Evaluation the level of service at a roundabout

- A case study on Al-Ibrahimeya roundabout in Alexandria, Egypt

Bachelor Thesis Project 2019

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Abstract

The capacity of today’s transportation network in Alexandria cannot handle the increasing number of vehicles. The root of traffic congestion in Alexandria is most likely a result of urban planning failure, an inadequate public transportation network, strong population growth, lack of enforcement of traffic laws, complex spatial street network and poor road quality.

The aim with this thesis is to simulate various traffic scenarios for the purpose of studying, evaluating and improving the traffic conditions on the intersection Al-Ibrahimeya, however, for long-term efficiency and improvement in Al-Ibrahimeya, the traffic conditions in the entire system be improved.

In this thesis, a model was built in the microscopic software VISSIM and macroscopic software SYNCHRO. The model is calibrated based on data collected from video recording. Two alternative solutions to overcome the congested traffic conditions were tested. Signalization has been the main alternative solution performed for intersection Al-Ibrahimeya.

The simulation results showed some improvements in terms of delay and travel time. Roundabouts are usually suitable for under low to mid traffic conditions. When there is a heavy traffic flow, as in this case, roundabouts are not suitable and may cause problem in the network. Implementing signals led to some decrease in the entering and exiting flows because the total network became more controlled. However, an organized and well-functioning signalization program helped to reduce delay and travel time in most of routes.

Keywords: congestion, roundabout, simulation, VISSIM, SYNCHRO, delay, traffic signal, Alexandria.
Sammanfattning

Kapaciteten på det rådande transportsystemet i den egyptiska staden Alexandria har svårigheter att hantera det ökande antalet fordon. Trafikstockningar i Alexandria är resultatet av en ineffektiv stadsplanering, bristfällig kollektivtrafiknät, kraftig befolkningsstillväxt, avsaknad av trafikregler, komplicerade gatunätverk och otillräcklig vägkvalité.

Syftet med detta examensarbete är att simulera olika scenarier för att studera, utvärdera och förbättra trafikförhållanden i korsningen Al-Ibrahimeya. Det är dock grundläggande att framhålla att för långsiktig effektivitet och förbättring av Al-Ibrahimeya måste trafikförhållanden i hela systemet utvecklas.

I detta examensarbete byggdes modeller med hjälp av simuleringsprogrammen PTV VISSIM och SYNCHRO. Modellerna är kalibrerade utifrån data som samlats in från videoinspelningar. Två alternativa lösningar för att övervinna de överbelastade trafikförhållanden testades. Signalisering har blivit huvudalternativet utförd i korsningen Al-Ibrahimeya.

Simuleringsresultat visade en del förbättringar såsom kortare fördröjningar och restider. Rondeller är i grunden lämpliga för låg till mellan trafik och när det är ett stort trafikflöde som i detta fall, är rondeller inte lämpliga utan kan istället verka som hinder i nätverket och resultera i motsättningar. Installation av trafiksignaler ledde till en viss minskning i in- och utflöden då det totala nätverket blev mer reglerat och ett välfungerande signalprogram bidrar till att minska fördröjningar och restider i de flesta ruterna.

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Alexandria, June 2019
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# Table of Contents

1. Introduction ................................................................................................................................. 5  
   1.1 Background ............................................................................................................................. 5  
   1.2 Aim ......................................................................................................................................... 8  
   1.3 Methodology ........................................................................................................................... 8  
   1.4 Limitation ............................................................................................................................... 8  
   2 Literature review ......................................................................................................................... 9  
   2.1 Geometry and design of roundabout ...................................................................................... 9  
      2.1.1 Regulations and capacity in roundabout ............................................................................. 10  
   2.2 Roundabout signalization ........................................................................................................ 11  
   2.3 Safety at roundabout ............................................................................................................... 12  
   2.4 Traffic simulation .................................................................................................................... 12  
      2.4.1 VISSIM ............................................................................................................................ 13  
      2.4.2 SYNCHRO ...................................................................................................................... 14  
3 Methodology ................................................................................................................................... 15  
   3.1 Case study ............................................................................................................................... 15  
   3.2 Data collection and area description ...................................................................................... 16  
4 Calibration and validation ............................................................................................................ 18  
   4.1 Model development ................................................................................................................ 18  
      4.1.1. VISSIM ........................................................................................................................ 18  
5 Simulation models ......................................................................................................................... 20  
   5.1 Calibration of the VISSIM model ............................................................................................ 20  
   5.2 SYNCHRO ............................................................................................................................ 22  
6 Base scenario selection .................................................................................................................. 23  
   6.1 Scenarios ............................................................................................................................... 24  
      6.1.2 Scenario 1: Change of the geometry and signalization ..................................................... 24  
      6.1.3 Scenario 2: Signalization of the current intersection ....................................................... 26  
7. Results .......................................................................................................................................... 27  
8 Discussion ..................................................................................................................................... 31  
9 Conclusions and future work ........................................................................................................ 33  
10 References ................................................................................................................................... 34
1. Introduction

In this chapter, a background about the city, description of the project area, the aim of this thesis, limitations and a methodology of this study is given.

1.1 Background

Alexandria, with its unique history, is one of the oldest cities with a population about 5.2 million, which makes it to the second-largest city in Egypt. This fast-growing city has an annual growth rate about 2-3% and covers a large area with a density of about 1920 persons per square kilometer, meanwhile the density at the city center goes up to 67 000 persons per square kilometer (CAPMAS, 2017), see figure 1.

![Figure 1. Density of persons per square kilometre in Alexandria. (CAPMAS, 2017).](image)

Travel demand in Alexandria is very high, there personal cars are the dominating transport mode followed by taxis and mini buses. A regular well planned Public transport in Alexandria is missing. This leads to high traffic flow, congestions, delays and long travel times.

One of the most congested major arterial is Fawzy Moaaz Street. This street is located in the old town area called Smouha. Along this street are several roundabouts. A major project was created by the Egyptian ministry of transportation with the purpose of evaluate and improve the traffic condition on Fawzy Moaaz street. Thereby, this study is focused on evaluating and improving the traffic performance on one of the roundabouts called Al-Ibrahimeya that may contribute to improve traffic condition along Fawzy Moaaz.
The project area includes 3 roundabouts, Al Ibrahimeya, Ali Ebn Abi taleb, Victor Amanoiel, and the intersection Mostafa Kamel, with a total length of 1.5 km. There are many private schools, sporting clubs and governmental buildings, which all generate the traffic. Figure 2 presents the big project area that includes roundabout Al-Ibrahimeya.

![Figure 2](image.jpg)

Figure 2. The project area, Fawzy Moaaz major arterial, marked on the map. (Google maps, 2019)

When traffic volume generates a demand greater than the actual road capacity, traffic congestion occurs, also called over saturation. The poor geometric characteristics elements and control conditions of the roundabout Al-Ibrahimeya leads to traffic congestion in the area.

A car ownership of about 300 cars/1000(CAPMAS, 2017) inhabitants makes Alexandria a city with larger number of cars compared to another cities in Egypt. The transportation system generally in Alexandria has a lot of problems with major congestions, it is most of long queues and delays. The system needs to expand along with the city and new solutions are needed to increase traffic safety, improve traffic conditions. In addition to private cars, it is very common with public transportation such as, buses, microbuses and minibuses, however, the poor quality of public transportation reduce the safety and efficiency. To improve the accessibility of public transportation and make it more comfortable and safer for people is an important point to solve transportation problems in Alexandria. It can make people to prefer public transportation over private cars, there the main goals with transportation are safety and, accessibility and comfort
According to World Health Organization (2010), about 12,000 lives loses due to traffic accidents in Egypt every year, which indicates that a lot of changes and improvements are required. No information about number of the accidents in this area could be found. However, there is poor road safety and need to be improved.

According to NCHRP Report 572 (2007), there are two main factors affecting on a roundabout; driver behavior and roadway design. Driver behavior appears to be the largest variable affecting roundabout performance. Aggressive driving is common behavior among Alexandria drivers and may include: making unsafe lane changes, zig-zagging, horn honking, tailgating, etc. According to The Egyptian Central Agency for Public Mobilization and Statistics (2017), 72% of traffic accidents of 11,000 in Egypt happen because of drivers behavior.

In addition to poor quality of the road networks and heavy traffic volume, the driver’s poor concentration and wrong passing while driving, leads to most of the accidents. Travel time, CO₂ emissions due to excess fuel consumption and delay are some quantitive factors of congestion. Safety, vehicle operation costs and emissions are some examples of the indirect costs of congestion. Traffic congestion does not affect only on transportation system, but considered a waste of resources as time and fuel. Subsequently, it affects the economy in Egypt in a negative way and also decreases human productivity. According to the World Bank report in 2012, the annual cost of congestion in Egypt is up to US$8.0 billion, which is equal to four percent of Egypt’s Gross Domestic Product.

A good transportation system is an important factor which affects social, economic and environmental development of a city. To reduce the congestion, there is a solution process including several steps, the following model shows the traffic solution model for an urban area.

Figure 3. Traffic solution model. (Soliman, 2016)
1.2 Aim

The aim of this project is to do inventory, evaluate and improve the performance of Al-Ibrahimeya’s intersection in Fawzy Moaaz arterial by using microsimulation software PTV VISSIM and macroscopic software SYNCHRO. Two alternative solutions to overcome the congested traffic increase the safety and the capacity of the roundabout were performed.

1.3 Methodology

Site visits are a crucial step to analyze local traffic problems in the studied area and the possible reasons behind these problems. This step is very important to be able to find efficient and long-term solutions. Two site visits, before data collection were conducted.

A literature study have been done to get basic knowledge about the main five points in this project: traffic and characteristic features of a roundabout, aggressive driving, as a possible solution roundabout signalization and 4E method as a supportive solution. Most of searching’s are gathered from other reports and studies that have been done.

For this study on Al-Ibrahimeya roundabout, a count plan has been developed together with other students at Pharos University in Alexandria and the data was collected on Tuesday 2 May 2019, by using camera on 2 buildings to see all traffic flows entering and exiting roundabout. Only the afternoon peak hour volume was recorded, between 3:00 and 4:00 PM. Both number of vehicles and the type of vehicles has been counted manual, the collection of data was followed:

- traffic flow (number of vehicle) on each approach, include cars and taxis, microbuses, minibuses, buses, trucks and motorcycles;
- pedestrian traffic;
- the length of the queue and stoppages.

Simulation technique is a useful tool in transportation to assess traffic performance and to measure and analyze the effectiveness of different scenarios that can improve traffic conditions. In this thesis, PTV-VISSIM and SYNCHRO are used as simulation software. The advantages with VISSIM, compared to other macroscopic software as SYNCHRO is that it is based on driver behavior model and its complexity makes it more useful in this case. SYNCHRO was used in this thesis because it is the software used by Pharos University, otherwise, it is not recommended to use for simulation of roundabouts.

(Synchro & SimTraffic Protocol, 2018)

1.4 Limitation

The limitations of this project are listed below:

The simulation is limited to about 200 meters from the approaches of the roundabout.

- The geographic borders of the study are limited to Al-Ibrahimeya roundabout.
- Data collection has been collected at afternoon only; the study is based on the afternoon peak hour volume.
- The model is limited to vehicles; no consideration has been given to pedestrian.
2 Literature review

In this chapter, a literature review to give a relevant and basic knowledge about this thesis is presented.

2.1 Geometry and design of roundabout

The following figures shows the yield rules and conflict points in a modern roundabout.

![Figure 4. A typical roundabout with conflict points. (U.S. Department of transportation, 2000)](image)

![Figure 5. A typical roundabout with yield-to-entry rules and conflict points. (M. Reza Shaebani, 2004)](image)

In a roundabout, two direction of traffic flow are available, clockwise for left-side driving and anticlockwise for right-side driving. This in turn means that vehicles are regulated to drive along the same direction and this reduces number of conflict points. (Wong et al.2012) Geometric characteristics of a roundabout, such as number of lanes circulating lanes, the lanes width, horizontal and vertical alignments, design speed, and availability of queuing space at the approaches has a clear effect on the capacity of a roundabout. Number of conflict points affects the capacity of the roundabout.
Base conditions, such as weather and pavement conditions, affect also the road capacity. Another factor is called traffic conditions, which include the different types of vehicle in traffic stream, such as cars, micro and mini buses, trucks etc. and the directional and lane distribution of the traffic volume on the highway. Control conditions, such as signal phasing, traffic lights, the length of cycle time etc. affect the capacity of the roundabout. (Mounir, 2018)

Designing a roundabout is a process of determining the optimal balance among several factors, operational performance and safety provisions. There are different designs of the geometry of the roundabouts, it may be a single or multi circulating lane roundabout. Theoretically, there are not big differences between a single and double lane roundabout concerning operating performance in terms of capacity and delay. There are clear regulations for driving through the roundabouts; however, not following the assigned driving regulation creates problems in terms of safety due to driver’s lane change and behavior when driving through a multilane roundabout or following the regulation of give way when entering the roundabout. (NCHRP Report 572, 2007).

2.1.1 Regulations and capacity in roundabout

A roundabout is a circular intersection designed to reduce delay, reduce crossing conflicts and promote an efficient and safe traffic flow.

In signalized or give way road intersection, crossing conflicts, like right-angle and head-on, is one of the main reasons to fatal traffic accidents. As the conflict points increase significantly, people get more opportunity to drive as they please with their own rules. This disorder increases aggression among drivers, which lead to accidents. (NCHRP Report 572, 2007).

Statistics show total crash reductions of 48% and a 78% reduction in personal injury or fatal collisions, according to NCHRP Report 572(2007). This makes a modern roundabout a safer alternative to signalized intersection. However, the capacity of a roundabout is lower than a signalized intersection especially when there is a mid to high traffic condition. Roundabout is usually designed for under low to mid traffic conditions. (Qu et al. 2014)

The capacity in each approach of a roundabout is calculated by estimating the number of vehicles that can enter the roundabout for a given certain circulating volume (Mathematical analysis for roundabout capacity, 2018). Roundabouts are functioning with priority rules, called yield-to-entry rules, thus this; the capacity depending on the gap acceptance model. Gap acceptance model is an analytical model common in analyzing unsignalized intersections, based on the traffic flow theory with the use of field measures of driver behavior. Gap acceptance, which is the minimum gap accepted for a vehicle to choose to enter the roundabout or to make a lane changing in the roundabout (NCHRP Report 572, 2007).
2.2 Roundabout signalization

A roundabout works as best and most efficient when the volume of traffic is balanced, an unbalanced traffic at roundabout leads to delays and queues. Huddart (1983) says that unbalanced traffic flow is limiting the capacity of the roundabout. If the traffic flow is very heavy and unbalanced, it is not suitable to build up a roundabout. The main goal with roundabouts is to reduce delay time at an intersection and it has fewer conflict points than signalized intersection, which is reducing collisions. However, a heavy unbalanced flow increases the delay time at an intersection and in this situation, signals are used to reduce platooning in the traffic flow and even balance the capacity. Integration of signalized roundabouts helps to increase violation of traffic rules and to balance the flow. (Huddart, K.W. 1983)

According to Charles R. Stevens, if there is an unbalanced traffic flow, full signalization of roundabout helps to reduce delays, the queue and increase capacity and safety in each approach. (Charles R. Stevens, 2005)

According to Natalizio (2005) and Stevens (2005) there are two main signal controls of roundabout: direct control and indirect control. With direct control both the entering and exiting approaches are controlled while indirect control is controlling the inflows to the roundabout. It can either be full signalization or partial signalization.

There are two ways to signalize the roundabout: fixed time or traffic adaptive signalization. The fixed time method is when traffic lights working with a predetermined cycle time, control the traffic flow. The length of cycle time for a fixed-time signalization depends on the traffic congestions. (M. Ebrahim, 2004)

According to R. J. Salter, Highway Traffic Analysis and Design “Where the intersection is heavily trafficked cycle times must be longer than when the intersection is lightly trafficked.”

To calculate the optimum cycle time ($C_0$) Webster's equation, which minimizes intersection delay, can be used.

\[
C_0 = \frac{1.5L + 5}{1 - \sum (V/s)}
\]  
(1) (Y. Salter & N.B. Hounsell, 1996)

Where:

$C_0$: Optimum cycle length (sec),

$L$; is the total lost time per cycle,

$V/s$; is the sum of the maximum $y$ value for all phases comprising the cycle.

The minimum cycle time with regard to safety is on 25 s, and a maximum on 120 s to minimize delay and driver frustration, is what generally is desirable.

(Y. Salter and N. B. Hounsell, 1996)
2.3 Safety at roundabout

Rules of the roads are based on the traffic and road safety. Rules exist to create safety, to protect and preserve the lives and to give an orderly and timely flow of traffic. It is well known that Egypt has a poor road safety; the question is how to improve road safety? Traffic problems, as congestions, cannot be improved or solved only by engineering. Especially in a country there 72% of traffic accidents depend on the human factor.

4E’s, formed by The Ministry of Road Transport & Highways, represents the 4 approach of the road safety:

- Education
- Engineering
- Emergency
- Enforcement

Traffic education programmers have an important role. It includes to give lessons about basic roles of road safety, traffic rules, signs, right of way, etc. in early school age so that future generations are well aware of the traffic rules. In addition, it is enormous important to have well educated employees, they are also role models for other drivers.

Driving school education should be improved and it should be a more demanding system. Drivers should be controlled by having monitor of new drivers so drivers with dangerous and aggressive behavior can be stopped early. Public campaigns, such as against speeding, aggressive driving, for respect traffic lights and signs, etc. are even a part of education.

Engineering should consider, such as safer pedestrian crosswalk with traffic signals or median/islands, implementation of tools to lowering vehicle speed and improve road safety, measures regarding to intersections, railway crossing and ITS to improve quality of travel, make it smarter and safer.

Emergency should consider black spot, which are the place where accidents have accrued several time. To inform people well regarding first aim, how to handle in the case of a traffic accident.

Enforcement is about preventive measures to reduce speeding by, for example using stationary safety cameras. To increase discipline of the drivers, a national penalty point system can be installed. It means that drivers committing accidents or offences, penalizes and with the risk of losing the driving license, drivers will be careful and drive more safely. (L. Pfeiffer, 2012).

2.4 Traffic simulation

For the design, evaluation and optimization of the roundabout, traffic simulation models have proven to be extremely useful tools.

Simulation models may be either deterministic or stochastic. The classification of simulation models often depends on the level of modelling details; macroscopic, microscopic and mesoscopic models are commonly used classifications. (Tapani, 2008)

Driving behavior is a socio-cultural term. Big lack of proper road design, rules and signs etc. make people find their own rules on the road, which is a major factor in causing traffic congestions and accidents. There are many aspects that affecting driver’s behavior on the road, such as geometrical features, flow rate, weather, culture of local driver, level of driving education and skills.
Aggressive driving behavior has been shown to result in more intersection delays and is a major cause of traffic accidents. Quantifying aggressive driving behavior and using simulation models with consideration to it, may help finding models to improve the traffic conditions on the project area. (Hegazy, 2016).

2.4.1 VISSIM

Some parameters in the microsimulation tool VISSIM is used to build up models depending on the local drivers’ behaviors, such as lane-changing and car-following. Lane-changing describes how drivers act when they want to change their lane and the causes of making a lane changing. Car-following is used to decide how the vehicles are related to each other in a lane.

“Car-following models form the basis of microscopic simulation models, and they explain the behavior of drivers in a platoon of vehicles.” (Aycin Benekohal, 1999).

In VISSIM, it is possible to find two car following models: Wiedemann 74 and Wiedemann 99. The Wiedemann 99 model differs from the Wiedemann 74 model by some added thresholds and definition of simplify expressway traffic modeling. Figure 6 is a represents the Wiedemann 99 car following model. It shows available parameters to adjust the effect of driving behavior in the network.

![Figure 6. Driving behavior parameters Wiedemann 99, Car-following model in VISSIM](image)

The lane-changing algorithm is one of the most complex algorithms to model in a simulation program. In this model, desire to switch the car and the decision to switch the car are different. The drivers decide if they are able to complete the lane change by 3 steps:

- **Is it necessary to make a lane-changing?** How is the traffic in the current lane?
- **Is the lane changing desirable?** The driver will check if it will be better after lane changing.
- **Is there enough room/space for lane changing?**
To be able to make a lane changing, there must be critical gap between in front of and in behind of the vehicle, in the lane where the lane changing will take place. It varies depending on the aggressiveness of the driver, thus, the level of the risk the driver accepts to take. An aggressive driver is able to take a higher risk and make a lane changing in a critical gap, where another less aggressive driver would decide to remain on the same lane.

The look-ahead distance is to determine how far ahead the drivers have to prepare themselves for conditions ahead. Lower value gives higher aggressiveness among driver through the model network. Following figure presents Lane Change parameters in VISSIM.

![Figure 7. Driving behavior parameters Wiedemann 99, Lane change model.](image)

Under title Necessary lane change (route), the level of aggressiveness of lane changing is defined by choosing the maximum deceleration between the vehicles wants to change lane and its following vehicle in the target lane. The waiting time before diffusion is the maximum time that a vehicle will wait to find a gap to change lanes. It leads to error in the network if the vehicle cannot change the lane during the set time. The min .Headway (front/rear) represents the minimum available gap in front of the vehicle to make lane change possible in standstill condition. The safety distance reduction factor is an important factor that affects aggressiveness among driver. It is about the safety distance between vehicles in the lane changing maneuver. Smaller safety distance means higher risk and more aggressive driving while lane changing. (Dr. Tom V. Mathew, 2014)

2.4.2 SYNCHRO

In SYNCHRO, it is possible to adjust Headway factor to customize the vehicles of a specific movement to drive faster or slower. In this way can driving behavior be calibrated. By using lower headway value than default, the aggressiveness can be increased. Yellow Decal is the maximum deceleration rate the driver is ready to use in yellow light. 12 ft/sec2 - 7 ft/sec2 is the default yellow deceleration rate. Increase in yellow decal will make the drivers' less prone to running red lights. To increase aggressive driving, green react can be reduced, which means that it will be a longer reaction time to green light. By gap acceptance factor the gap that the driver will accept can be adjusted to increase or decrease aggressive driving. (Mounir, 2018)
3 Methodology

3.1 Case study

A site visit to Al-Ibrahimeya roundabout was conducted on March 24 2019 from 2.10 pm to 3.10 pm and another site visit was conducted on April 05 from 10.15 am to 11.15 am. The site visit was to make an inventory of the site, observe the driver behavior and the conflicts that usually occur.

The geometric design of the roundabout Al-Ibrahimeya has not the characteristic and design feature a roundabout should have. Al-Ibrahimeya roundabout has a special geometry and a different operating system, there a policeman uses to control the traffic in the roundabout.

The north part of the Al-Ibrahimeya is blocked for traffic. Which means that it is not a circular intersection where drivers travel counterclockwise around the central island. The following figure 8 shows Al-Ibrahimeya and streets connected to it and the blocked part is marked with red.

![Figure 8. Project area, Al-Ibrahimeya. The blocked part is marked in the figure.](image)

Lanes are missing marks and signs which lead to a varied number of lanes by time according to traffic demand, two to five lanes are common. The intersection has five exits and four enteris. Mohammed Fawzi Moaz and El-Shaheed Gawad Housny are the roads with heaviest traffic flow and leads to and from the roundabout with three to five lanes on each direction. Even the highest long queue can be seen on these roads. Fawzi Moaz, El-Shaheed and Zaki Ragab and Al Nakib have 2 directions; however, El Jawaher has only one leading from the roundabout. By El Jawaher and Al Nakib, there are minibuses, minibuses that stop to load and unload passengers and pedestrians are crossing the roads without any crosswalk.

Public transportation in this area includes most minibuses, they stop anywhere along the route to pick up people; this creates obstacles for vehicles behind. In Ibrahimieyana, they almost lways stop in front of Al Nakib and Al Jawaher to pick-up and drop-off passengers.
A roundabout works without any traffic signals in the normal case. However, the intersection Ibrahimeya has two traffic officers who control the traffic on the roads with heaviest traffic flow, Fawzy Moaz driving to circulating roadway and Elshahed entering the roundabout, only on afternoon, depending on the information from Alexandria Traffic Office.

There is no fixed cycle time, they did not follow a predetermined timetable, the green and red time depends on the traffic flows coming from Fawzy Moaz and Elshahed and varied quite a lot. This may be attributed to that traffic flow is as heaviest on these two streets during afternoon. Therefore, it has to be controlled due to the heavy flow on the peak hour, driver's behavior and roundabouts design. Traffic officers were not available during the measurement period.

At the first half hour, the officers were on the place and a few times, about twentyfive second had both Elshahed and Fawzy Moaz green time but the traffic was mostly controlled. On the second part, the situation was different because the totally traffic flow became more stable, the flow was not less according to the counted volume but the queue was lower than the first thirty minutes.

3.2 Data collection and area description

Data collection is another crucial step in this project, this data is used as input the model that should give a reality-based model and efficiency of its output. Figure 9 presents the count plan that has been developed together with other students at Pharos University in Alexandria.

Data collection was made by using camera on two buildings to see all traffic flows entering and exiting roundabout. Pedestrian and stops that were not possible to see in the videos have been counted manual. Morning peak hour has been counted by using the morning peak hour flow coming from the roundabout Ali Ebn Abi Taleb to Al-Ibrahimeya. Afternoon peak hour volume was selected to use due to the higher congestion. The following figure shows AM and PM peak hour volumes.
To get an average speed of the cars in the videos, random 30 cars, in each 30 minutes, has been selected and the speed has been calculated between determined distances. 2 different average speeds have been calculated to use in the software VISSIM. The data has been counted in fifteen minutes, and the highest flow in each thirty minutes, has been multiplied by four to get the traffic flow during one hour. In this way, two separate, one signalized and one unsignalized models has been built up by using the software VISSIM. For the signalized one, the average of the cycle time, the green time and the red time were calculated to use in the signalized model. The following table shows the data collection result from video tabbing for 1 hour, some data may contain error, due to the human counting.

<table>
<thead>
<tr>
<th>From/to</th>
<th>Fawzi Moaz</th>
<th>El-Shaheed</th>
<th>Al Nakib</th>
<th>Al Jawaher</th>
<th>Zaki Rakib</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fawzi Moaz</td>
<td>120</td>
<td>2946</td>
<td>78</td>
<td>105</td>
<td>238</td>
</tr>
<tr>
<td>El-Shaheed</td>
<td>1172</td>
<td>-</td>
<td>120</td>
<td>287</td>
<td>1046</td>
</tr>
<tr>
<td>Al Nakib</td>
<td>84</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>59</td>
</tr>
<tr>
<td>Zaki Rakib</td>
<td>1508</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Percentage distributions of vehicles in the entering legs are as in the following:

![Figure 11. Percentage distribution of vehicles in main roads.](image-url)
4 Calibration and validation

Calibration is the step after building up and running the simulation model and very important to do for reliable results. Both measured parameters, as traffic flow, and visually parameters, as model behavior can be calibrated. Validation is the step after calibration and it is the action of proving the accuracy of the calibrated model. (Trafikverket, 2013)

4.1 Model development

The main purpose of traffic simulation is to increase understanding and analyzing of how a traffic system is working and how changes in the system affect the capacity, the flow, traffic performance, etc. The simulation models are effective in analyzing the dynamics of detecting traffic problems can be improved, such as queues and delays.

Figure 12, shows the simulation process, including estimation, validation and calibration.

![Simulation process diagram](image)

Figure 12. Relation between reality and simulation (Daamen, W., Buisson, C., & Hoogendoorn, S.P., 2015).

The big challenges with simulate a roundabout model are to know how the drivers choose lanes during the trip, in the roundabout and also when the driver has the possibility to drive into the roundabout, depending on the circulating traffic flow on the roundabout. (Trafikverket, 2013)

4.1.1. VISSIM

Micro simulation Vissim model was used to evaluate Al-Ibrahimeya roundabout. Links and connectors are important features in VISSIM when simulating a model. By using connectors to connecting different links, vehicle distribution, entering flows, routing decisions, reduced speed in the roundabout, priority rules to coding the yielding at entries and exiting, can the total traffic flow and capacity of the roundabout be changed.

Delay results are calculated by VISSIM by subtracting ideal time and actual travel time. The parameter Vehicle Travel Time has been used to get output of the speed. After running the model with default vehicle speed, within the distance as in the video recording, it has been reported that the detected speed and the average travel time in the VISSIM for both models were different. Therefore, the speed has been calibrated.
In VISSIM, there are six different types of vehicles predefined: cars, HGV, buses, trams, bicycles and pedestrians. For the roundabout Ibrahimeya, cars, minibuses and microbuses are selected as cars, due to the length and width. HGV (trucks), buses and bicycles have been added to separate categories. The distribution of vehicles type was calibrated according to the data collected so that the percentage of different vehicles matched the local conditions.

Vehicle inputs have been added by using parameter vehicle inputs according to the counting results from video recording. The parameter data collection points have been used to determine the points on the links, so that vehicles that pass those points can be recorded in the network. In this way, the entering and exiting flows have been recorded to compare with the video counting. Route selection in VISSIM was made according to video recording; the percentage was calculated for each specific route.

In the parameter connector, it is possible to choose lane changing behavior of vehicles on the road by using lane change and emergency stop distance. Lane change distance defines the last possible distance for a vehicle to make a lane changing; it can be selected between 10 to 200 meters, depending on the driver’s behavior in the study area.

The default lane change distance for a connector is 200 meter and for roundabout Ibrahimeya, the lowest distance was 10 meter and the highest was 200 meter. During the model development process, different lane change distance has been tested. When the distance was not enough for the vehicle or if there was a car in front that constitutes an obstacle, the vehicle was standing still to find a space. Lane changing distance and parameters for conflict areas have been adjusted during the calibration.

The model was tested with default driver behavior settings first to see if the model, without any calibration, match traffic conditions in the field. But some calibration considering to the local driver was needed. Therefore, the driver behavior parameters that affect the capacity of roundabout have been calibrated to create a more realistic model and then get a realistic output.

In Vissim CC1(Headway Time) was reduced from 0.9 s to 0.5 s, which means a reduction of 44%, as well as the CC0 standstill distance, to increase aggressiveness of driver. Also, the parameter safety distance reduction factor in the Lane Change model was reduced to increase aggression.
5 Simulation models

A traffic simulation study consists of the following steps:
1. Formulation of purpose and boundaries,
2. Data collection,
3. Building of the basic model,
4. Verification,
5. Calibration,
6. Validation,
7. Analysis of options and
8. Documentation.

These steps, recommended by Trafikverket, have been followed in this thesis. (Trafikverket, 2013)

“Actually, however, the proper question to ask is not how good the assumptions are, but how good the results are.” (John Wiley & Sons, 1987). Assumptions can be used even knowing that they are not exactly correct, the point is that they give an acceptable result.

5.1 Calibration of the VISSIM model

In this study, a visually calibration of the model was performed, with regard to the queue, stops as well as driving behavior on the roundabout Al-Ibrahimeya. Driving behavior appears to be largest factor affecting roundabout performance, the capacity of the roundabout varies depending on the driving behaviors. Due to this, the models required calibration considering to the local driver behavior and changes in driver experience over time to get accurate capacity estimates. The model has been calibrated so that queue is created in the same routes as in the video recording. Due to the unstable signalization of the roundabout, 2 separate models have been calibrated. In order to reflect real interaction behavior, conflict area was adjusted. Depending on how modeled it is, varied priority rules between vehicles. Conflict areas occur between all conflicting movements, where connectors were used to connect links to each other. For visual calibration of network, conflict areas were adjusted to get the model more similar the reality, for example to create queue or control the priority rules so that vehicles can run or stop as in reality.

Travel time varied between Fawzi Moaz entering-center of the roundabout to center of the roundabout-Fawzi Moaz exiting. Because the biggest flow comes from Fawzi Moaz and El-Shaaheh and the conflict between this approach leads to a long queuing in the network. The estimated average travel time between two selected distances varies from 22 seconds to 7 seconds. After passing this section, obstacle decreases so that cars starting to drive with higher speed to Fawzi Moaz or Zaki Ragib, exits of the intersection.

For calibration the model, a minimum number of needed runs was determined by using the following formula:

\[ n = \left( \frac{t_1 - \frac{3}{2} \sigma_d}{\epsilon d} \right)^2 \]  \hspace{1cm} (2), (Irфан Batur, 2014)
where
- \( N \); is the required minimum number of simulation runs,
- \( t_{1-2} \); is the t-distribution with a confidence level, in this case is 0.05,
- \( \sigma_d \); is standard deviation of travel times and
- \( \varepsilon_d \); the accepted error the is the accepted error.

After calculating this equation, the required number of simulation runs was resulted as 8 but it was been selected to run the simulation 10 times, to get more significant result. In this thesis Geoffrey E. Havers (GEH) formula, presented by ODOT (2011) was used for volume calibration. The network is said to be calibrated if the GEH value after counting the formula is less than 5 for 85% of the links and less than 5 for sum of all link counts.

These 2 \( y \) values represent the counted traffic volume and the output from data collection points, simulation value, after running the model.

\[
GEH = \sqrt{\frac{2(m-c)^2}{m+c}}
\]  
\( (3) \), \( (ODOT, 2011) \)

where \( m \) is the simulation output [veh/h/ln] and \( c \) is the field data observation [veh/h/ln].

The vehicle travel time has been calibrated by comparing the output average travel time in simulation to the estimated travel time from video recordings. The speed estimated in the video was less than the speed observed in the VISSIM, thus, the travel time in VISSIM was much shorter when the model was running with default speed.

High variation in speed was noticed in the video, due to several factors, such as queuing, unstable signalization etc. Therefore, the speed was calibrated in both base models. For calibration of speed the parameter reduced speed was used. Due that vehicles have a lower speed between some specific conflict areas in the video recording. A short section, where vehicles drive slower due to the conflicting traffic, was made to get more similar conditions in VISSIM.

There is a formula by Trafikverket to check if the model is considered enough good:

\[
\bar{x} \pm t_{n-1} \left( \frac{\sigma}{\sqrt{2}} \right) s \sqrt{n + \frac{1}{N}}
\]  
\( (4), (Trafikverket, 2013) \)

Where
- \( \bar{x} \); is the average travel time value according to the software,
- \( \sigma \); the standard deviation for the \( N \), equal to 10 in this case, simulation replication,
- \( t_{n-1} \); is the confidence level, there N-1 is degrees of freedom and
- \( N \); the number of simulation runs.

As a result, the travel time from VISSIM is within the confidence level and calibrated according the manual calculation for both models.

The afternoon data was counted to use for calibration of the models. To investigate that these data were valid, the morning peak hour volume were used for validation of the models. The peak hour factor has been counted as 0.86 and was used to calculate the morning traffic volumes in Al-Ibrahimeya. After running the model with morning traffic flows, the result had been checked to ensure that the model works as it should. In this way, even incorrectly calibrated parameters in the model could be detected. Circulating flows and total flows entering and exiting the roundabout were used to ensure that models can handle flows through it and works properly.
5.2 SYNCHRO

Parallel to Vissim model Synchro model was used. The same collected data used for VISSIM was used in SYNCHRO. A gain a map over Al- Ibrahimeya was selected as background. The links were connected to each other with nodes and each node has lane settings. In lane settings, it is possible to select and adjust traffic volume, lanes and sharing and links speed etc. The model was run with default and then calibrated by decreasing saturation flow in nodes, also heady way factor and gap acceptance has been reduced to increase aggressive driving.

The base model calibrated in VISSIM was selected to be used in SYNCHRO. For calibration in SYNCHRO driving behavior parameters such as; gap acceptance and headway factor were adjusted. Saturation flow, which describes the number of passenger car units in a dense flow of traffic for a specific lane group, was adjusted to calibrate the queue.
6 Base scenario selection

Two different base scenarios had been built up; one signalized and one unsignalized scenarios. The signalized one had a higher queue in the videotaping than the unsignalized one. This difference is probably due to the fact that the unsignalized part falls outside the actual peak hour volume and number of cars in queue, according the calculation during data collection, began to decrease in almost all approaches. It also explains why the traffic police left the roundabout completely on the last 30-20 minutes. The flow and actual demand are actually key to analyze inputs of traffic models.

Flow is the volume of the vehicle that passing the selected point on the system and the demand is the volume of the vehicle that wanting to pass the selected point on the system. A higher demand than the actual capacity of the roundabout results in a queue. Based on the video recording, the queue was significantly more in the first 30 minutes. The model with worst case assumed to give a more reality based model and therefore, it has been selected to compare with the solution scenarios.

The signalized intersection was regulated with signals in two places; El-Shaheed entering the roundabout and where vehicles coming from Fawzi Moaz continue into the roundabout. The cycle time varies between 90 s to 230 s, where the limits of recommended cycle time is between 20 s to 120 s. The average cycle time is calculated as 158 s, there the green time is 105 s and the red time is 53 s. The following figures show the location of signals and the selected base model that was built in VISSIM.

Figure 13. The colored parts show the signalized part of the roundabout Ibrahimeya.
Data count used in simulation is as in table 2 and table 3:

**Table 2. Entering flows**

<table>
<thead>
<tr>
<th>Location</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fawzi Moaz</td>
<td>3440</td>
</tr>
<tr>
<td>El-Shaheed</td>
<td>2664</td>
</tr>
<tr>
<td>Zaki Rakib</td>
<td>1528</td>
</tr>
<tr>
<td>Al-Nakib</td>
<td>380</td>
</tr>
</tbody>
</table>

**Table 3. Exiting flows**

<table>
<thead>
<tr>
<th>Location</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fawzi Moaz</td>
<td>2688</td>
</tr>
<tr>
<td>El-Shaheed</td>
<td>2908</td>
</tr>
<tr>
<td>Zaki Rakib</td>
<td>1344</td>
</tr>
<tr>
<td>Al-Nakib</td>
<td>284</td>
</tr>
<tr>
<td>El-Jawahr</td>
<td>508</td>
</tr>
</tbody>
</table>

### 6.1 Scenarios

Scenarios in this thesis are selected based on the structure of the area. Possible changes have figured out and two scenarios have been created. There is a high volume of vehicles that passes this intersection every day and the traffic demands in the intersections exceed the current capacity.

In this chapter, the different scenarios to overcome this problem are represented.

#### 6.1.2 Scenario 1: Change of the geometry and signalization

Since the intersection was built to work as a roundabout, one of the scenarios is to develop a model there Ibrahimeya is made into a modern roundabout with signalization. By this scenario it is possible to ensure if a roundabout with signalization will be the solution to
overcome the congested traffic conditions in this area. To make it a circular roundabout, the blocked part of the intersection was removed. Some new vehicle routes were counted, due to the modified geometry. The roundabout has been signalized where there are intersecting flows in conflict. In addition to El-Shaheed and circulating flow, the link Zaki Rakib entering the roundabout and the circulating flow crossing the Zaki approach were signalized. The logic behind signalization is that conflicting movements should not have red/green at the same time. Traffic signals were installed on west (El-Shaheed) and east (Zaki Rakib) approaches and on their conflicting flows circulating the roundabout, as in following figure 15.

Figure 15. Scenario 1 in VISSIM, the model of roundabout.

Scenario 1 in SYNCHRO was modelled as a t-intersection, see figure 16. Because in SYNCHRO, it is not possible to signalize a circular intersection. As described before, SYNCHRO is not recommended to use for simulation of roundabouts.

Figure 16. T-intersection model developed in SYNCHRO for scenario 1.
6.1.3 Scenario 2: Signalization of the current intersection

Al-Ibrahimeya is a small roundabout and there are small roads, such as Al Nakib and Al Jawaher that crossing the roundabout. The reason behind the blocked part is that the heaviest flow coming from Fawzi Moaz, 84%, continues out to El-Shaheed. This scenario is a solution based on previous experiences of the project area. It aims to retain the geometry as it is today but the traffic will be controlled by more signals. In order to increase the capacity and reduce the high delay by balancing the traffic volumes. Fawzi Moaz street, with the highest traffic volume compared to all other approaches, it has its highest outflow to the El-Shaheed street. Therefore, regulating this approach with signals is assumed to lead a major congestion, in fact that it is not in conflict with other movements. The traffic lights were applied on the same areas as in scenario 1, see chapter 6.1.2.
7. Results

In this chapter, the results from developed models and the alternative solution scenarios are presented.

The following figures present the results from VISSIM.

The following figures show a comparison between outflows and inflows for each scenario in each leg. Comparison between entering and exiting flows helps to determine performance of roundabout based on the capacity.

Scenario 2 shows a better performance compared to scenario 1. Especially in Fawzi, Zaki and Eljawaher exiting and Fawzi, El-Shaheed and Al-Nakib entering the roundabout.

However, compared to base scenario, no obvious improvement has been reached with Scenario 2 in terms of traffic flow. Base scenario and scenario 2 showed almost same performance. In scenario 2, El-Shaheed exiting the roundabout was lower than base scenario, this probably depends on that Fawzi Moaz entering the roundabout was also a little lower in scenario 2 compared to base scenario. El-Shaheed exiting the roundabout is only affected by Fawzi Moaz approach.
Otherwise, scenario 2 and base scenario had almost same traffic volume. Scenario 1 has a low traffic volume passing it, compared to both scenario 2 and base scenario.

To see if the alternative scenarios provide a better result in terms of travel time, a comparison of between alternative scenarios has been performed. The following figure shows travel time in main routes.

![Travel time](image)

*Figure 19. Travel time results in each scenario for each route.*

Scenario 1, compared to base scenario and scenario 2, has a higher travel time in all routes, except Fawzi Moaz approach; there the travel time is lower by 7% compared to base scenario. In terms of travel time, scenario 2 provides a better performance; it decreased in all routes except Zaki entering. This is probably due to added signalization in this approach.

The following figure presents a comparison between average queue delay results in all routes for each scenario.

![Average queue delay](image)

*Figure 20. Average queue delay in each scenario for each route.*
Scenario 1 has a higher queue delay than base scenario and scenario 1, except in El-Shaheed leaving the roundabout. As has been mentioned before, Fawzi Moaz approach is the leg with highest flow and 84% of Fawzi Moaz traffic volume continues to El-Shaheed. Inflow and outflow results for Fawzi Moaz for scenario 1 were lower than other scenarios; however, the average queue delay result has not been worse compared to base scenario. Scenario 2, as a total, nor does shows a better performance in terms of average queue delay.

The following figure shows a comparison in vehicle delay between base scenario and scenario 2. It provides a better performance than scenario 1, due to this, a separate comparison is presented. Results of average vehicle delay/s are as the following figure. In terms of vehicle delay, scenario 2 provides a better performance. Major improvement can be seen main streets with heaviest flow; in Fawzi Moaz exit, the delay reduced by 74%, El-Shaheed entering by 21% and Fawzi Moaz entering by 1%.

![Figure 21. Average queue delay for base scenario and scenario 2 in each route.](image)
The following figures present total vehicle delay and total travel time results from SYNCHRO.

**Figure 22.** Total delay per vehicle results for each scenario.

**Figure 23.** Travel time results for each scenario.

According to results from SYNCHRO, base scenario is the best alternative. Both travel time and delay increased in alternative scenarios. *Scenario 2* showed better performance than *scenario 1* but it is still worse than base scenario.
8 Discussion

Video recording and manual counting were used for data collection. Video recording was used to count traffic volumes entering, circulating and exiting the roundabout. The manual counting, for example to count the queue in different approaches, was counted by different persons during same peak hour. Due to the heavy traffic volume and human error, lack of data collection may occur.

Pedestrians have not been included into the model. Due to the local behavior and traffic conditions, pedestrians in modelling would have increased the complexity to unmanageable level. It would also increase the error of the model.

Two different software were used for modeling, VISSIM and SYNCHRO. The geometrical features used for modeling were measured by using Google Maps. Since the lanes are not marked, the number of lanes in each link were observed from video recording. The measurements are approximate and features such as number of lanes is based on the peak hour driving, the number of used lanes is probably different in the morning.

Aggressive driving behavior has been an important parameter for calibration of models. With the word aggressiveness means actually the level of risk that driver accepts while driving. For example, in this case, lower safety distance was used to increase aggressiveness, so that the distance between two cars while driving is lower than the VISSIM has as default. Once the model is developed, the important step is to calibrate the model to get reliable results and thereby propose reliable solution.

In this thesis two models were made due to the unstable signalization of roundabout. Making two different models has been the way to handle this situation. The base model selection was made based on the video recording and manual counting of the queue in the streets entering the roundabout. The number of cars in queue decreases over time almost in all approaches. This has affected the choice of the base model. Both models could be used as a base model but this study is based on using peak hour volumes where the traffic is high congested. Therefore, the second model was determined to be uninteresting to use in analyzing and compare with other scenarios.

Both in scenario 1 and scenario 2, indirect partial signalization is used, as has been mentioned in chapter 2.2. Roundabout signalization. In this case, signalization of Al-Ibrahimeya has been determined to produce a better performance based on the geometry of the area and the heavy traffic flow.

In Scenario 1, the blocked part was removed and the intersection was changed to a circular roundabout with added traffic signals on east approach and its conflicting flow. This scenario was expected to create a more balanced traffic flow and increase the capacity. The results confirmed that it was a right choice to close the circulation roadway. The traffic volume was decreased after the traffic was completely opened. There is also a worsening in terms of travel time and delay. It is probably due to the heavy flow because roundabouts are usually suitable for under low to mid traffic conditions. When there is a heavy traffic flow as in this case, roundabouts are not suitable and may cause problem in the network.

In Scenario 2, it was tested to improve traffic conditions by keeping the geometry with added traffic signals on east approach and its conflicting flow. This scenario was chosen to be tested, because the flow is very high and the blocked part is blocked for a reason. With better signal program, the capacity of the intersection can be increased and the delay can decrease. The results confirmed that signalization helps to reduce the delay. Traffic volumes showed no major improvement throughout the system, however, no deterioration has occurred. The
results show that signalization of current intersection may help to decrease delay and improve traffic conditions. The model developed in this thesis may not be the optimal way to represent the studied area because of my limited experience in VISSIM. It has certainly affected the development of base model and other models and for better signalization, more accurate calculations of signal program can be performed.

Results from SYNCHRO simulations are different compared to VISSIM. In SYNCHRO, results of total network performance in each scenario are compared; no comparison between each route is performed. Because of geometrical weakness in the built models, a comparison between total network performances should have a minor error. In addition to my limited experience in SYNCHRO, it is not recommended software to use for roundabout modeling, which has affected the calibration and modeling process in a negative way.
9 Conclusions and future work

The purpose of this paper is to estimate and improve traffic conditions and capacity of the intersection Al-Ibrahimeya by using simulation for analysis of different scenarios. This study is a part of a larger project along Fawzi Moaz arterial, include 3 roundabouts connected by a major arterial, with many private schools, sporting clubs and governmental buildings. This thesis is focused on 1 of 3 roundabouts in Fawzy Moaaz, called Al- Ibrahimeya. The aim with this study is to improve traffic conditions focused on this roundabout.

The intersection has a special geometry that makes it difficult to categorize, it has an unconventional geometry due to the blocked in the north part of its central island. Al-Ibrahimeya has a central location which makes it to a heavily trafficked intersection. The capacity of today’s intersection is less than the demand, which results in long travel time, high delay and long queues in the network. Therefore, a study on this area has been performed to test 2 alternative solution scenarios. The results show that an organized and well-functioning signalization program may help to reduce delay and travel time in main roads.

Traffic congestion is a highly complex problem and its solution requires an individual approach, depending on the urban agglomeration. For a long term comprehensive solution the root of problem must be understood and processed. By creating road safety and making changes for a smart, sustainable mobility in transportation system, can traffic situation in Alexandria can be improved. 4E method, as a strategic supportive solution can help in this way, to evaluate and improve transportation system and increase safety. The improving requires a coordination of different viewpoints; traffic education program, improving road safety, infrastructure and public transportation, traffic laws and regulations are key points.

This thesis has only focus on a limited area when the problem applies in a much larger area, which means that the solution will also be affected and even affect a larger area. Therefore, for future work, a more extensive work such as, traffic signals near Ibrahimeya that affect traffic in Ibrahimeya and pedestrian crossing, can be carried out. The recommendation after this study is to establish a right-turn island and create a green wave for Fawzi Moaz to El-Shahaeed in coordination with well-organized traffic signal management plan to minimize the delay and improve the traffic conditions in Al-Ibrahimeya.
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