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Chapter 12

Enhancing Urban Mobility in Cairo A PTV VISSIM-Based Simulation of Salah Salem Corridor

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Introduction

Problem Statement and Research Gap
"Cities have distinctive identities that vary physically according to their geographical location, demographics, culture, environment, and economic factors" (Nafa & Husain, 2021). Cairo in particular suffer from severe traffic congestion is driven by its high population density, limited public transportation, and inadequate road infrastructure. With over 20 million residents, the demand for road space far exceeds supply, pushing many people to use private vehicles or taxis due to gaps in the metro and bus systems (Hegazy, 2020). The city's narrow, outdated roads, initially designed for a much smaller population, have struggled to adapt to the surge in vehicle use. This urban sprawl, often developed without cohesive planning, has led to poorly connected neighborhoods and bottlenecked routes that exacerbate traffic issues (UN-Habitat, 2016). Subsequently, "Rapid urbanization in many parts of the world has resulted in inadequate housing, social segregation and the deterioration of open spaces, all of which have had a negativeimpact on the quality of life for residents" (Husain and Salem, 2024).

Cairo's congestion continues to worsen due to inadequate traffic management practices and cultural driving habits. Drivers frequently ignore signals and lane markings, adding to the gridlock and reducing the effectiveness of existing traffic control measures (Abd El-Rahman & Fathy, 2021). Kadri and Husain indicate that "Egypt's population has grown by 154% over the last 40 years, reaching 105 million people in 2023. Nearly 27% of thispopulation is concentrated in the Greater Cairo Region (GCR), including the governoratesof Cairo, Qalyubia and Giza" (Kadri & Husain, 2024). They further highlight that "The factors needing the most improvement are the cost of living, affordable housing, and adequate public transportation, which received the lowest ratings from the experts" (Kadry & Husain, 2025). According to the Cairo Traffic Index, car users spent an average of 42% extra journey time due to traffic congestion in 2019. Thanks to recent transportation projects and infrastructure developments in Greater Cairo, this number decreased to 40% in 2023. Meanwhile, according to the World Bank (2019) Arab's Voice article, time wasted in traffic in the Greater Cairo Metropolitan Area translates to approximately $8 billion per year, with expectations that this figure will rise to $18 billion by 2030—over three percent of Egypt's total Gross Domestic Product (GDP).

In recent years, urban traffic congestion has become one of the most pressing challenges for cities worldwide, with significant implications for economic productivity, environmental health, and quality of life. In cities like Cairo, where rapid urbanization and high vehicle density have exacerbated traffic issues, congestion often leads to extended travel times and increased pollution. Addressing congestion has therefore become a critical focus for transportation planners, urban policymakers, and researchers. Since traffic congestion is one of the most widely discussed issues in developing countries, Cairo is no exception. The following factors have been identified as key contributors to traffic congestion in Cairo, based on studies conducted over the past decade: Poor public transit system, Lack of intersection management, Heterogeneous traffic conditions, Non-lane-based traffic system, Conflicts between formal and informal modes of transportation, Inadequate street design elements, Shortage of pedestrian walkways and cycling paths, Lack of affordable public transportation, Overcrowded and low-quality public mobility

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services, Poor connectivity, Congested corridors, Traffic delays, Road geometry issues, Limited accessibility, Driver behavior.

Connectivity has been identified as one of the main challenges in large-scale transit networks, as the number of transfers required for a trip is considered a major inconvenience for transit users (Owais et al., 2020). Cairo's transportation network suffers from several issues, including congested corridors, traffic delays, and overcrowded transit vehicles during peak hours. The complexity of the transportation network forces multiple transfers between transit modes, leading public transport users to perceive the system as inefficient. This situation has encouraged a growing preference for private car ownership and use were private cars mandatory in Major arterials like "Salah Salem", which has one of the highest records in term of delay in Travel time according to Google Typical Maps during the year of 2024. Most recent research has linked traffic congestion in Cairo to various theories and perspectives, leading to different proposed solutions, such as road geometry redesign, traffic signal optimization, and public transportation projects. However, the selection of these approaches for specific case studies has not been adequately justified. Despite the extensive literature on transit network design, further research is needed to establish a comprehensive framework for addressing Cairo's congestion challenges. Accordingly, this Thesis is addressing the two major problems mentioned being: the time wasted in Traffic congestion in Cairo as well as the lack of clear vision among urban planners in identifying the main causes behind the traffic congestion phenomena in Cairo.

Significance of the Study

"Approximately 28% of [Egypt's] population is concentrated within the three governorates constituting the Greater Cairo Region (GCR), intensifying the pressure on existing urban infrastructure and resources." (Kadry & Husain, 2025) Which in consequence, makes addressing traffic congestion in Cairo is one of the most critical responsibilities of urban planners, especially in developing cities. As one of the most densely populated cities in the world, Cairo requires effective traffic management to ensure mobility and access to resources for millions of residents. Urban planners play a pivotal role in developing strategies that alleviate congestion while fostering sustainable urban growth.

Studies focused on traffic congestion provide invaluable insights into the underlying causes, patterns, and potential solutions. By prioritizing such studies, urban planners can contribute to creating a more livable city, reducing air pollution, and supporting Cairo's long-term socio-economic development. Traffic congestion in Cairo leads to higher emissions and environmental degradation, as idling vehicles release more pollutants into the air (UN-Habitat, 2016). By designing infrastructure and transportation systems that minimize congestion, planners can contribute to improved air quality and public health. They can also integrate green spaces, pedestrian-friendly areas, and more efficient transit solutions that address both environmental concerns and urban livability (Abd El-Rahman & Fathy, 2021). Understanding the root causes of Cairo's traffic issues allows planners to make informed, sustainable decisions when designing urban spaces that accommodate the city's rapid growth and complex mobility needs. Approaches to addressing the problem and the suggested solutions vary across different studies. However, the majority of studies encourage the use of traffic simulation tools as a method for evaluating different strategies to reduce congestion. In addition, Level of Service (LOS) has been selected as a key performance indicator to assess the effectiveness of each scenario in the corresponding case study. Accordingly, a similar approach will be adopted in this Research, incorporating scenarios from various research studies to provide a broader analytical foundation.

This study explores the potential of advanced traffic simulation tools, specifically PTV VISSIM, to provide innovative solutions to this persistent issue. By simulating and analyzing traffic flow patterns, the study aims to demonstrate how these tools can optimize traffic signal timings, reduce delays, and enhance overall mobility within the city. The findings are expected to provide critical insights for urban planners and policymakers, enabling evidence-based decision-making to address congestion more effectively. Moreover, this research contributes to the growing body of knowledge on the application of simulation technologies in urban traffic management, paving the way for sustainable transportation systems in Cairo and other megacities worldwide. The outcomes hold the promise of improving the quality of life for millions of residents by fostering a more efficient and environmentally friendly transportation network.

Research Question and Objectives

This research investigates the most efficient urban method that can be utilized to reduce time wasted in traffic congestion in Cairo. It aims to identify the most common parameters that cause congestion and its accumulation across consecutive traffic nodes in the city. The study also compares various researchers' perspectives on the most effective methods and tools used over the past decade to reduce congestion-related delays, with a particular focus on their applicability to a selected case study area. Ultimately, the research seeks to provide urban planners with a clear and practical framework for selecting the most efficient approaches to minimizing time lost in traffic, based on specific parameter measurements relevant to different urban contexts. The figure below highlights and clarifies the overall research structure.

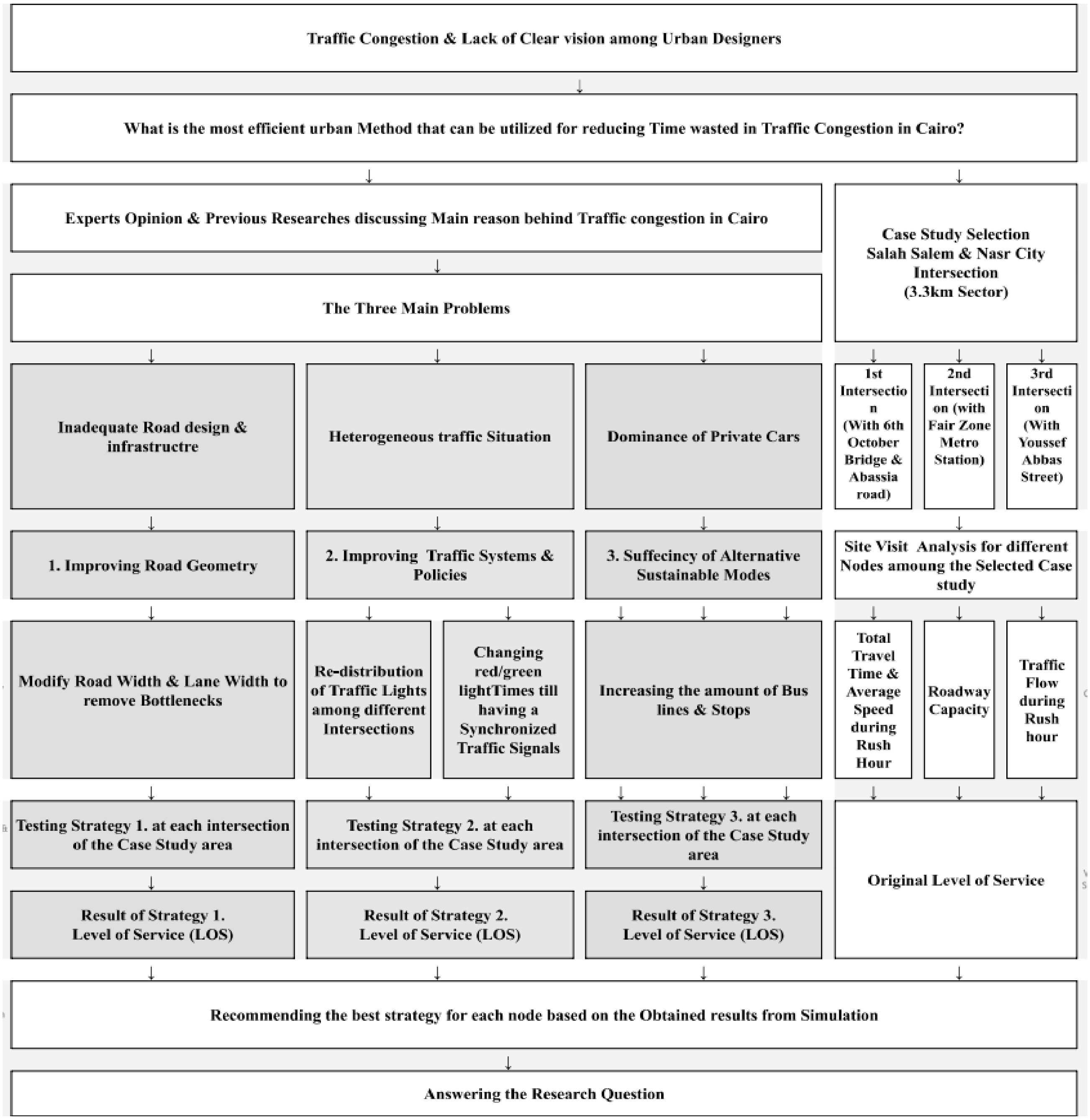


Figure 1. Research Outline.

Material and Methods

The Research is using mixed approach (Quantitative & Qualitative). The primary data collection method employed in this research involved video recordings captured at multiple consecutive nodes within the designated case study area in Cairo. These recordings provided a detailed visual account of traffic conditions, capturing vehicle movements, signal timings, congestion levels, and driver behaviors at various times of the day. Strategic placement of camera ensured comprehensive coverage of key intersections and road segments, enabling accurate documentation of traffic flow patterns and bottlenecks. The collected video data was subsequently analyzed to extract critical parameters such as vehicle counts, delay times, queue lengths, and average travel speeds. This research methodology employs PTV VISSIM software to simulate and optimize urban traffic flow, addressing congestion through three primary Methods: bottleneck mitigation, traffic signal optimization, and public transit enhancement. For the first approach, Bottlenecks, or points of severe congestion due to high traffic demand or inadequate infrastructure, are critical in traffic management as they reduce flow efficiency and increase delays. Using VISSIM's network analysis, locations with high congestion are identified, and potential solutions such as additional lanes, dynamic lane allocation, or ramp metering are tested to reduce time consumed in congestion (Khan et al, 2021). Such interventions have shown to improve throughput and reduce delays in micro-simulation environments by allowing more efficient vehicle movement across critical areas (Zhang et al, 2020).

The second Method involves optimizing traffic signaling and lights to reduce intersection delays and improve traffic flow. Adaptive signal control and coordinated control Methods are tested within VISSIM, which allows for precise modeling of signal timing and coordination to maintain smooth transitions between intersections (Feng et al, 2018). By adjusting these settings, delays at signalized intersections are minimized, improving the overall efficiency of the network. Studies indicate that adaptive signaling can significantly reduce vehicle stops and wait times when well-coordinated, which is essential for high-traffic urban areas where intersections are common (Chen et al, 2019).

Enhancing public transit lines and stations is critical for reducing road congestion by shifting demand from private vehicles to more efficient mass transit. PTV VISSIM's public transport module enables testing of transit priority Methods, including dedicated lanes and signal prioritization at intersections, which increases bus and train efficiency and reduce wait times for passengers. Optimizing public transit can ease congestion on roads and improve travel reliability for users, providing an appealing alternative to private vehicles and helping to reduce overall traffic density. Through these combined Methods, this study seeks a comprehensive approach to urban traffic congestion management.

Finally, two data categories were required for the simulation model at each of these nodes: network geometry and traffic volumes. Site visits have been done by the author to collect the required geometric data such as intersections configurations, lanes alignment, lanes widths, number of lanes of both the major corridor as well as the minor intersected streets and U-turns locations. On the other hand, video observations and traffic counts & Travel Time were obtained via video recording in different days of the week (weekdays & weekends) and during different period of the day (morning & evening), also the selected time periods were chosen using upon the high congested times during the day as shown in Google Typical Traffic flow map. These data are recorded in a 5 min video each to show the traffic flow, capacity and the pass-by Public transportation.

Site Analysis

Case Studies Selection Criteria

In order to ensure that the case study is both relevant to Cairo's unique traffic environment and suitable for in-depth analysis using PTV VISSIM. Proper selection can help illuminate specific urban traffic issues and explore Methods that align with Cairo's urban planning goals. The primary criterion for case study selection is the severity and persistence of congestion at the site. High-traffic areas where congestion leads to significant delays, especially during peak hours, provide the most fertile ground for testing congestion-reducing Methods. Such areas are often central corridors or major arterials, such as Salah Salem Road in Cairo, known for its heavy traffic and strategic importance in connecting different parts of the city. Studying high-congestion areas allows researchers to focus on the most pressing traffic problems and evaluate the potential impact of various Methods on real-world scenarios. According to Litman (2019), targeting high congested zones is essential for maximizing the effectiveness of urban traffic interventions and ensuring that resources address critical needs availability and accessibility of Traffic Data. The study area should experience significant levels of congestion, particularly during peak hours, to ensure that tested interventions address relevant, real-world issues. Comprehensive traffic data availability is also essential, including traffic volumes, vehicle types, and intersection timings, which supports accurate calibration and validation of simulation models. The selected site should exhibit complex traffic patterns, such as intersections and pedestrian crossings, to enable a realistic simulation of Cairo's urban traffic dynamics. Also the feasibility of modeling within the capabilities of simulation tools like PTV VISSIM ensures that the study remains practical and achievable.

A 3.3-kilometer section of Salah Salem arterial road in Cairo aligns well with the selection criteria for a case study on traffic congestion. This corridor experiences severe congestion, particularly during peak hours, and serves as a vital link between key urban areas, accommodating high volumes of daily commuters and public transport vehicles. The road features a variety of traffic interactions, including multiple intersections and pedestrian crossings, which add complexity to traffic flow and allow for comprehensive testing of congestion-mitigation Methods. Furthermore, as a primary route within the city's transportation network, improvements here could have a widespread impact on overall travel times and align with broader urban planning objectives (refer to Figure 4 & 5).

Figure 2. Cairo Map - Salah Salem Road (Google Maps).

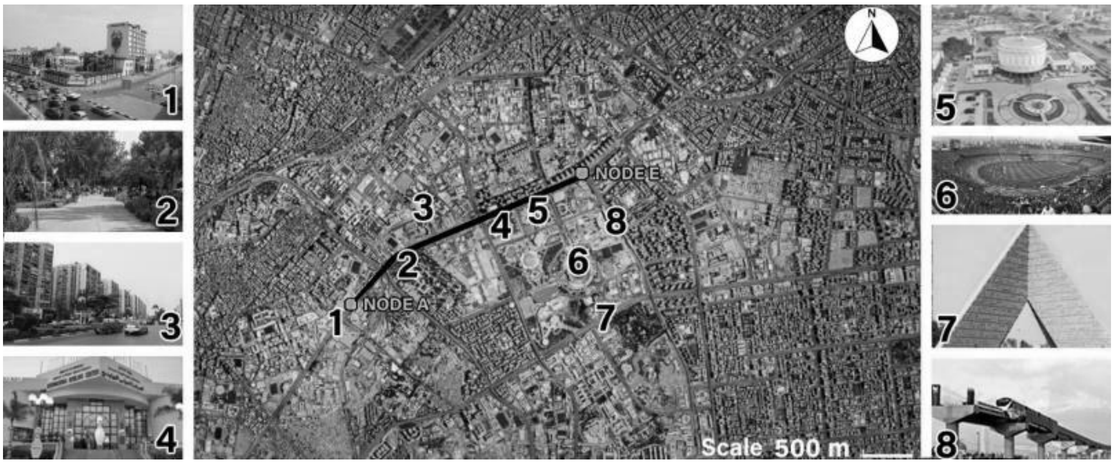


Figure 3. Landmarks around Case study area

1- Vehicles House – (Intersection with El-seka El-beda street)
2- El Ouroba Garden
3- Mixed Use/Commercial Area (El-Obour Buildings)
4- International Bowling Center
5- Panorama 6th October
6- Cairo International Stadium
7- Memorial of the Unknown Soldier
8- Start of Cairo Monorail Line + Stadium Metro Station

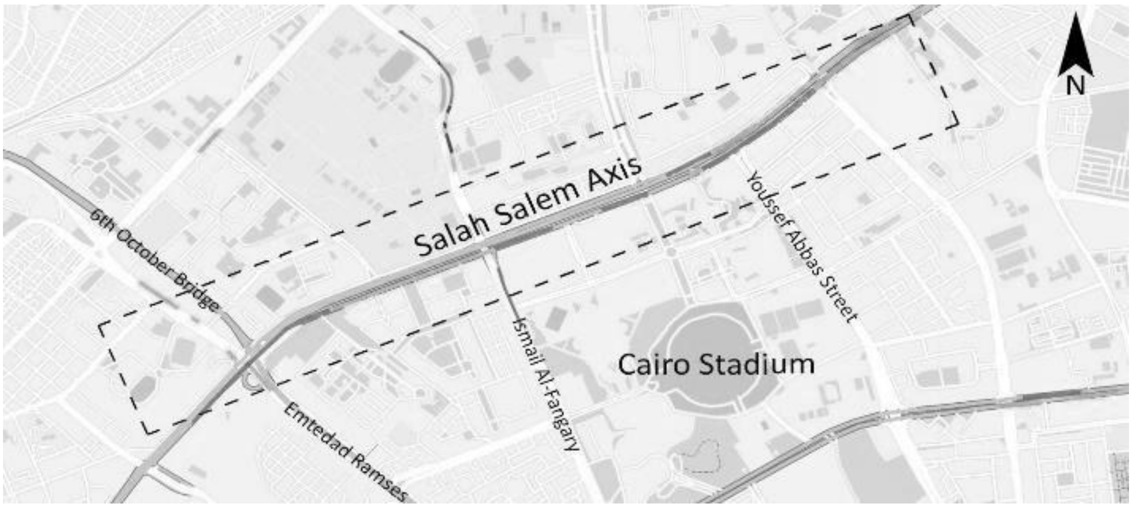


Figure 4. Case Study area Map

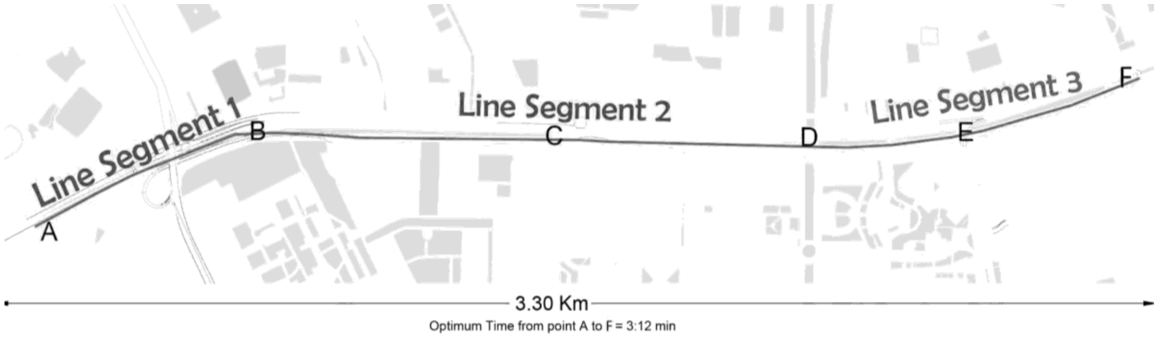


Figure 5. Case study Area boundaries & Segmentation.

Point A (starting of the bridge entering Nasr City) Point B (End of multiple Bridges including 6th October bridge), Point C Ismail el fangary intersection, Point D Fair Zone Metro station, Point E Youssef Abbas street (Stadium Metro and monorail station)

Measurements & Variables

Travel Time & Average speed

Below table shows a sample after a site visit done at 3PM (the most congested Peak hour according to Google maps typical Traffic) on 26th June 2024. the expansion happening in the Travel Time do reflect the reduction in speed of the vehicles thus causing the high traffic congestion at each of the areas (highlighted in Red).

Table 1. Typical Speed & Travel Tima at weekday 2:00 PM

Typical Speed & Travel Time at Weekday 2:00 PM					
Point	A	B	C	D	E
Number of Lanes	3 Lanes	4 Lanes	4 Lanes	3 Lanes	4 Lanes
Distance till next Point (in Km)	0.75	0.85	0.73	0.44	0.5
Speed Limit (Km/h)	60	60	60	60	60
Optimal Time in minutes	0:45	0:51	0:43	0:26	0:30
Typical Time spent in min.	3:00	1:40	0:52	0:34	0:50
Typical Speed at Peak hour (Km/h)	15	30	50	45	35

Road Design & Geometry

Regarding Road Design & Geometry, Google Maps was used as a base for the main map and a site visit has been done by the author in order to validate the online data. such data do include multiple variables that can be examined during the simulation process such as, number of lanes, Road length, U-turn location. Pedestrian areas, pedestrian bridges, ramps. It was noticed that the Number of Lanes does vary starts with 3 Lanes at point A (before the bridge) Then road width increases at Node B and C to become 4 Lanes, then it reduces again to 3 Lanes at point E (Intersection with Youssef Abbas street), then returns to 4 Lanes at point F.

Traffic Volume

Traffic volume was observed via recorded videos by author including Car count at during week days & weekends. First a primary data has been taken from Google Typical Maps (refer to table 2) showing the rate of flow of the Traffic. At which green is the free flow, Orange is the medium flow, Red is Congested and Dark red the most congested Time (2:00 to 4:00 PM at Weekdays). Videos has been recorded by the author during different Times and Days of the week in order to observe the Traffic flow as well as taking counts of Private vs Public Vehicles. The videos were taken at each node during the following Times on: Saturday 22nd June 2024 - 2:00 PM and 8:00 PM, Wednesday 26th June 2024 - 2:00 PM and 8:00 PM, Tuesday 9th July 2024 - 2:00 PM and 8:00 PM. Then the counted numbers are inserted inside Table 3 and 4 in order to show the amount of Passing by cars at each node. Positive Numbers are the number of Cars passing by the Node and negative numbers are the number of Cars leaving the Node (refer to Table 3).

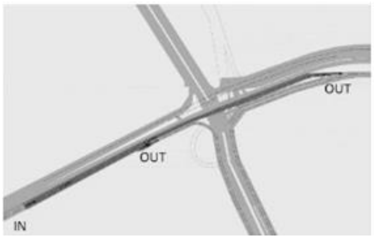
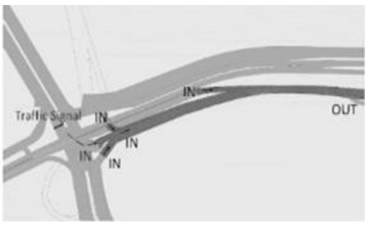
Table 2. Typical Traffic flow according to Google Maps at the 3 selected nodes during Weekday & Weekend day.

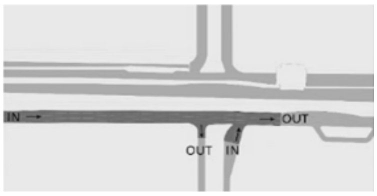
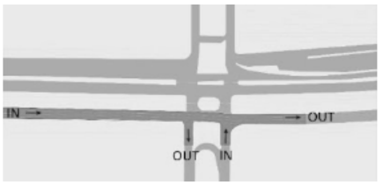
		Typical Traffic flow according to Google Maps at the 3 selected nodes during Weekday & Weekend days								
		6AM - 8AM	8AM - 10AM	10AM - 12PM	12PM - 2PM	2PM - 4PM	4PM - 6PM	6PM - 8PM	8PM - 10PM	10PM - 12AM
Weekday	A									
	C									
	E									
Weekend	A									
	C									
	E									

Table 3. Typical Traffic count at Weekday 2:00 PM.

Typical Traffic count at Weekday 2:00 PM					
Point	**A**	**B**	**C**	**D**	**E**
Number of pass-by Vehicles	4356	3684	5268	5396	4484
	-672	630	528	72	960
		738	-400	-984	132
		108			-72
		108			
Typical Traffic Count	**3684**	**5268**	**5396**	**4484**	**5504**

Table 4. Vehicle routing as recording by the Author at each node.

Node	Plan	Vehicle routing (In)	Vehicle routing (Out)
A		Salah Salem (4356) = 3 Lanes 100%	Bridge (SS) (3684) = 2 Lanes 83% Secondary Road (-672) = 2 Lanes 17%
B		Bridge (SS) (3684) = 2 Lanes 66% October Bridge (+630) = 2 Lanes 13% Emtedad Ramses (+730) = 2 Lanes 16% Ramses Road (+108) = 2 Lanes 3% U-Turn (+108) = 1 Lane 3%	Main Road (5268) = 4 Lanes 100%

C		Main Road (5268) = 4 Lanes 91% Secondary Road (+528) = 2 Lanes 9%	Main Road (5396) = 4 Lanes 85% Secondary Road (-400) = 2 Lanes 15%
D		Main Road (5396) = 4 Lanes 97% Secondary Road (+72) = 2 Lanes 3%	Main Road (4484) = 3 Lanes 90% Secondary Road (-984) = 2 Lanes 10%
E		Main Road (4484) = 3 Lanes 85% U-Turn (+960) = 1 Lanes 13% Secondary Road (+132) = 2 Lanes 15%	Main Road (5504) = 4 Lanes 85% Secondary Road (-72) = 2 Lanes 15%

Traffic Signaling
This Parameters do include all of the data related to Traffic system at each node such as, Traffic Signal location, Speed limit, stopping period, Bottle necks, Speed bumpers and obstacles in Asphalt (if any). As per the site visit of the Case study area, 2 Traffic light have been indicated at between points A & B with approx. 30 second headway.

Public Transportation
This Parameter is addressing the location of Public transportation stations, the amount of bus stops within a walkable area, below Table do illustrate the quantity of passing by Vehicles type at each of the case study nodes and as per recorded videos done by the author at the most congested time of the week. The amount of Formal Public Transportation passing by (Buses and Minibuses) has been counted during Peak hour, around 50 Bus counted at each node (refer to Table 5). In addition, Bus lines have been summarized in the below table as mentioned in the official Website of the Egyptian Public transportation lines (2024): https://www.cairo.gov.eg/ (refer to Table 6 and Figure 11) which shows that there should be 57 Buses and/or Minibuses passing by during peak hour (assuming that each bus passes by each 20 min. (approx. 3 cycles for each line per Hour).

Table 5. Capacity of Public Transportation Vs Capacity of Private Vehicles from videos recorded by Author.

Ratio of Public Transit to Private Vehicles at Weekday 2:00 PM					
Point	**A**	**B**	**C**	**D**	**E**
Number of Private Vehicles	3540	5040	5120	4244	5252
Microbuses	144	180	228	192	192
Buses		48	48	48	60
Typical Traffic Count	**3684**	**5268**	**5396**	**4484**	**5504**

Table 6. Public Buses/ Minibuses Lines passing by the Case study area - Developed by Author taken from website https://www.cairo.gov.eg/

#	Route	Type	No. of Bus lines	No. of passing by Buses during Peak Hour	Capacity (No. of Passengers pe bus)
1	Abbasiya - Salah Salem – Youssef Abbas Street	Bus (50 Passenger)	1	3	200
2	Emtedad Ramses - Salah Salem - El-Tayaran	Bus (50 Passenger)	2	6	400
3	Abbasiya - Salah Salem	Bus	7	21	1400

	- El-Tayaran	(50 Passenger)			
4	Abbasiya - Salah Salem - El-Tayaran	Mini Bus (27 Passenger)	7	21	756
5	Hadayek El-Quba - Fare Zone - Salah Salem - El-Tayaran	Mini Bus (27 Passenger)	2	6	216
	Total		19	57	2972

In addition, the amount of informal public transportation (Microbuses) has been counted (refer to Table 5). Which concludes that on average, around 185 Microbuses passes by the Cases study axis. The mentioned Microbuses are the 14 Passenger ones which means that the passengers' capacity of Microbus users during peak hour can be calculated as below:

185 x 14 = 2590 passenger

While the Total amount of Private Cars continued from A to point B (refer to Table 4) = 5040 Car

- Capacity of existing Public Transit (Formal + Informal) = Buses/Minibuses + Microbuses = 2972 + 2590 = 5562 Passenger
- Total Amount of Car users = Car count x average number of passengers (3) =

5040 x 3 = 15,120 Passenger

Ratio between Public Transit & Private Car users/ passengers = 5562: 15,120 ~ 2:5

Site Analysis illustration

As shown below at the first Line segment of the selected Case study area, Cars coming from point A (4 Lanes) will have to pass by a 2-Lane Bridge in order to continue on Salah Salem Street (Airport direction). According to the site Analysis and multiple videos recorded by the Author in June 2024 during Peak hours, around 87% of the passing-by Vehicles do take this route while the rest do not take that bridge and go toward the other Lane (toward Emtedad Ramses Street) creating a major Stop at the start of the bridge that continues till reaching point C; creating a huge Queue line along Line segments 1 & 2.

Figure 6. Line Segment 1 analysis - Developed by Author.

In addition, the road underneath the Bridge, do also contain 2 manual Traffic lights as shown in the below Figure, where each Traffic Light have both Red and Green Lights (30 seconds each) in order to monitor the Cars coming from Abbassia and Emtedad Ramses direction. Around 35% of the passing-by Vehicles coming from Traffic Signal 1 go toward point B (2 Lane Curve), while 45% of the passing-by vehicles coming from Emtedad Ramsis Street do go toward point B (2 Lane Curve). With all of these Inputs (2 Lanes from Abbasia Street, 2 Lanes from Emtedad Ramsis Street, 2 Lanes from the bridge coming from Point A, as well as 2 Lanes from October Bridge = 8 Lanes) this leads to large queue of a completely stopping Vehicles at point B (Only 4 Lanes). Below 3rd illustration is done by PTV VISSIM and Adobe Photoshop in order to highlight the Heterogeneous traffic at this Line segment.

Regarding Line segment 2 and as shown in Figure 15, The Majority of passing-by Vehicles do go in a straight line from Point B to Point D, however the number of Lanes does decrease at point D, forming another Bottleneck at which a Queue of Stopping vehicles at this line segment. Point C can be considered an essential stop as it is located beside Fair Zone Metro station. Another observed point during the Recorded videos of this line segment is that

Buses/ Microbuses coming from both Emtedad Ramsis and Abbasia street do stop at point C (under the bridge) with no safe way to pass the street for pedestrians nor enough seating area for pedestrian. which might be a reason for people preferring to use Private cars over Public buses / microbuses.

Figure 7. Line Segment 2 analysis (Developed by Author).

Regarding Line segment 3 and as shown in figure 17, The Majority of passing-by Vehicles do go in a straight line from Point D to Point F, however an additional Lane comes in the middle from the U-turn, this added Lane is then overlap the existing lanes forming another Bottleneck at which a Queue of Stopping vehicles at this line segment. It is also worth mentioning that the start of the Stadium Metro station as well as the new Monorail Station Line coming (Stadium Monorail station) located at Youssef Abbas street is currently under construction and is 650m away from point E.

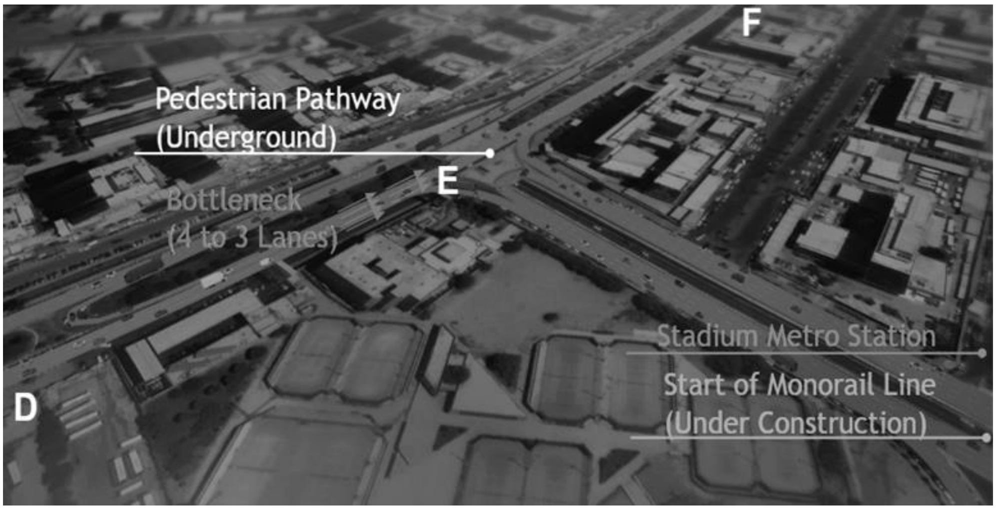


Figure 8. Line Segment 3 analysis (Developed by Author).

Model Making "Model 0"

PTV VISSIM software is selected as a Traffic simulation tool that is used as an easy way to optimize each of the related parameters. (Travel Time, Traffic count, Level of service, Road geometry, Traffic signals, Capacity of accessible Public transportation vehicles). Main steps for using the software are:

1. Inserting Road geometry (source: Google map & Site visit)
2. Inserting Traffic volume (Recorded Videos by Author)
3. Inserting Signal Heads (Traffic Lights shown in recorded videos)
4. Inserting Public Transport Lines & Stops (Recorded Videos by Author + Official websites of bus lines)
5. Model Calibration & Validation: Examining the different parameters (according to the 3 Methods mentioned in the Literature review for each node.)
6. Observing the best results: (Least Travel time, and highest Level of Service LOS)

Results and Discussion

Simulation Model #1: Bottlenecks Removal

During the Site analysis, Multiple Bottlenecks were observed as result of the non-linear road width changes from one zone to the other, which could be potentially one of the main reasons behind Traffic congestion. This Method aim is to try to fix the road design from the Geometrical perspective in order to maintain the flow of the Cars uninterrupted as much as possible, while also providing the highest possible safe area for non-car users (Pedestrian & cyclist).

Figure 9. Existing Number of Lanes.

Figure 10. Updated Number of Lanes (Method 1)

Below Map showing the Typical traffic during peak hour according to Google Maps (Wednesday at 3:00 PM) which is directly reflecting the changes happening in the Road width. Accordingly, it was recommended to check the LOS of each Node as well as total traveling time before and after road width updates done in this Method via PTV VISSIM.

Method 1:

Step 1: Road geometry was modified in PTV VISSIM through changing the number Lanes using the "Links" Tool at the high congested nodes that have a smaller number of Lanes (Point C & E) in order to remove all Bottlenecks.

Step 2: The area taken from the Curb (highlighted in Red in Figure 42 & 43.) is recommended to be relocated along the case study area and enhanced as a Pedestrian area with greenery and shading in order to provide a sufficient and safe alternative for car and to avoid induced demand Gabe Klien (2012).

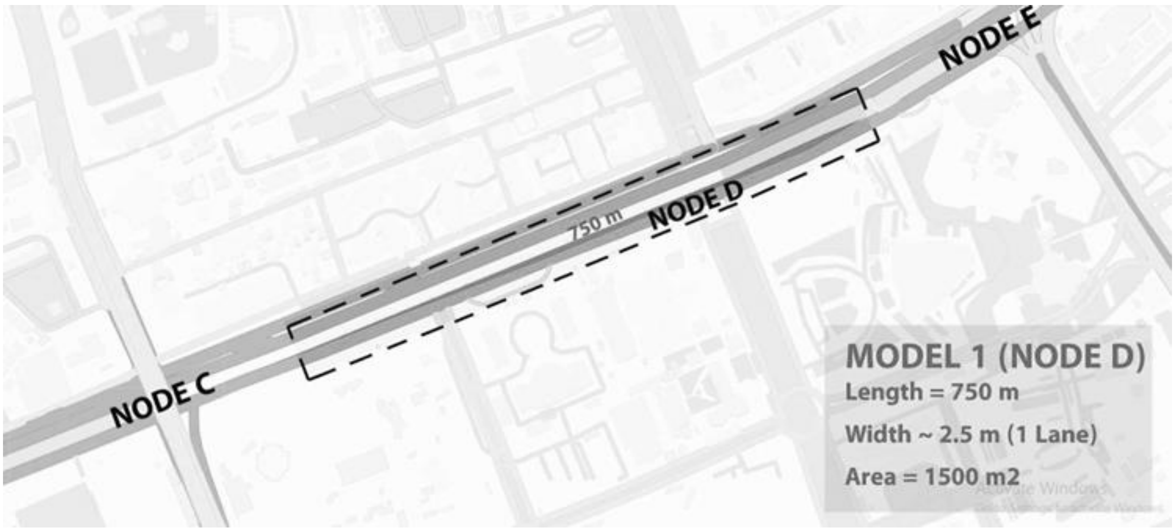


Figure 11. Intervention area around Node D (Sidewalk to Asphalt).

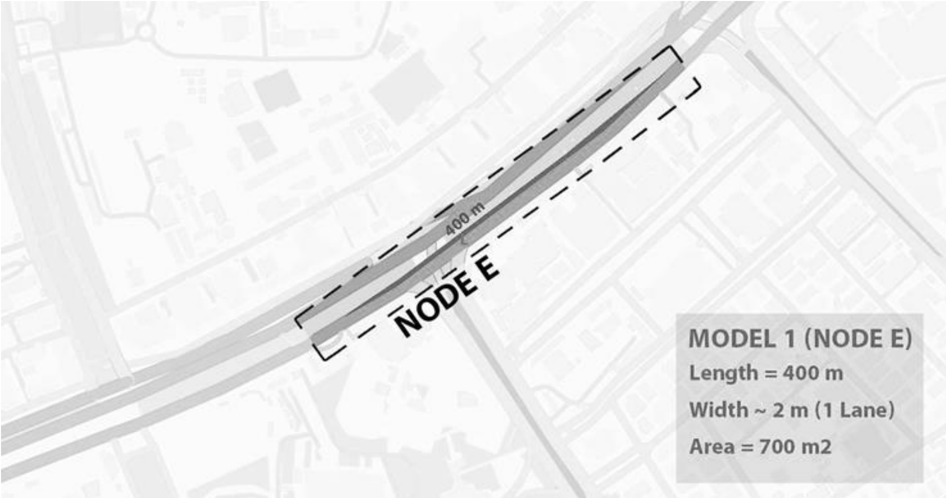


Figure 12. Intervention area around Node E (Sidewalk to Asphalt).

Simulation Model #2: Traffic signaling Optimization

During the Site analysis, it was observed that there are 2 Manual Traffic Signals between Node A & B. Each of these two Traffic signals includes approx. 30 Seconds Green Light and 30 Seconds Red Light. The Car flow coming from those two Traffic signals is directly interesting Node B from:

"Abassia" (Traffic Signal 1) & "Emtedad Ramsis" (Traffic Signal 2)

This Method does study the impact of Optimizing the Traffic lights duration in order to check whether the Traffic signaling is impacting the Traffic congestion and to what extent. Thus, different the Total Travel time as well as LOS at each node are calculated using PTV VISSIM software before and after each iteration.

Method 2:

Signal Timing sequence was modified to different timing iterations (0, 30, 60, 90, 120, 150, 180) and the result of LOS & Travel time was inserted in the below Table Figure 10.

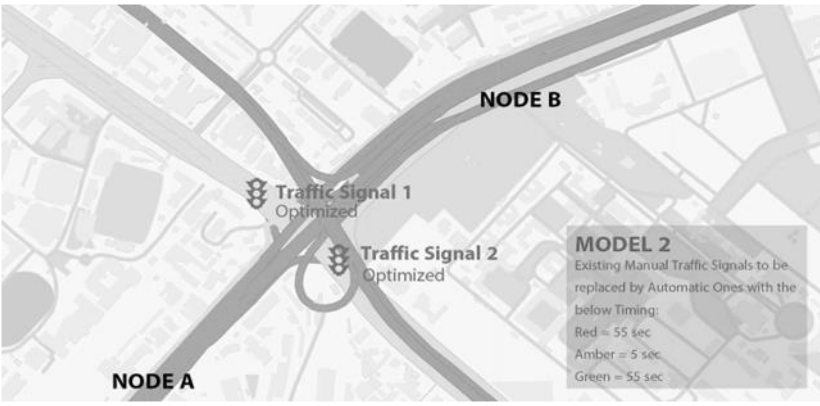


Figure 13. Method 2 Traffic signaling Optimization (Developed by Author).

Simulation Model #3: Public Transportation Revitalization

The amount of Formal Public Transportation passing by (Buses and Minibuses) has been counted during Peak hour, around 50 Bus counted at each node (refer to Table 4). In addition, Bus lines have been summarized in the below table as mentioned in the official Website of the Egyptian Public transportation lines: https://www.cairo.gov.eg/ (See Table 5) which shows that there should be 57 Buses and/or Mini-buses passing by during peak hour (assuming that each bus passes by each 20 min. (approx. 3 cycles for each line per Hour)

This Method aim is to show the impact of increasing Public Transit lines on the existing Traffic situation, (Assuming that the new Public Transit lines are running at full capacity). For the purpose of this study, the amount of Buses is increased in order to accommodate the difference between Private and Public Transit users till reaching the 1:1 ratio in order to see the impact of such concept on the Total Travel time as well as the level of service. Total amount of Passengers in the Case study area = 13,740 + 5562 = 19,302 Passenger

Targeted number of Passengers for the new Public transit lines (19,302 / 2) - 5562 = 4089 Passenger

Which means that almost double the existing number of buses is needed to accommodate the difference

Method 3:

Step 1: Calculate the needed amount of the extra public Buses at peak hour that will replace the Private Cars.

4089 / 3 = 1363 Cars

4089 / 50 = 81 Bus

Step 2: Replacing the existing extra Car counts (1363) with the new Buses (81) inside the PTV VISSIM software with the same stop location using the Public Transport Line / Stop tool.

Step 3: Calculate the Total Travel Time & LOS at each point.

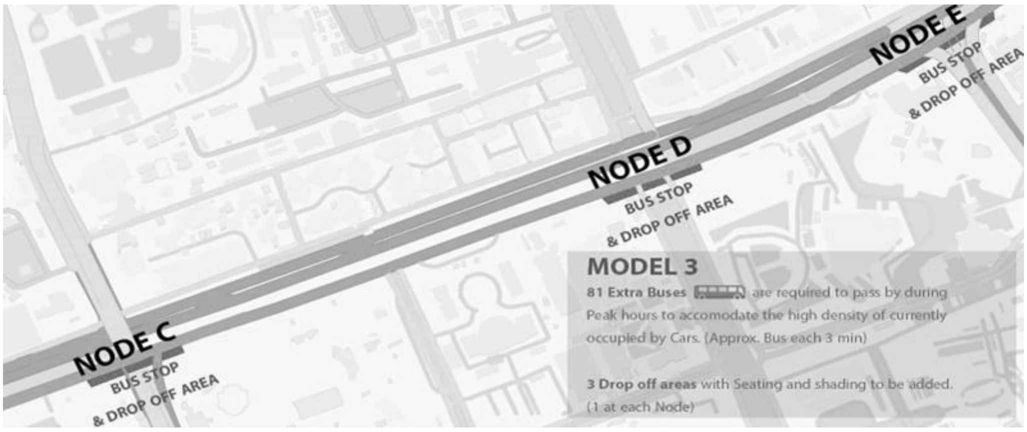
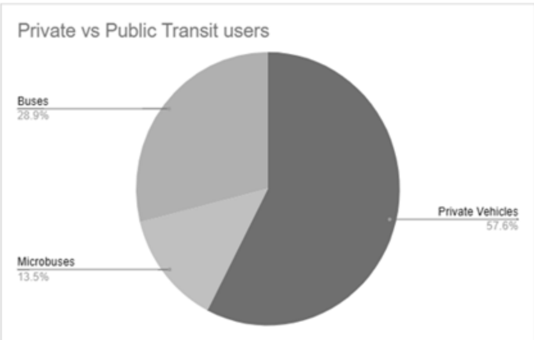
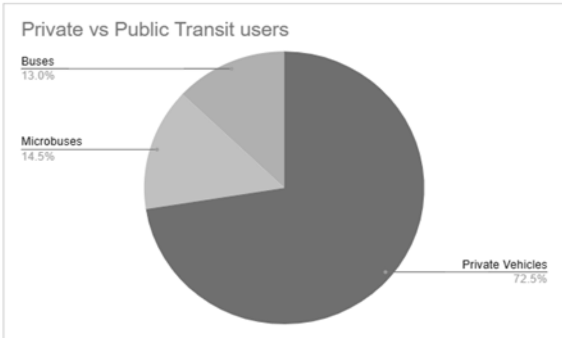


Figure 14. Method 3 Public Transportation Revitalization (Developed by Author).

Public Transportation vs Private Vehicles ratio (Proposed)				
Vehicle Type	Count durin Peak hour	Capacity	No. oF users	
Private Vehicles	2856	3	8568	- 500 Cars
Microbuses	144	14	2016	
Buses	86	50	4300	+ 50 Bus

Public Transportation vs Private Vehicles ratio (Existing)			
Vehicle Type	Count durin Peak hour	Capacity	No. oF users
Private Vehicles	3356	3	10068
Microbuses	144	14	2016
Buses	36	50	1800





Observed outputs

According to PTV VISSIM result for the first Scenario, The Total Travel time has been decreased by 48% (4.13 min instead of 8.08) while the number of passing by Vehicles has been increased to 3868 instead of 3277, it was shown that the Level of Service of NODE A has been boosted became A instead of E. For point B, it was shown that the Level of Service has been boosted to become A instead of C, while also the number of passing by Car has been increased (5226 instead of 4546), for point C, it was shown that the Level of Service has been boosted to become B instead of D, while the car count has been also increase to become 5286 instead of 4448. For Node D the LOS has been boosted to B instead of D, while in NODE E the Level of Service has remained the same (D). According to PTV VISSIM result for the second Scenario, the Total Travel time has been decreased by just 5% (7.45 instead of 8.08 min) while the number of passing by Vehicles has been increased to 3357 instead of 3277, it was shown that the Level of Service of NODE A has been boosted to became C instead of E. For point B, it was shown that the Level of Service has not been affected (remains C), while also the number of passing by Car has been increased (4617 instead of 4546), for point C, it was shown that the Level of Service has remained as it is (D), while the car count has also remained the same (4448). For Node D & E the Level of Service has also remained as it is (D) and the amount of passing by cars has a very minor increase (4474 instead of 4428).Regarding the result for the Third Scenario, The Total Travel time has been decreased by 43% (4.38 min instead of 8.08) while the number of passing by Vehicles has been increased to 2766 instead of 3277, it was shown that the Level of Service of NODE A has been boosted became A instead of E. For point B, it was shown that the Level of Service has been boosted to become A instead of C, while also the number of passing by Car has been increased 4173 instead of 4546), for point C, it was shown that the Level of Service has a minor boost to become C instead of D, while the car count has been also increase to become 4196 instead of 4448. For Node D & E the Level of Service has been boosted to become C instead of D and the amount of passing by cars has also increased (4168 instead of 4428). Regarding the result for the Scenarios Combined, The Total Travel time has been decreased by 49% (4.06 min instead of 8.08) while the number of passing by Vehicles has been increased to 3273 instead of 3277, it was shown that the Level of Service of NODE A has been boosted became A instead of E. For point B, it was shown that the Level of Service has been boosted to become A instead of C, while also the number of passing by Car has been increased 4588 instead of 4546, for point C, it was shown that the Level of Service has been boosted to become A instead of D, while the car count has been also increase to become 4620 instead of 4448. For Node D & E, the Level of Service has been boosted to become A instead of D and the amount of passing by cars has also increased (4679 instead of 4428).

Conclusion

Research Summary

As Traffic congestion became a critical issue that affects Cairo in different scales being the time wasted by Private Car users as well as a significant Loss in Egypt's GDP. It was essential to find the main reasons causing such phenomena from the various possibilities suggested in the prior researches / studies. Thus, a consolidated framework has been developed in this Research for urban designers to diagnose the primary causes of traffic congestion and select the most effective solutions using traffic simulation tools. Salah Salem Axis, one of Cairo's most congested roads, was chosen as the case study. PTV VISSIM software was used to simulate traffic flow, with key parameters such as network geometry, traffic volumes, and travel times recorded and analyzed. Three Scenarios has been chosen according to the Literature review and all of those Scenarios had been simulated inside the Traffic simulation software. After running the Simulation Model for 1 hour after implementing each Method inside the Traffic simulation Tool, it was observed that, Method no.1 (Enhancing the road geometry) had the most impact in reducing total Travel time "4:13 min" which is 48% less of the existing situation "8:08 min", as well as the Best Value for the LOS at NODE B & C. Which reflects how drastic the road design in causing Traffic congestion, hence resulting in a significant delay in Travel Time.

On the other hand, Method no.2 (Traffic Signals optimization) had the least impact on the total Travel time "7:45 min" which is just a 5% reduction of the existing Travel Time, which reflects how poorly the development of Traffic Lights affect the flow of the cars at that area. For Method no. 3, the Travel time has also a significant reduction of "4:38 min" which is 43% less of the existing Travel time. In term of NODES, For Node A, B, C the most efficient Method used was the third approach to increase the Public Transport reliance. For Node D The most effective approach to solve the Bottleneck. 2nd Approach (Optimizing the Traffic Signals) was the least effective Method.

Table 7. Analysis Results - LOS (Level of Service) vs Travel Time according to PTV VISSIM software.

NODE	Original Case	Bottlenecks removal	Traffic Signals	Public Transit	3 Scenarios Combined
NODE A	E	A	C	A	A
NODE B	C	A	C	A	A
NODE C	D	A	D	C	A
NODE D	D	B	D	C	A
NODE E	D	D	D	C	A
Travel Time in Min.	**8.08**	**4.13**	**7.45**	**4.38**	**4.06**

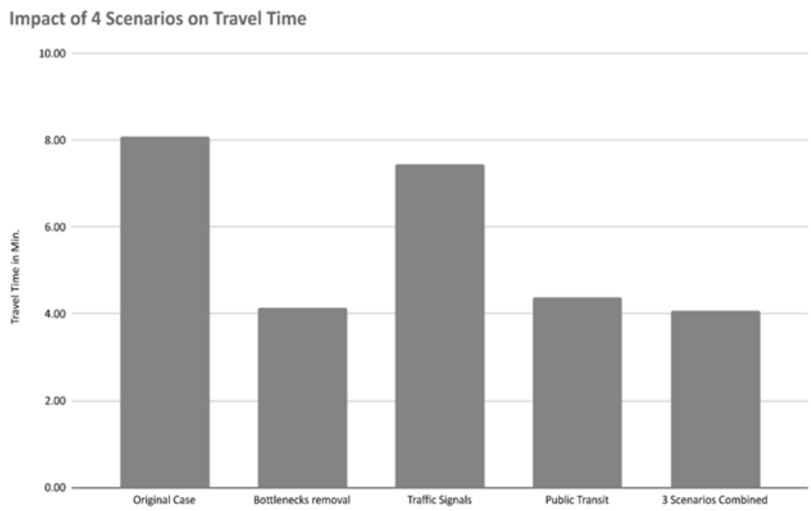


Figure 15. Impact of the 4 Scenarios on Travel Time.

Regarding the Research question, “What are the most efficient urban Methods and Tools that can be utilized for reducing Time wasted in Traffic Congestion in Cairo?” it was concluded that all of the three mentioned Methods have different implication among different nodes, however for the purpose of this Research and with the selected case study area, Method no. 1 “Road Geometry enhancement” was the most efficient and impactful Method in term of Travel Time and Level of Service (LOS) at the multiple intersections. In addition, the results came out of the PTV VISSIM can be reliable however the parameters identification are needed to be observed as already done by the author at site analysis, thus this Master Research should be provided as a consolidated a step by step framework/guide for Urban Designers and planners for future studies before committing to Design, which do satisfy the recommendation done in the previous researches. However, as already mentioned in the (M. Abdel Wahed and N. Abd El Monem, 2020). Urban Planning is about having a continuous check and revise over the existing Master plan in order to validate if the current design can accommodate the continuous changes and updates happening by the people.

For future studies, researchers could explore the impact of different time-of-day traffic patterns. Extending data collection methods to include more advanced technology, like drone footage and AI-based video analysis, could provide a more comprehensive view of traffic flow and driver behavior. Additionally, future studies could benefit from a multi-arterial approach to better understand network-wide traffic dynamics. Examining the effect of specific interventions, such as dedicated lanes for public transport or signal prioritization for buses, could also positively affects the Traffic flow as already suggested in previous studies. Further research might also investigate driver’s behavior and preferences, which could inform targeted awareness campaigns. In addition, long-term monitoring and evaluation of the implemented recommendations would be essential for measuring impact and making continuous improvements based on real-world data. It is also recommended that different Case studies areas be done using the same approach as this study, in order to have a wider ground and have a better approach among different patterns of the selected parameters. Another recommendation is to keep in consideration the surrounding Transportation projects. Another recommendation is that, urban planners should consider integrated Methods that prioritize public transport, non-motorized options, and modernized infrastructure. Expanding the public transportation network, including bus rapid transit systems and dedicated lanes, could mitigate, road congestion while reducing dependency on private vehicle.

Limitations

One of the primary issues is data availability and quality. Traffic simulation relies heavily on accurate, detailed, and current data, yet in Cairo, obtaining comprehensive data on traffic flow, signal timings, vehicle counts, and travel times can be difficult. Often, online data may be incomplete or inconsistent. Thus, the Author has relied on the Site visit done as well as some Traffic data from Google typical maps. In addition, one of the parameters that do affect the Traffic congestion worldwide in developing countries such as Cairo is Driver behavior. Such parameters have been ignored in this study as is a very wide term and it will be very difficult to assess all of the possibilities because of the random factor that comes with this parameter. Cairo’s traffic involves unique behavioral factors, including frequent lane changes, sudden stops, and aggressive driving that are hard to quantify in simulation terms. VISSIM typically uses standard behavioral models, which might not capture the nuances of local driving habits effectively. Calibration and validation of the model to ensure accuracy is a critical, yet time-intensive, process, particularly with these behavioral differences. Another limitation lies in impact measurement. Evaluating the effectiveness of various congestion-reducing Methods can be challenging, as traffic systems are complex, and isolating the effect of each Method from other influencing variables is often difficult. Additionally, implementing and validating Methods may require cooperation from local stakeholders, including traffic authorities or urban planning departments.

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Conflict of Interests

The author(s) declare(s) no conflict of interest.

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