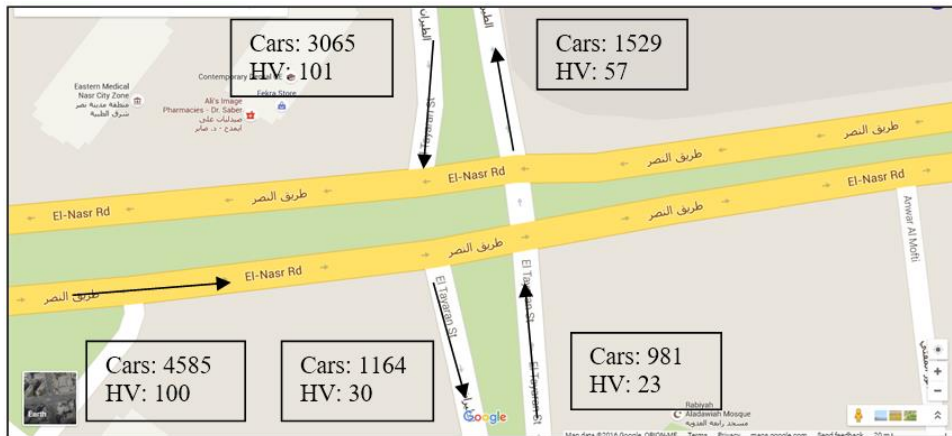


Figure 4: Intersection Hourly Count

3.6 Traffic Simulation parameters & Simulation Package

The model presented in this study falls under the category of “Traffic Models”, according to criteria mentioned in the Handbook of Transportation Engineering (Kutz 2011). *The model* completes detailed analyses of traffic operations for the network available and analyzes the influence of traffic control systems and geometric adjustments on the facility.

The main parameters for the analysis and the simulation are: travel times, time delays, average speed and the geometry of the study area.

The modelling package, PTV VISSIM 7 (PTV Group 2013), is chosen to perform this task. The choice of this program is based on various aspects: the ease to model the geometry of the study area which varies along the span, the provided number of integrated systems such as signal controllers and its option to control and specify the behavior of the driver and the characteristics of the vehicles. It offers a 3D animation of the modelled scenarios and is able to present a graspable demonstration of the traffic situation of the study. (PTV Group 2013)

Calibration of the Vehicle Count Data:

To insure the accuracy of the simulation model and its output, the vehicle count had to be calibrated in order to assess inaccuracies.

First, all vehicle counts were added on the study are:

$$[2] \quad \sum \text{Vehicle Inputs (number of vehicles entering the model from all directions)} = \sum \text{Vehicle Outputs (number of vehicles exiting the model from all directions)}$$

$$[3] \quad \sum \text{number of vehicles entering the intersection (entrance, U-turn or intersecting street)} = \sum \text{Number of vehicles exiting the intersection (exit, U-turn or intersecting street)}$$

3.7 Important modelling factors of the Simulation Package:

In the simulation model, the following inputs are required to start the simulation:

- **Street Network’s Geometry:** to be able to illustrate the network on the program, the dimensions of the road have to be measured and drawn via links and connectors.
- **Vehicle Input** at the different entrances to the study area (e.g. at intersection of Makram Ebeid Street with Nasr Road).
- **Decision Routes:** specify the routes for the vehicles coming into and leaving the model during the simulation along with the relative flow (i.e. how the vehicle input from one end would disperse in the model with the

desired percentage). The relative flow percentages is based on assumptions made while observing the recorded videos.

- **Data Collection Points:** to specify the points at which program shall count the vehicles and measure the velocity.
- **Travel Time Measurements:** this input is similar to the routes, but the routes are selected to measure a specific distance along with its travel time to use it later for the delay measurement.
- **Driving Behavior:** To effectively take the wrong driving behaviour factors into consideration, some changes and adjustments were made to the model to reflect the traffic situation as realistic as possible. First of all, to accommodate the illegal parking situation, each lane which is used as a parking spot is discarded from the model (i.e.: if the road has 4 lanes and one of them is occupied by parked cars, only 3 lanes were entered in the simulation model). A lot of changes were made in the settings “*Driving Behaviour*” in the program (e.g. sudden maneuver, sudden change of lanes, no gaps between the cars...etc.).

3.8 Rate of Traffic Increase

From an urban planning point of view, the predicted traffic flow in that area would increase due to the urban development in terms of residential compounds; e.g. the “Gate” compound currently under construction near Omar Ibn El Khattab Street. Also, the increasing demand on the various commercial facilities in the area has been causing a lot of traffic in that area. For example, “City Stars” mall, which is one of the most important causes for the traffic increase in the surroundings of the study area, attracts many people who come from different districts of Greater Cairo – mainly using 6th of October Bridge.

Hence, the previously mentioned commercial development would attract traffic and warrant an assumption of annual increase of 5% over a time period of 20 years in traffic volumes entering and leaving the study area. This assumption is based on the annual population increase plus retail and commercial attractions that would exist in that area in the next 20 years. Normal growth in Egypt is around 2.3%. This may create significant delay times.

3.9 Analysis of Facility Performance

The measures of effectiveness for this case study are delay times of the vehicles at the end of the simulation run and the overall vehicle network performance evaluation. The decrease of delay times is a clear indication of the effectiveness of the chosen alternative solution. To form the basis for a clear reliable evaluation, the current traffic flow is entered into the traffic simulation model and its output in terms delay times is recorded. The same procedure is done for the estimated future short and long term traffic flow.

The suggested implemented solutions are divided into and named as “short” and “long” term solution. **The Short Term Solution** involves geometric re-design of the artery and the intersection. It is meant to provide better performance for 5 years, i.e. till year 2020.

The Long-Term Solution approach is to consider an interchange to separate directional traffic flows; in this case study a tunnel is the proposed long term solution. The tunnel is a two directional longitudinal one with only one entrance and one exit on each side (i.e. west bound tunnel and east bound tunnel) and stretches along the whole study area starting before the Tayaran intersection and ends after Ahmed Fakhry intersection (check Figure 5).

The short term solution consists of transforming all four legged intersections from un-signalized to signalized intersections with fixed times signal control systems calculated according to the method of Garber, J. and Hoel, A. 2008, and removing most of the U-turns unless needed. Results show clear reductions in the delay times between the expected future without changes and the one with signalized intersections.

To differentiate the appropriate solution approaches, the traffic flow is simulated 3 times: 1- without making changes for the current situation, 2- no changes to area with the five years anticipated and estimated flow and finally no changes to the area with the 20 years anticipated and estimated flow. The results of these 3 simulation runs will be used as a basis to demonstrate the improvements in delay times done by the short term solution and long term solution.

3.10 Simulation Results

The following graphs present the simulation results of different scenarios, with or without solution(s), to illustrate the traffic problem and its suggested solutions. Table (3) shows the key map for the study artery. It identifies the inlets and outlets of the main road and the main circulation in that area. The study area, Al Nasr Road, consists of a main two directional arterial road with a total stretch of approximately 2.9 km long, two main entrances to the area from each side – one coming from the direction of the Airport (west bound) and the other from October Bridge heading in the opposite direction (east bound). Seven streets intersect perpendicularly with the main road and one at lightly skewed angle. These intersections are considered as in and out flow sources.

Figure (6) presents the delay results per distance at the near future time with and without the short term solution. The figure illustrates clearly the critical sections with very high delay times such as at the first section (1), figure (5), which reaches a delay of approximately 18 minutes without the short time solution.

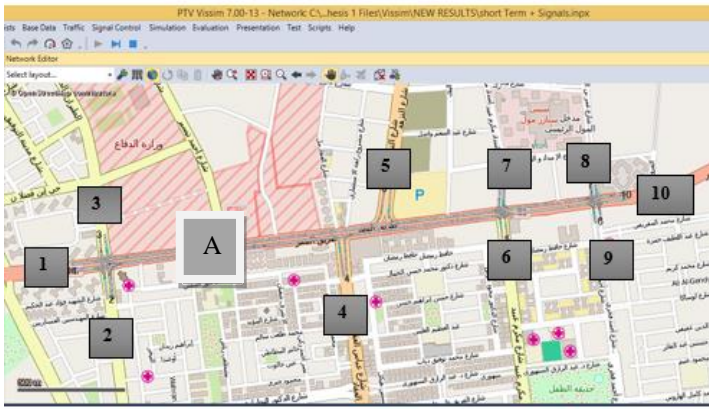


Figure 5: Key Map of the Study Area

Table 3 Key Map for the Study Area

LINK NO.	LINKS	SECTION	DISTANCE (KM)	LINK NO.	LINKS	SECTION	DISTANCE (KM)
1	1 to 2	October Bridge to Tayaran Exit	0.4	8	7 to 5	Makram opp. to Nozha	1.3
2	A to 4	Tiba U-turn to Abbas El Akkad Exit	0.4	9	5 to 3	Nozha to Tayaran opp.	1.3
3	4 to 6	Abbas El Akkad to Makram Ebeid Exit	0.7	10	3 to 1	Tayaran opp. to October Bridge	0.4
4	6 to 9	Makram Ebeid to Ahmed Fakhry Exit	0.4	11	1 to 10	October Bridge to Airport	2.8
5	9 to 10	Ahmed Fakhry to Airport	0.3	12	10 to 1	Airport to October Bridge	2.8
6	10 to 8	Airport to Omar Ibn El Khattab	0.3	13	1 to 10	October Bridge to Airport	2.8
7	7 to 8	Omar Ibn El Khattab to Makram Opp.	0.4	14	10 to 1	Airport to October Bridge	2.8

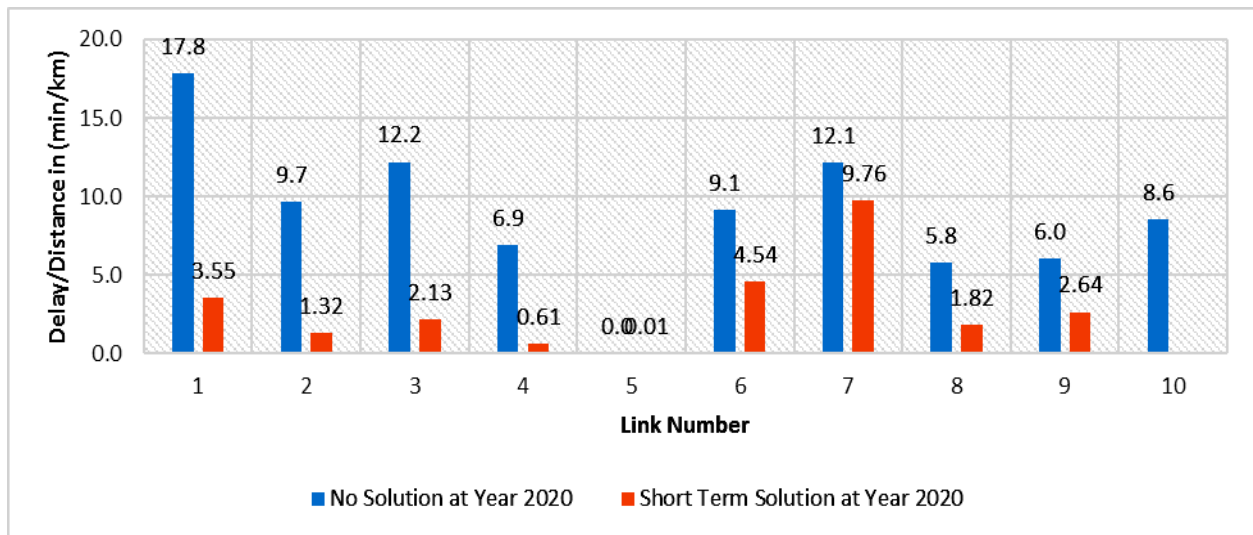


Figure 6: Average vehicle Delay per Distance at Year 2020

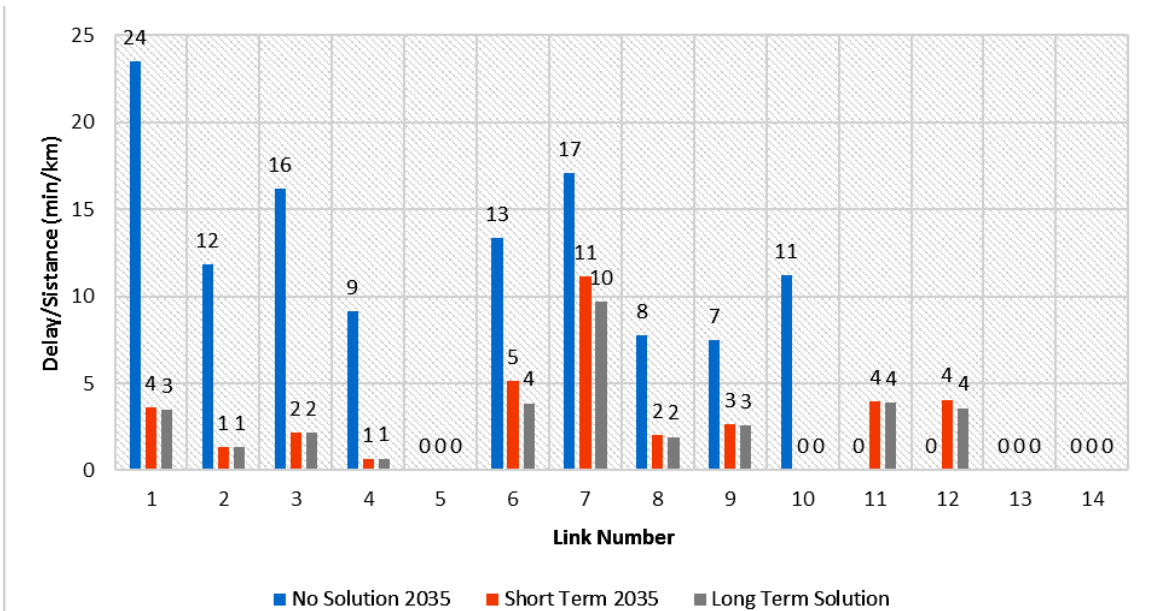


Figure 7: Average vehicle Delay per Distance at Year 2035

Figure (7) shows the far future delay results of three different scenarios: expected flow without any solutions, expected flow with the short term solution and finally the delay of the long term solution. The drastic decrease in delay which reaches up to 0 minutes delay time (i.e. no delay time, travel time will be the distance multiplied by the speed) at some sections such as opposite Tayaran Street to October Bridge emphasises the effectiveness of the suggested solutions. It can be observed that the difference between the short and long term solution do not show a significant change; however, the capacity of the road increases significantly with the addition of the tunnel. For example; at the entrance of the area coming from October Bridge, the capacity without the tunnel was 2143 vehicles per hour in the future with the short term solution only. After the addition of the tunnel to the model, the capacity of the area increases to 2200 vehicles per hour on surface and 2461 vehicles per hour driving through the tunnel. The same significant increase is visible in the other direction. Therefore it is safe to say that the dual improvement in the capacity and delay time shows the success of such model.

3.10.1 Performance Evaluation of the whole Network

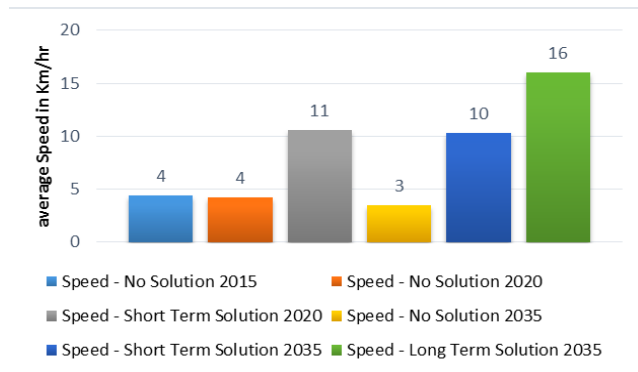


Figure 8: Average Speed over Total Network

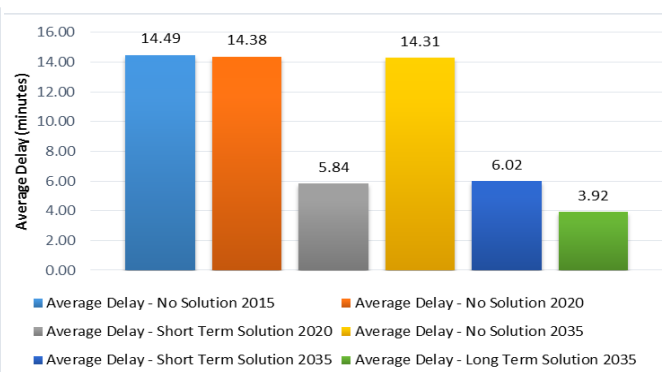


Figure 9: Average Delay of total network

Figure (8) and (9) are different measures, average delay time and average speed, over the whole network. Such evaluation is useful when comparing the overall performance of the network and pointing out the improvement over the whole area and not at specific locations. For example, the average speed in the far future (2035) increases from 3km/hr to 10 km/hr to finally 16 km/hr due to the implementation of the short term and long term solution,

respectively. The average delay over the whole network experiences a clear decrease starting with 15 minutes in the present situation and reaching 3.5 minutes in the long term solution after 20 years.

3.10.2 Limitations of the Suggestions

The main limitation the group has faced during examining such a heavily congested urban traffic sector, is the attempt of improvement of the capacity of the study area (i.e. Nasr Road) by increasing capacity of the road. The model states the level of service or the volume per capacity ratio is one of the measures of effectiveness of any suggested solution. In the case of the study area, the increase of capacity of such area is very limited due to the existing structures, buildings, geometric traffic features in that area and the unacceptable driving behavior of the drivers (e.g. illegal parking and illegal bus stops). Various solutions were discarded due to the lack of space in that road (i.e. constructing a tunnel with multi-entrances and exists to serve more than two points).

The application of the model for that area, however, has succeeded to drastically decrease the delay time in that area in the far future, which is the point in time analyzed in any traffic planning study.

Because the model is applied on a fully saturated area with a critical existing level of service F due to very high traffic demand, in addition to the 2.5% assumed and anticipated increase in population growth, the short and long term solution will limit the increase in capacity of the sector.

The success of other measures in terms of delay time and speed compensate for the lack of variety in solution options that could be applied in such section according to the model.

3.11 Analysis of Proposed Solutions

It is clear from figure (8), that the short term solution decreased the average travel delay time per vehicle per distance from 19 minutes to 11 minutes at the east bound, which is an evident improvement for the short term period. The long term solution includes a multi-layer interchange, which proposes to combine the short term solution with the construction of a two directional 3 lanes tunnel with its entrances at both ends of the study stretch artery at the west and east bound. This solution intends to serve the traffic volumes for the next 20 years, i.e. till year 2035. Figure (9) provides comparison performance for the traffic situation in 20 years without any changes, short term and that associated with the long term solution in terms of delays. The simulation results show gradual improvement corresponding to the short term and long term solutions. Although a large number of vehicles have been taken off the surface using the proposed tunnel, the signal timings are still necessary in the future network improvement solutions to control the reduction of delay times across the study stretch.

Figure (8) shows improvement in the average travel speed at present time (4 km/hr), year 2020 with short term solution (10 km/hr) and year 2035 with long term solution (18 km/hr) which confirms the statements of the JICA report stated at the introduction of this study.

4. CONCLUSIONS & RECOMMENDATIONS

The following can be concluded;

1. The proposed model is used successfully to pinpoint, analyze and assess the congestion problem within a proposed study area
2. The proposed model is flexible enough to provide different solution scenarios; both surface geometric adjustments and construction (Tunnel) solution
3. The used simulation tool (Vissim PTV) is a powerful tool to simulate local traffic flows including providing flexibility in network geometrics and modeling driver behaviour.
4. The traffic simulation model results indicate the criticality of the traffic situation in the next 20 years, if study area remains at its current state without any traffic solution attempts, and emphasises the need for fast strict decisions which have to be taken to face Cairo Chronic traffic congestion problems.
5. The proposed traffic congestion model is a good tool for helping decision makers specify their appropriate decision

The following can be recommended for future work:

1. Undertake an environmental assessment after reaching a conclusion with the help of the simulation tool
2. Consider additional MOE's in the iterations (e.g. pedestrian circulations) to make the model as robust as possible.

ACKNOWLEDGMENTS

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