PENANG SMART MOBILITY MICRO-SIMULATION MODEL DEVELOPMENT

FINAL REPORT

FEBRUARY 2024

ASEAN AUSTRALIA SMART CITIES TRUST FUND
Asian Development Bank

Australian Government
Department of Foreign Affairs and Trade

ADB

Project name	**Task Order No. 6 – Penang Smart Mobility Micro-Simulation Model Development**
Client name	**Asian Development Bank**
Type of report	**Final Report**
Date	**21/02/2024**
Company	**Ramboll**
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1. INTRODUCTION

1.1 Background

Ramboll has been engaged through the ASEAN Australia Smart Cities Trust Fund (AASCTF) to conduct a smart city project for Penang. This project intervention involves the development of a Transport Micro-Simulation Model of the historical center of Georgetown that can be used to assess future mobility interventions such as public transport, traffic improvements, pedestrianization and cycling improvements.

The Pilot Project involved the development and calibration of the micro-simulation model using PTV Vissim software and testing of a limited set of potential future interventions for Georgetown, as well as training of Digital Penang / MBPP staff in the use of PTV Vissim for Stage 1 of the project.

Stage 2 of the project covered an extended heritage area covering Stage 1 and an additional area agreed with stakeholders.

Both the stages covered the calibrated Vissim micro-simulation model results for the study area as defined for the study as well as scenarios developed as part of sustainable development. The use of this Vissim micro-simulation model will enable Penang to:

- provide the authority with an efficient tool to check and assess the implications of developer plans, and thus improve the implementation and enforcement of transportation policies;
- test and trial the implication of different transportation policies and designs (e.g., parking, e-buses, micro-mobility, car-free spaces, etc.);
- better communicate implications of transport policies and solutions to decision makers, developers and to the public; and
- knowledge-share with planners in Georgetown to provide the skills and tools to continue to enhance and improve smart mobility strategies moving forward.

1.2 Project Objectives

The expected outcome is to provide Penang with a **calibrated VISSIM micro-simulation** model of the core historic city center of Georgetown, and **to use the model to test Smart Mobility strategies**. The use of this VISSIM micro-simulation model will enable Penang to:

- provide the authority with an efficient tool to check and assess the implications of developer plans, and thus improve the implementation and enforcement of transportation policies;
- test and trial the implication of different transportation policies and designs (e.g., parking, e-buses, micro-mobility, car-free spaces, etc.);
- better communicate implications of transport policies and solutions to decision makers, developers and to the public; and
- knowledge-share with planners in Georgetown to provide the skills and tools to continue to enhance and improve smart mobility strategies moving forward.

The following table examines the success factors planned to ensure each objective is achieved throughout the Pilot Project intervention methodology.

Table 1-1 Success Factors

Objective	Ensuring Success
Provide the authority with an efficient tool to check and assess the implications of developer plans, and thus improve the implementation and enforcement of transportation policies	• Model structured in a way where testing changes to demand, public transport options, mode share etc. is logical and easy • Model parameters, development, calibration and network performance are fully documented • Supporting documents / spreadsheets • Measurements within the model
Test and trial the implication of different transportation policies and designs (e.g., parking, e-buses, micro-mobility, car-free spaces, etc.)	• Full review of existing and proposed plans with a summary of potential interventions in Georgetown that can be translated into simulation model tests • Stakeholder consultation (interviews) with all relevant personnel to ascertain their thoughts on mobility for Georgetown • Four intervention scenarios will be developed from the plan review and stakeholder consultation, and tested within the model as part of this study
Better communicate implications of transport policies and solutions to decision makers, developers and to the public	• Scenarios are translated into the model such that it gives policy makers a good visual and quantitative assessment of impacts • High quality 3D representation of Georgetown transport
Knowledge-share with planners in Georgetown to provide the skills and tools to continue to enhance and improve smart mobility strategies moving forward	• Model handover and documentation is clear • VISSIM training course covers the technical requirements for running and utilizing this model

1.3 Deliverables

The following section outlines the agreed deliverables in the Task Order (i.e., the basis for the Pilot Project) as developed by Ramboll, as main framework consultant to the implementation of the AASCTF, in conjunction with the Asian Development Bank (ADB), Digital Penang and MBPP.

1.3.1 Outcome

The expected outcome of the Pilot Project is to provide Penang with a calibrated VISSIM micro-simulation model of the core historic city center of Georgetown, and to use the model to test Smart Mobility strategies.[1] The use of this VISSIM micro-simulation model will enable Digital Penang and Penang City Council engineering department to:

1. provide the authority with an efficient tool to check and assess the implications of developer plans, thus improving implementation/enforcement of transportation policies.
2. test/trial the implication of different transportation policies and designs.
3. better communicate implications of transport policies and solutions to key stakeholders.
4. knowledge-share to provide skills and tools to enhance/improve smart mobility strategies.

1.3.2 Output

The proposed Pilot Project intervention is broken down into two stages within the proposed Task Order on 'Smart Mobility Micro-Simulation Model Development' – Stage 1: Pilot Area Micro-Simulation and Stage 2: Expanded Area Micro/Macro-Simulation and Training / Handover. The following key outputs are sought:

- Output 1. Survey and Model Inception Report
- Output 2. Trial Micro-simulation Model Report (Stage 1 Trial Area)
- Output 3. Micro-simulation Model Report (Stage 2 Wider Area)
- Output 4. Final Report

1.3.3 Implementation Arrangement

Executing agency: Asian Development Bank

Implementing agency: Digital Penang/Penang City Council Engineering Dept

Both Digital Penang and Penang City Council Engineering Department represent the Penang State Government team for this project, vis-à-vis:

Digital Penang is the State's agency tasked to lead digitalization efforts across the State Government. In this respect, Digital Penang's role is to connect with external stakeholders to bring in technology and at the same time support internal agencies with their digitalization journey. Digital Penang reports to the Penang State Cabinet.
Penang City Council Engineering Department acts as matter expert for traffic policy/regulations and implementation. Penang City Council Engineering Department has decision making power on changing traffic flow, re-positioning CCTV, etc. The aim through the project intervention is to empower the Engineering Department with a traffic simulation model to better manage traffic on Penang island.

Implementation period: May 2021 to March 2024

1.3.4 ADB Project Officer

Main Responsible: Kyaw Thu, Senior Urban Development Specialist

[1] PTV VISSIM is an industry standard traffic micro-simulation software package, developed by PTV Group. VISSIM allows the simulation of vehicle, pedestrian, and cyclist movements within a simulated transport network. By calibrating a simulation to the existing environment, various future scenarios/solutions can be tested to evaluate their effectiveness.

Technical Point of Contact: Elizabeth Jung, Urban Development Specialist

1.3.5 Scope of the Task Order

The following table outlines the methodology for this task order covering Stage 1 as well as Stage 2 deliverables.

Table 1-2 Task Order Scope

No.	Activity	Output
1	**STAGE 1 - PILOT AREA MICRO-SIMULATION**	
1.1	**Mobilization**[2]	**Survey and Model Inception Report (D1A & D1B)**
1.2	**Data Review**	
1.2.1	Review and collation of data/reports	
1.2.2	Review TIA guidelines for Penang	
1.2.3	Preliminary desktop assessment	
1.3	**Initial Stakeholder Consultations**	
1.3.1	Stakeholder mapping	
1.3.2	Stakeholder liaison/consultation with key agencies, incl. Digital Penang, Penang City Council, etc.	
1.3.3	Liaison/consultation with other consultancies/project initiatives active in Georgetown/pilot area	
1.3.4	**Workshop 1 (W1)** - Kick-off Meeting/Preliminary Scoping Workshop	
1.4	**Develop/calibrate a VISSIM micro-simulation model of trial/pilot area of Georgetown**	**Trial Micro-simulation Model Report (D2A & D2B)**
1.4.1	Collect road layout, lane markings and signal timings (as appropriate) for the trial model area	
1.4.2	Collect and analyze traffic data required for the model	
1.4.3	Build the base year (current year) VISSIM model for the trial area, calibrated to traffic information collected	
1.4.4	Test elements of the current transport masterplans using the model	

[2] Mobilization/commencement subject to COVID-19 mobility restrictions being lifted (i.e. easing of current Movement Control Order in Malaysia), and ground movement in pilot area at essentially "normal" level.

No.	Activity	Output
1.4.4.1	Mixed Use mobility trial zone along Beach Street within the VISSIM model	
1.4.4.2	Vehicular optimization trial zone along Pengkalan Weld within the VISSIM model	
1.4.4.3	Pedestrian optimization trial in the pedestrian simulation zone within the VISSIM model	
1.4.5	**Workshop 2 (W2)** - Micro-simulation model of pilot area	
2	**STAGE 2 - EXPANDED AREA MICRO-SIMULATION AND TRAINING/HANDOVER**	
2.1	**Develop the micro-simulation model to cover a greater area of Georgetown (UNESCO World Heritage Zone)**	**Micro-simulation Model Report** **(D3A & D3B)**
2.1.1	Expanding and calibrating the VISSIM model to an extended area of historical Georgetown	
2.1.2	Testing the transport master planning strategies from Stage 1 for the wider area model	
2.1.3	Evaluate the potential impact of the master planning strategies as tested, and advise on enhancements to the strategies	
2.2	**Propose changes to the Traffic Impact Assessment (TIA) guidelines (and other plans/policies) for Penang**	**Final Report** **(D4)**
2.2.1	Recommend changes to the Traffic Impact Assessment (TIA) guidelines and other plans for Penang	
2.2.2	Recommend any other implementation strategies to achieve pathways to implementation of the mobility improvements recommended	
2.3	**Conduct accredited PTV VISSIM training**	
2.3.1	Conduct a full, accredited PTV VISSIM training course for potential users of the model at the Penang authority	
2.3.2	Conduct a handover training session with the Penang authority	
2.4	**Stage 2 Model handover (base year + scenario tests)**	
2.4.1	**Workshop 3 (W3)** - Stakeholder workshop to validate findings on Stage 2 model	
2.4.2	Model handover (base year + scenario tests) to the authority	
2.4.3	Video product development	

1.3.6 Key Milestones

Modified planned milestones are shown below. These have been changed as a result of COVID-19 delays and further adjustments to the project methodology.

For Stage 2 project Ramboll conducted the following workshops with Penang government authorities:

1. Stage 2 Kick off Workshop – 31 August 2023
2. Stage 2 Inception & Scenario Development Workshop – 14 September 2023
3. Stage 2 Calibration and Scenario Testing Workshop – 5 December 2023

Table 1-3 Milestones

No.	Output and Milestone	Dates
1	Model Inception and Trial Model Report (D1A)	4 November 2021
2	Survey Report (D1B)	17 December 2021
3	Stage 1 Base Model Calibration Report (D2A)	14 January 2022
4	Stage 1 Scenario Testing Report (D2B)	4 February 2022
5	Stage 2 Base Model Calibration Report (D3A)	25 October 2023
6	Stage 2 Scenario Testing Report (D3B)	30 November 2023
7	Final Report (D4)	23 February 2024

1.3.7 Team Composition

The project was delivered with a team of national and international experience as presented below.

Table 1-4 Task Team Composition

No.	Position	Candidate
A.	**CORE TEAM**	
1	Urban Planner/Core Team Leader	Mr. Søren Hansen
2	Smart Technology Expert	Mr. Jacob Olsen
3	GESI Specialist	Ms. Catherine Grant
4	M&E Specialist	Mr. Xavier Le Den
5	Communication and Outreach Specialist	Mr. Jens Christian Riise
B.	**SENIOR INTERNATIONAL EXPERTS**	
6	Task Team Leader	Mr. Nick Fellows
7	Senior Smart Mobility Expert	Mr. Richard Sprosen
C.	**MID-INTERNATIONAL EXPERTS**	
8	Senior Modeller & PTV Vissim Accredited Trainer	Mr. Yiheng Xu
D.	**JUNIOR INTERNATIONAL EXPERTS**	

No.	Position	Candidate
9	Traffic Modeller	Mr. Prasanna Venkatesan
10	Video Production Specialist	Ms. Elga Reyes
E.	**SENIOR NATIONAL EXPERTS**	
11	Deputy Task Team Leader	Ms. Ashita Pereira
12	Senior Transport Planner	Mr. Irman Haizal Sulaiman
13	Networking/M&E Expert	Mr. Jackson I. Pereira

2. PLAN AND POLICY REVIEW

The following chapter outlines a review conducted on the Penang Transport Master Plan (2030) and Penang Green Transportation Plan, as they relate to potential interventions in Georgetown. This review formed the basis for development of scenarios to test within the micro-simulation model.

2.1 Penang Transport Master Plan (2030)

Penang Transport Master Plan, also known as PTMP, is a comprehensive plan formed by the Penang state government to improve transportation within the entire state of Penang. The Plan envisages more alternative transportation modes to combat worsening traffic congestion across the state, such as Light Rail Transit (LRT) and monorail lines, a cable car line, and an undersea tunnel linking Georgetown with the town of Butterworth on the mainland. The timeline below (Figure 2.1) outlines the chronology of PTMP from inception onwards.

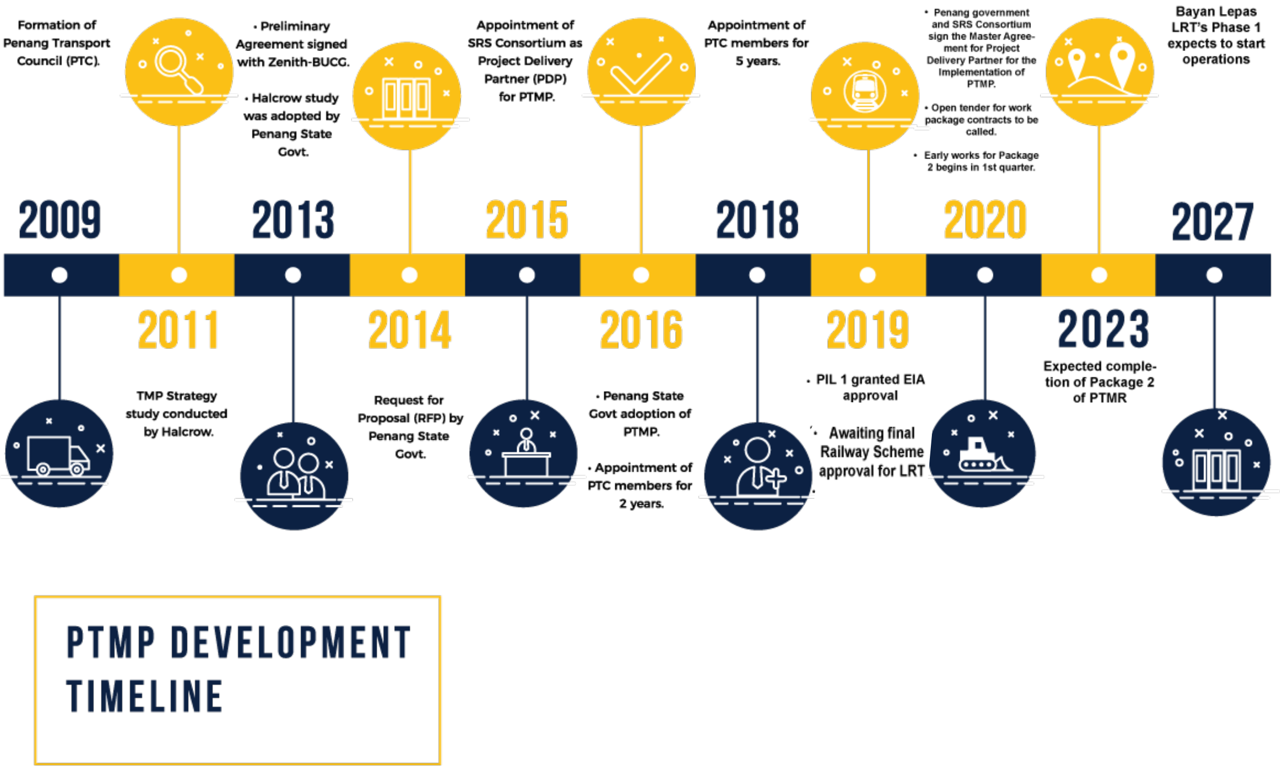


Figure 2-1 PTMP Development Timeline

The PTMP study was commissioned in recognition of the growing transportation issues within the state and aims to adopt a holistic approach in resolving transportation issues, whilst ensuring that roads are safe and user-friendly for all. PTMP emphasizes moving towards greater public transport dependence, and ultimately aiming to achieve public transport to private transport modal share of 40:60 by the year 2030.

PTMP also looks into integration between transport systems and development plans between the island and mainland of the state of Penang, as shown in Figure 2.2 below.

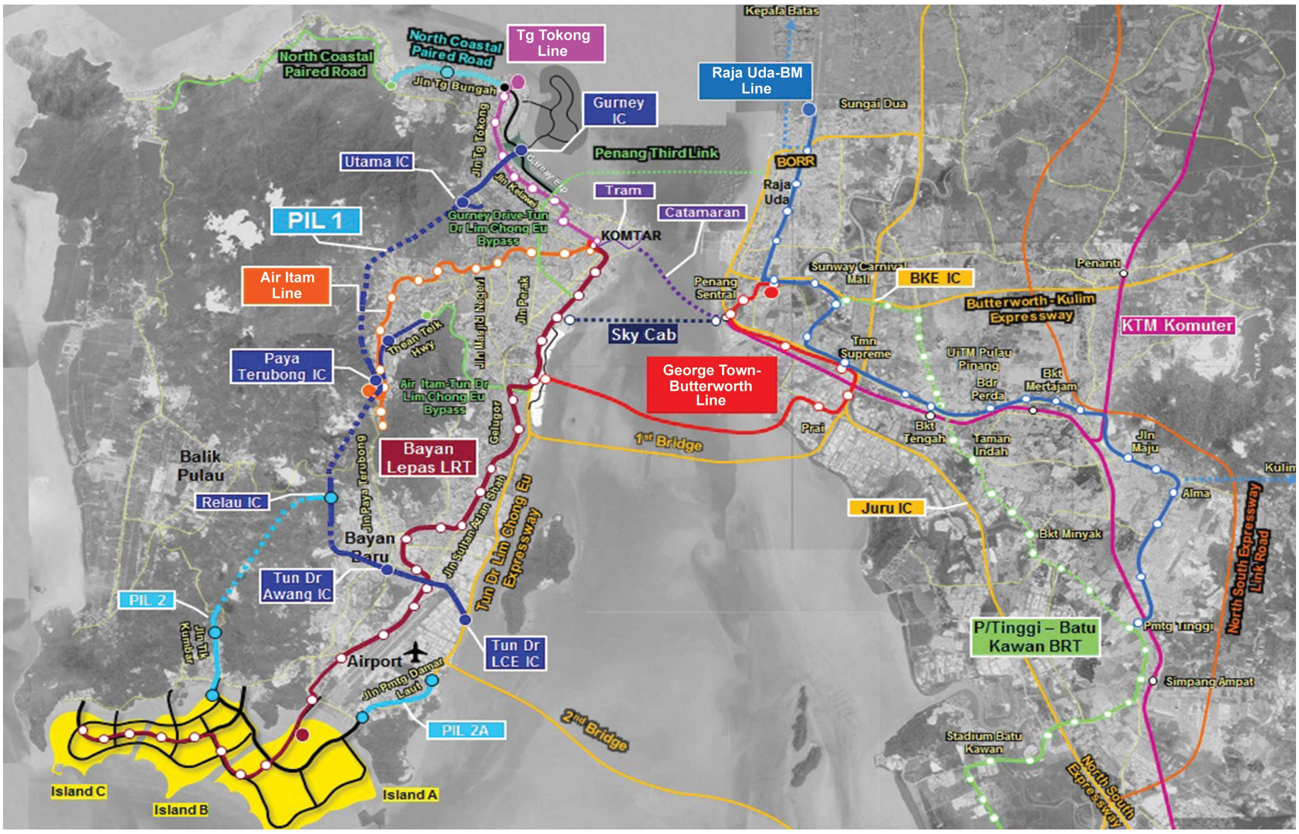


Figure 2-2 PTMP Masterplan

2.1.1 Recommended Transport Master Plan Strategy

As deliberated in the PTMP, the following proposals are pivotal in the road infrastructure development in the state of Penang, being identified through a process and designed to meet the transportation objectives:

i. Short- to medium-term proposal designed to make better use of the state's existing transport network.
ii. Longer-term proposal to provide additional highway and public transport infrastructure.
iii. Policy-based proposals aimed at reducing the future growth in private vehicle activity.

The PTMP consists of two (2) strategies, namely the highway strategy and the public transport strategy, which were identified through a process of technical analysis, stakeholder engagement and public consultation.

2.1.2 Highway Strategy

The Highway Strategy was developed to ensure that road safety, accessibility, connectivity and traffic dispersal are considered as key factors to update regional and local highway and road network parameters, such as improved conditions for pedestrians, cyclists and motorcyclists, and the need to enhance existing traffic signal intersections. Regulation and enforcement of loading, waiting parking and hawker activity are paramount to ensure smooth flow of traffic in the city center and other activity centers whilst maintaining road safety. PTMP has highlighted the need to improve signages, way finding and road marking to provide a better driving experience. PTMP has designated to widen some 150 kilometers of existing roads, partial grade separation of 40 intersections, introduction of traffic control at a further 64 intersections and provision of full grade separation at three locations where the regional highways meet.

One of the key projects identified in the PTMP is the creation of three (3) major dispersal roads which are toll-free, believed to alleviate traffic congestion towards the northern, central and eastern parts of Penang, as listed below:

- The North Coastal Paired Road from Tanjong Bungah to Teluk Bahang (Figure 2.3)
- The Ayer Itam – Lebuhraya Tun Dr. Lim Chong Eu Bypass (Figure 2.4)
- Persiaran Gurney – Lebuhraya Tun Dr. Lim Chong Eu Bypass (Figure 2.5)

Further, Table 2.1 summarizes details and strategies that would be scrutinized by the PTMP for highway network development, which includes type of highway, intersection type, and needs for vulnerable road users.

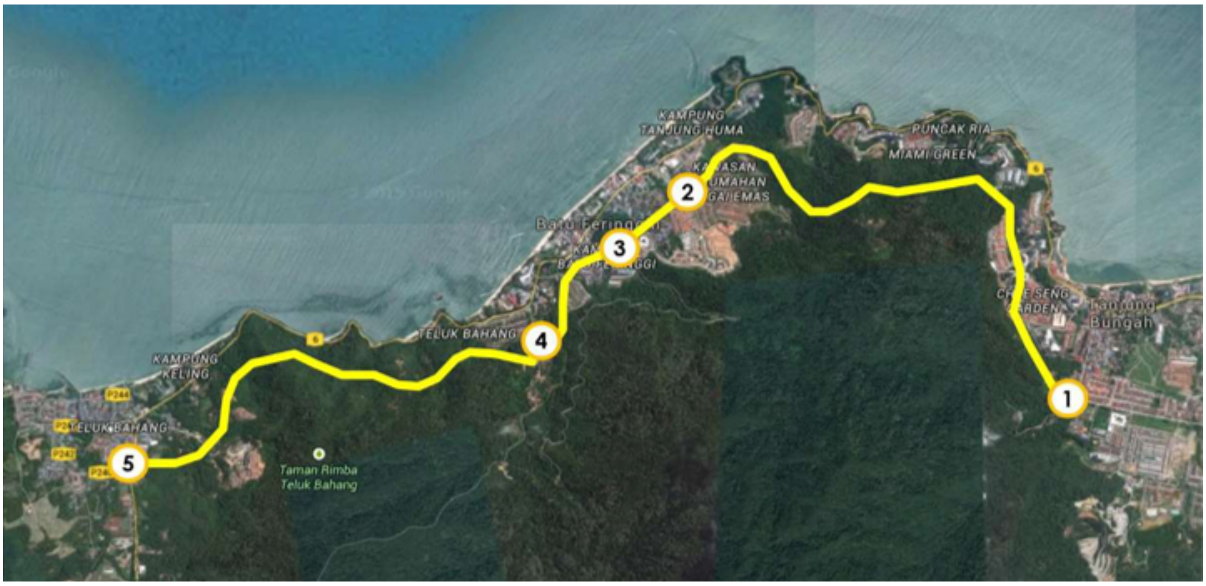


Figure 2-3 The North Coastal Paired Road from Tanjong Bungah to Teluk Bahang

Figure 2-4 The Ayer Itam – Lebuhraya Tun Dr. Lim Chong Eu Bypass

Figure 2-5 Persiaran Gurney – Lebuhraya Tun Dr. Lim Chong Eu Bypass

Table 2-1 Proposed Strategies for Highway Standard by the PTMP

Highway Status	Minimum Highway Standard	Typical Intersection Treatment	Carriageway Access Policy	Motorcycle Policy	Pedestrian Policy	Cycling Policy
Strategic National Highway	Non – tolled highways • D3 lane Tolled highway • D2 lane, except where traffic volumes justify D3 lane	• Full grade separation at all major interchanges • Partial grade separation elsewhere	• Only via grade separated intersections • No direct frontage access from premises	Fully segregated facilities to be provided for motorcycles, adjacent to traffic lanes	• Prohibited along road • Footbridges or underpasses to be provided across road corridor so as to provide access between adjoining communities and / or / to public transport stations / bus stops	• Prohibited along road • Footbridges or underpasses to be provided across road corridor providing access between adjoining communities.
Strategic State Highway	• D2 lane	• Partial grade separation to be used at all major intersections • Left-in / Left-out control to be imposed at minor side roads • U-turn facilities to be provided within all partially grade separated intersections	• Limited to partially grade separated interchanges and left-in left-out minor roads • No direct frontage access from premises	Un all rural locations, and where possible in Urban locations • Fully segregated facilities should be provided for motorcycles In other Urban locations • Nearside traffic lanes should have adequate width to allow a car to overtake a motorcycle In all situations • Motorcycles under 250cc should be prohibited from using the elevated portion of partially grade separated intersections	In urban areas • Footways to be provided adjacent to highway • At-grade fully protected crossings to be provided within all partially grade separated intersections • Footbridges and / or underpasses to be provided elsewhere, linking communities and paired public transport stations / bus stops In rural areas • Pedestrian should be prohibited all access to the road • Footbridges or underpass should still be provided, linking communities and paired public transport stops	In urban areas • Where possible, off carriageway cycle lanes should be provided adjacent to pedestrian footways. • Cyclist should be prohibited from using the elevated portions of partially grade separated intersections In rural areas • Prohibited along road In all situations Footbridges and / or underpasses should be provided between adjoining communities.
Strategic District Highways	• D2 lane carriageway outside Georgetown • S4 carriageway within Georgetown	• Traffic signal control at all significant intersections	• Through signalised intersections and side roads • Direct frontage access from premises should be limited as much as is possible	• Where possible, nearside traffic lanes should have adequate width to allow a car to overtake a motorcycle	In urban areas • Adequate footways to be provided • Fully protected walk the traffic pedestrian facilities to provided at all intersections. Intermediate mid-block signalised pedestrian crossings to be provided adjacent to all transit stations. In rural areas • Provision should be matched to local pedestrian / public transport passenger needs	In urban areas • On-street cycle lanes to be provided where space allows • Otherwise, parallel, off-corridor, cycle routes to be provided. In rural areas • No special provision

2.1.3 Public Transport Strategy

The PTMP has looked into details on rationalizing and regulating public transportation, in order to improve the current situation of inconsistent demand and supply. The new public transport efforts outlined in the PTMP need to be a seamless and integrated public transport network, touching on the following salient points:

- To rationalize the existing bus network into a series of core bus routes, feeder bus routes and other supporting bus routes.
- To improve public transport integration through introduction of integrated ticketing, good interchange facilities and better management of private sector activities.
- To improve the standard of exiting public transport provision through upgrading of existing bus service to Tram (Figure 2.6), Light Rail Transit (Figure 2.7), or Bus Rapid Transit operations.
- To introduce new Tram or Bus Rapid Transit based services linked to serve the suburbs of Georgetown and to the residential and industrial areas of Bayan Lepas.
- To introduce new commuter rail service on the mainland between Butterworth and Pinang Tunggal, and Butterworth and Nibong Tebal.
- To upgrade the current ferry service between Butterworth and Georgetown.
- To introduce new ferry service between Butterworth and Gurney Quay, Butterworth and Queensbay and Straits Quay, Tanjong Tokong Island, Gurney Quay, Weld Quay, the Light and Queensbay.

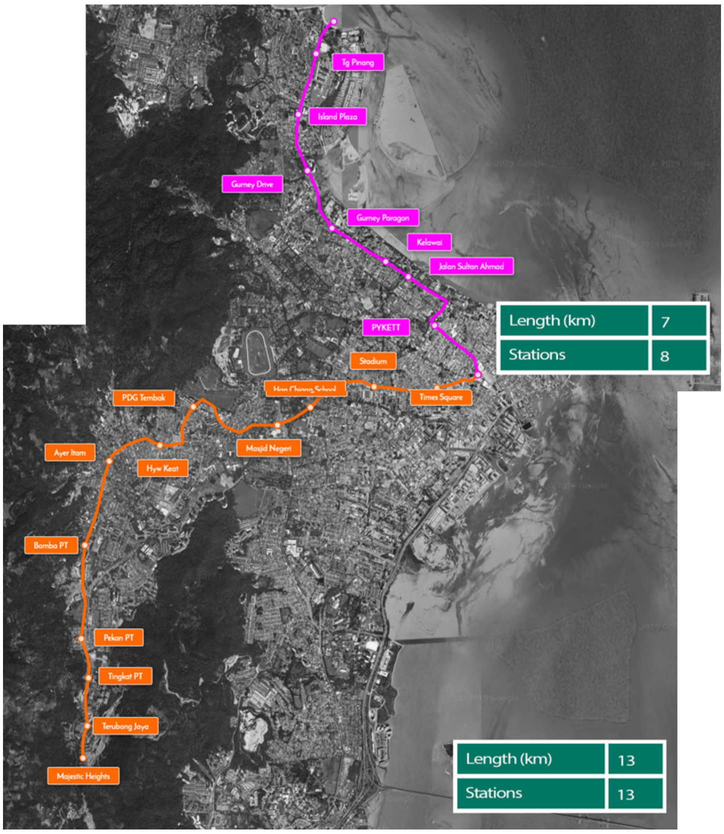


Figure 2-6 Proposed Tram

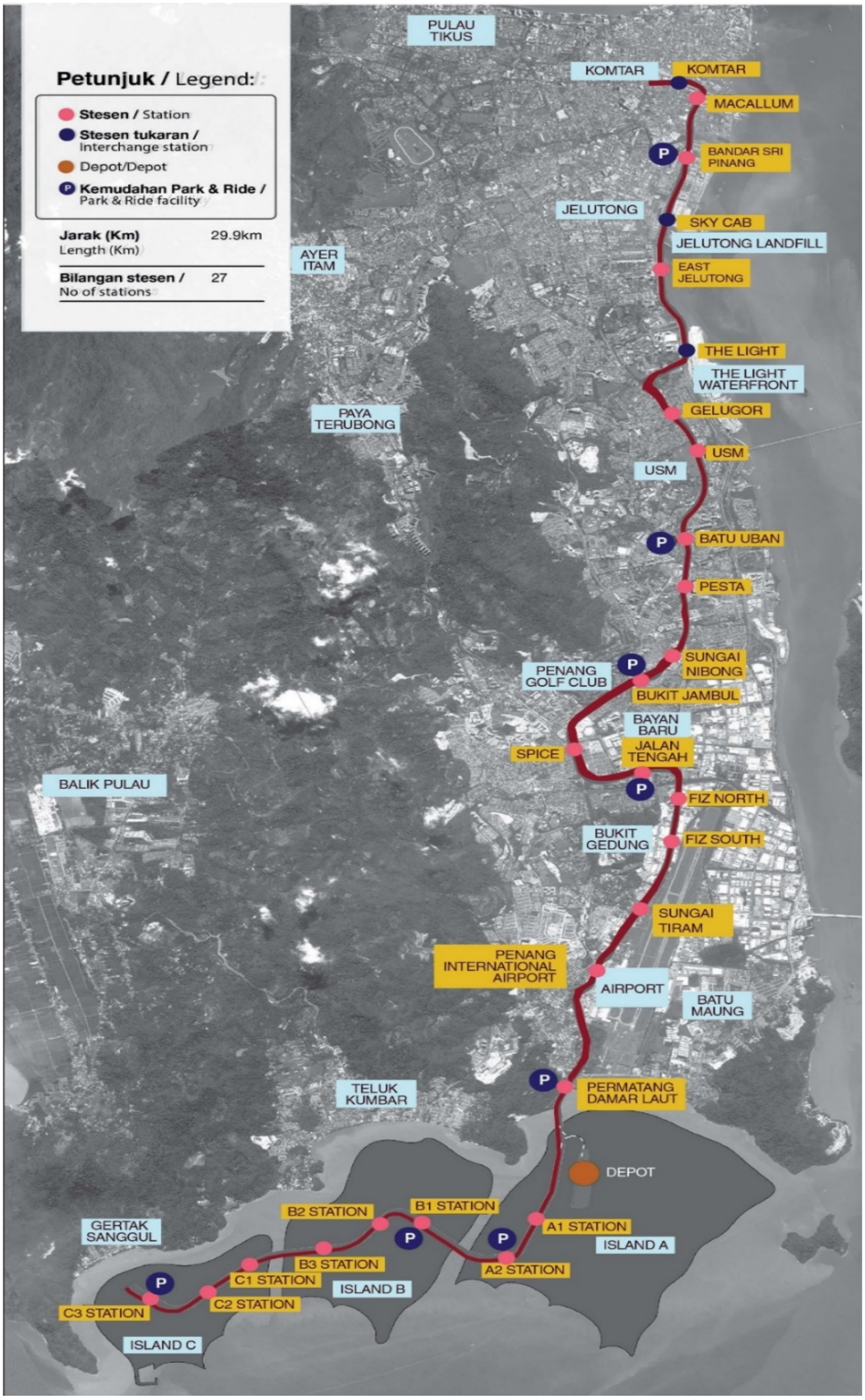


Figure 2-7 Proposed LRT Penang

2.1.4 Conclusion

Under the Penang Transport Master Plan, the highway improvement plan has identified and described a series of new road proposals. The need for these new roads has been demonstrated as part of the strategy development activity. On the basis of that, this functional role reflects the future importance of each highway to each road user. Figure 2.8 below is the status of highway/road network proposals outlined in the PTMP, that has been constructed and would be constructed in the future. Table 2.2 shows the implementation year for each of the public transportation plan.

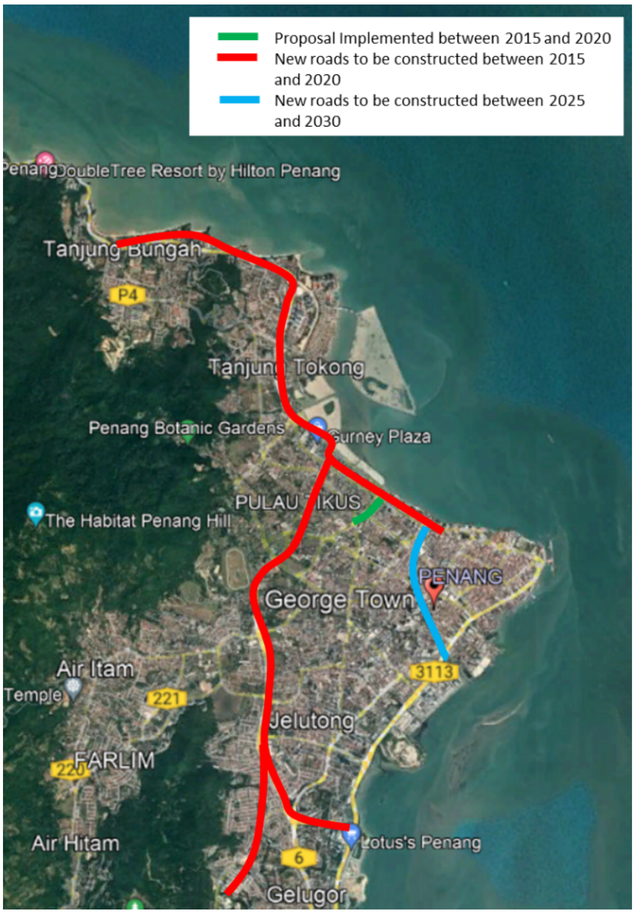


Figure 2-8 Timeline of Road Network Development

Table 2-2 Timeline of Public Transport Planning

	2012	2015	2020 2030
	Stabilize and Plan	**Reorganize Bus Network**	**Implement Full Strategy Measures**
Network Management	Set up public transport task force to plan, regulate and oversee.	Formalize role of task force.	Oversee implementation and operation. Set policy and monitor performance.
Network Planning and Implementation	Stabilize operations, introduce new service, commence pilot core route / feeder routes.	Reorganize buses into core, feeder and other services. Introduce commuter rail, upgrade ferry.	Progressively replace core bus routes with Trams / Bus Rapid Transit. Add new ferries.
Network Accessibility	Improve bus stop access, implement UNDP Study Accessibility Schemes.	Upgrade pedestrian regime, maximize feeder bus access, introduce primary Park and Ride sites.	Complete Park and Ride network, review and improve network accessibility.

	2012	2015	2020	2030
Network Awareness	Provide timetable information at bus stops. Improve mapping. Start mobile phone services.	Increase real time information services. Increase overall public transport awareness.	Expand real time service, continue awareness initiatives.	
Pilot Schemes	Reorganize bus service in Air Itam corridor in core route and feeder service.	Introduce Tram in Georgetown – airport corridor.	Introduce Bus Rapid Transit in Bayan Lepas areas.	

2.2 Penang Green Transport Plan

The Penang Green Transportation Plan (PGTP) serves only as guidance for establishing action plans (scoping) and a framework towards achievement of Green Transportation and Green City as outlined below:

i. Aiming at a significant reduction of road transport CO2 emission.
ii. Promotion of walking, cycling and public spaces through greening and beautification and providing shade.
iii. Making the city more attractive for tourists by easing moving around.
iv. Enhancing the livability for all citizens.
v. Shifting the focus from a city for cars to a city for people.

The objective of PGTP study is to set out a framework towards a greener urban transport system on Penang Island and to identify potential green transportation projects (scoping). The PGTP's main focus is on an action plan for green transportation projects for the short- and medium-terms involving:

i. Non-Motorized Transport, including Street Design, Traffic Calming and Public Spaces
ii. Public Transport
iii. Parking Management
iv. Electrification Vehicle Fleet (EV)

2.2.1 Approach Towards a Greener Transport System

To achieve a greener transport system and green city, the following approach needs to be considered:

i. Working on a significant reduction of road transport emissions and pollution.
ii. Promotion of walking, cycling and public transport by creating appropriate facilities.
iii. Creating better and more attractive public spaces through greening and beautification.
iv. Making the city more attractive for tourists by easing the way moving around.
v. Enhancing the livability of the city for all its residents.
vi. Transforming a city for cars into a city for people.
vii. Creating a Green City by moving towards Green Transportation.

The PGTP is based on three (3) thematic areas to create a people-oriented city, to provide a better-quality public transport service and to manage car-use, as shown in Figure 2-9.

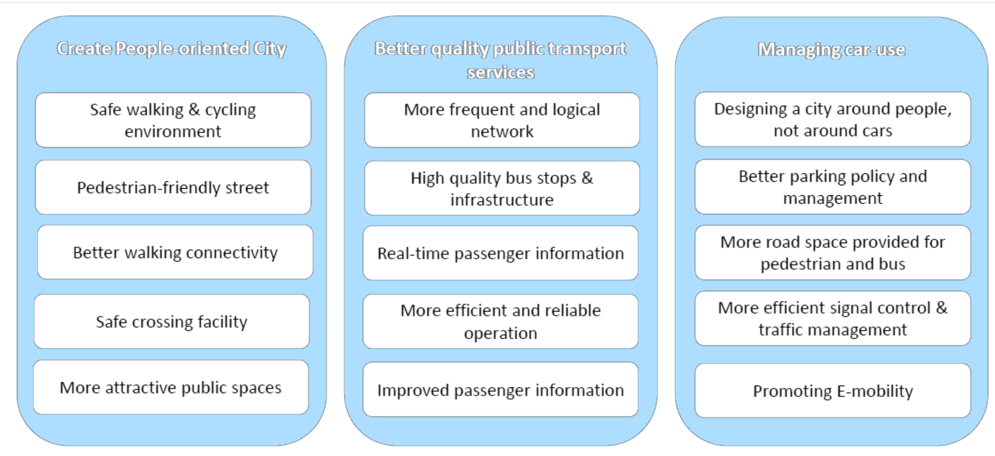


Figure 2-9 PGTP Thematic Areas

Green transportation or sustainable transportation comprises of modes of transportation that do not depend on diminishing natural resources. Lesser numbers of people travelling by car will reduce emissions. Within the framework of the PGTP study, potential green transportation projects are identified as follow:

i. Non-motorized transport and urban street design
ii. Public transport
iii. Parking
iv. Traffic management
v. E-Mobility

2.3 PGTP Project Packages

2.3.1 Non-Motorized Transport and Street Design

The PGTP has identified that more space for pedestrian and cycling at the Georgetown Heritage Site is necessary. Walking should play an important role in supporting the Heritage Site of Georgetown. Although walking is in principle well supported by the block configuration of streets and five foot-way concept, nowadays walking around in Georgetown is hampered by blocked walkway, parking of cars and motorcycles, and traffic. Figure 2-10 below is the summary of the non-motorized transport plan and proposal adopted from the Georgetown Heritage Site Special Area Plan.

Current Condition	• The walkability of the city is poor because of the poor quality of the walkways. • Pedestrian crossing is limited and the design of intersection often does not take pedestrian facilities into consideration. • The waiting time for pedestrians at the traffic light is very long. •Not more than 1% of people use bicycle. • Most of the bicycle routes do not have dedicated lanes. • The design of bicycle lane is often of poor quality. • The painted bicycle lanes are not respected by motorists and often violated.
Target	• To achieve active mobility by the year 2025
Initial Proposal	• To provide safe and user-friendly pedestrian walkways and bicycle routes along the Heritage areas.

Figure 2-10 Summary of Non-Motorized Transport Plan

2.3.2 Public Transport

To achieve a greener Penang and improve the quality of life in the city, public transport needs to be enhanced. Public transport efforts are to be enhanced with the following strategies depicted in the PGTP, as summarized in Figure 2-11:

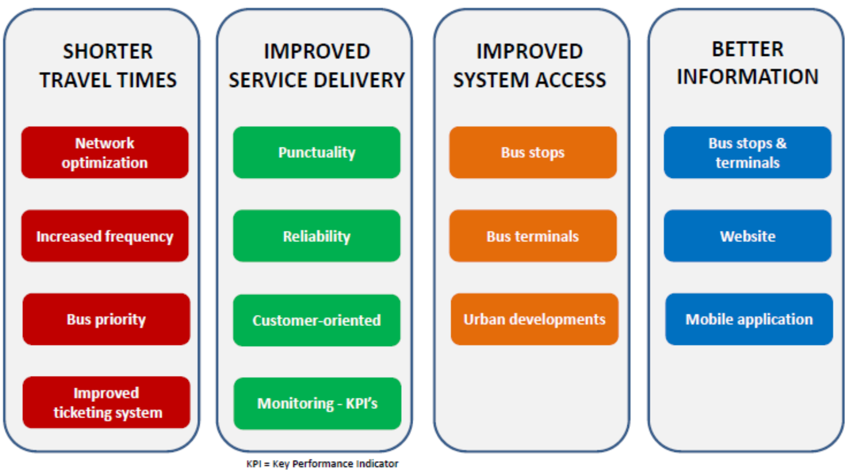


Figure 2-11 PGTP Strategies for Improving Public Transport

Figure 2-12 provides a summary of the non-motorized transport plan and proposal adopted from the Georgetown Heritage Site Special Area Plan.

Current Condition	• A marginal role as estimated mode share of 3% - 4% are observed. • The ridership for public transport is declining. • Public transport in Penang is rarely used by those who own a car. • The route network is not managed properly. • The route is long and complicated. • The one-way circulation within the CBD has affected the bus routes. • No detailed overall map of the route network exists. • No timetables. • Low frequency for urban services (30 – 45 minutes). • Unreliable because of congestion. • Incomplete bus lanes. • Lack of unified design and without proper lanes marking. • Very long dwell times. • Long lay-over times, low productivity. • Buses do not show their route numbers.
Target	• To achieve a variety of public transport services with broader network by the year 2025.
Initial Proposal	• To build a Tram network around Heritage areas. • To improve bus frequency around the Heritage areas. • To propose bettter ferry-taxi services.

Figure 2-12 Summary of Non-Motorized Transportation Plan

2.3.3 Parking

On-street parking is prevalent in Penang which requires to be regulated and relocated to enhance better street usage in lieu of green transportation. The crucial element for parking management is to create more attractive spaces for pedestrians and bicyclists. The PGTP has suggested the following strategies on parking, as shown in Figure 2-13.

Current Condition	• Not very effective in terms of regulation. • Parking discipline of drivers is very poor. • Illegal parking in the Heritage Area. • Regulated hours appear to be insufficient. • Parking fines are difficult to collect. • Shortage of on-street parking and an oversupply of off-street parking.
Target	• To achieve complete smart parking system by the year 2025.
Initial Proposal	• To improve smart parking within the Georgetown areas. • To widen the areas that use Penang smart parking. • To build a live (real-time) electronic/digital signboard.

Figure 2-13 Summary of Parking Plan

2.3.4 Traffic Management

Improvement of traffic management at intersections with the aim to reduce waiting times and congestion is endorsed by the PGTP.

The PGTP suggests that a technical study by traffic management experts should be initiated to:

i. Identify measures for improvement of traffic lights in combination with the geometric design at intersections.

ii. Study the options for implementing an Integrated Traffic Management System for Penang by applying Intelligent Transport Systems (ITS) applications and identifying the cost and benefits.

2.3.5 Electric Mobility

The market for Electric Vehicles (EV) has grown rapidly worldwide, in particular the deployment of electric buses is growing fast. The implementation of electric buses is possible through special financial support programs of the national government. The pace of transition from fossil fuel-powered private cars to EVs is highly dependent on local conditions. The PGTP outlines the main conditions below:

i. The extent to which the national and local governments provide financial incentives to promote a shift towards EVs and/or penalize polluting cars.

ii. The difference in costs - Total Costs of Ownership (TCO)- between owning and using a petrol/diesel vehicle and an EV (mainly the difference in energy costs).

iii. The availability of battery charging facilities.

2.3.6 Conclusion

For green transportation to take place, some of the challenges need to be handled accordingly. One of the challenges Penang Island faces is that it is currently a predominantly car-oriented island, more than 85% of households owned a private vehicle and only 3-4% of trips are made by public transport. The local authority needs to support and implement the policy to include green components for future development.

The local authority may also plan attractive alternative transport modes for car users by offering safe and appropriate facilities for walking and cycling and improvement and expansion of the service level of public transport. Table 2-3 shows the indicative planning schedule by the Penang Green Transport Plan.

Table 2-3 Indicative Planning by Penang Green Transportation Plan

	Project Description	2020				2021				2022				2023				2024			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
A. WALKING, CYCLING AND PUBLIC SPACE																					
A1	More space for pedestrians and cycling - George Town																				
A2	Transformation Loring Love																				
A3	Transformation Armenian Street																				
A4	Transit Mall Get Lebuh																				
A5	Pedestrian walkway Swettenham Pier - Heritage Zone																				
A6	Pedestrian connection Heritage Zone and KOMTAR																				
A7	Bike-sharing system expansion																				
A8	Northern Coastal Bicycle Route																				
B. PUBLIC TRANSPORT																					
B1	Improved bus route network and service level																				
B2	Bus priority measures																				
B3	Reduction of stopping times at bus stops																				
B4	Bus stop enhancement program																				
B5	Improvement of passenger information																				
B6	Improvement bus terminal and bus stops KOMTAR																				
B7	Improvement Weld Quay Bus Terminal																				
B8	Improved bus stop accessibility at attraction points																				
B9	Improvement operations performance Rapid Penang																				
B10	Improvement bus service Airport – George Town																				
B11	Improvement Ferry Services																				
C. PARKING																					
C1	Adoption and implementation of Parking Policy																				
C2	Reduction on-street parking Heritage Zone																				
C3	Dedicated parking locations for coaches (tourist buses)																				
C4	Improved P&R facilities and services																				
D. TRAFFIC MANAGEMENT																					
D1	Traffic lights and Traffic management																				
E. ELECTRIC MOBILITY – E-VEHICLES																					
E1	Adoption of Electric Mobility Policy																				
E2	Introduction of Electric buses public transport [1]																				
E3	E-vehicles Penang State and Municipalities																				
E4	Taxi's, ride hail servcies and rental cars E-vehicles																				
E5	Public charging facilities E-vehicles																				
E6	Emission standards George Town Heritage Zone																				

3. TRAFFIC SURVEY

3.1 Survey Introduction

To develop a representative simulation of transportation in Georgetown for this study, accurate and comprehensive multi-modal transport data is required to be collected across the network with a combination of on-site video capture and remote GPS data collection.

Survey data came from two sources for this project, namely video traffic surveys and GPS data collection. On-site video traffic surveys allow us to capture an accurate and highly detailed snapshot of traffic movement around every junction and parking area, disaggregated across each peak period. GPS data collection gives us a 'birds eye view' of movement across the network, aggregated into weeks or months of travel patterns, travel times and speeds across a collective group of user experiences. Bringing these two data sources together gives us an accurate picture of transport to develop and calibrate a simulation model that is representative of on-site conditions.

The following sections describe the details of survey methodology for each type of survey.

3.2 Traffic Surveys

For video-based traffic surveys, classified movement counts were conducted during peak morning periods (7:00am to 10:00am) and peak afternoon/evening periods (4:30pm to 7:30pm) for the following dates:

- 9 November 2021 (Tuesday),
- 10 November 2021 (Wednesday), and
- 11 November 2021 (Thursday)

'Classified' refers to counting separately the different vehicle classes including motorbikes, cars, light goods vehicles, heavy goods vehicles, buses etc. The following sections outline the survey specifications for this study.

3.2.1 Classified Vehicle Count Surveys

The specifications for the classified vehicle count survey are shown in the table below. All junction surveys were disaggregated into the various classifications for each turning movement at the junction separately.

Table 3-1 Classified Vehicle Count Survey Specifications

Item	Specifications
Survey Locations	Junctions shown in Figure 3-1
Survey Classifications	Cars, Taxis, Motorcycles, Light Goods Vehicles & Small Vans, Heavy Goods Vehicles with 3 axles and above, Buses
Aggregation	All counts to be in 15-minute intervals
Pedestrians and Cyclists	All junction surveys to include pedestrian and cyclist counts across each junction arm
Queues	Maximum observed queue lengths should be recorded for each junction approach in 15-minute intervals
Signal Phase and Timings	Junction signal phase and timings should be taken from video recordings of the signal for a minimum of continuous 15 minutes in each one-hour of junction survey. Recorded signal phases, timings and videos are required to be submitted.
Survey Days	9 November 2021 (Tuesday), 10 November 2021 (Wednesday), and 11 November 2021 (Thursday);
Survey Time Periods	07:00 – 10:00 and 16:30 – 19:30

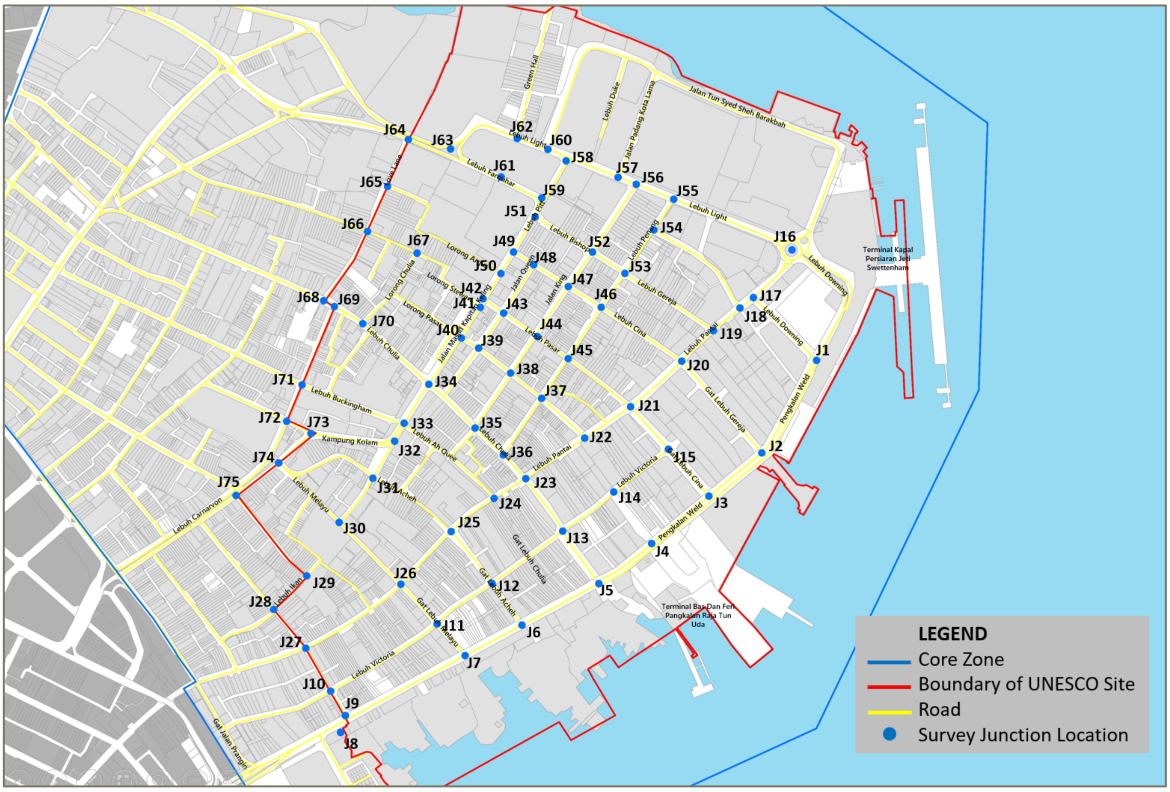


Figure 3-1 Classified Vehicle Count Survey Junctions

The survey has been carried out from 9 November 2021 to 11 November 2021. It is observed that during this week traffic volume has picked up following the ending of MCO[3] period in Penang state. All junctions part of survey are presented in Appendix 1.

3.2.2 Unclassified Pedestrian / Cyclist Count Surveys

During the same date and time duration of vehicle count survey, number of pedestrians and cyclists crossing the identified junctions was also surveyed to provide a comprehensive picture of the pedestrian and cyclist demand throughout the study area.

Pedestrian and cyclists were recorded at crossing point throughout the road network when they were crossing the street. The number for pedestrians and cyclists is unclassified, which means the results are in single combined class without further differentiation of user profiles (such as students, elderly, etc.). This approach was selected as it provides sufficient basis to evaluate the impact of pedestrian and cyclist movement to an overall traffic network, which suits the purpose of this report.

Further details of the unclassified pedestrian / cyclist survey are presented in the table and figure below.

[3] MCO refers to Movement Control Order, a directive from the Malaysian central government restricting movement of persons within or between states to limit the spread of Covid-19.

Table 3-2 Unclassified Pedestrian / Cyclist Count Survey Specifications

Item	Specifications
Survey Locations	Pedestrians and cyclists crossing each arm of junctions shown in Figure 3.2
Survey Classifications	Single Class
Aggregation	All counts to be in 15-minute intervals
Survey Days	9 November 2021 (Tuesday), 10 November 2021 (Wednesday), and 11 November 2021 (Thursday);
Survey Time Periods	07:00 – 10:00 and 16:30 – 19:30

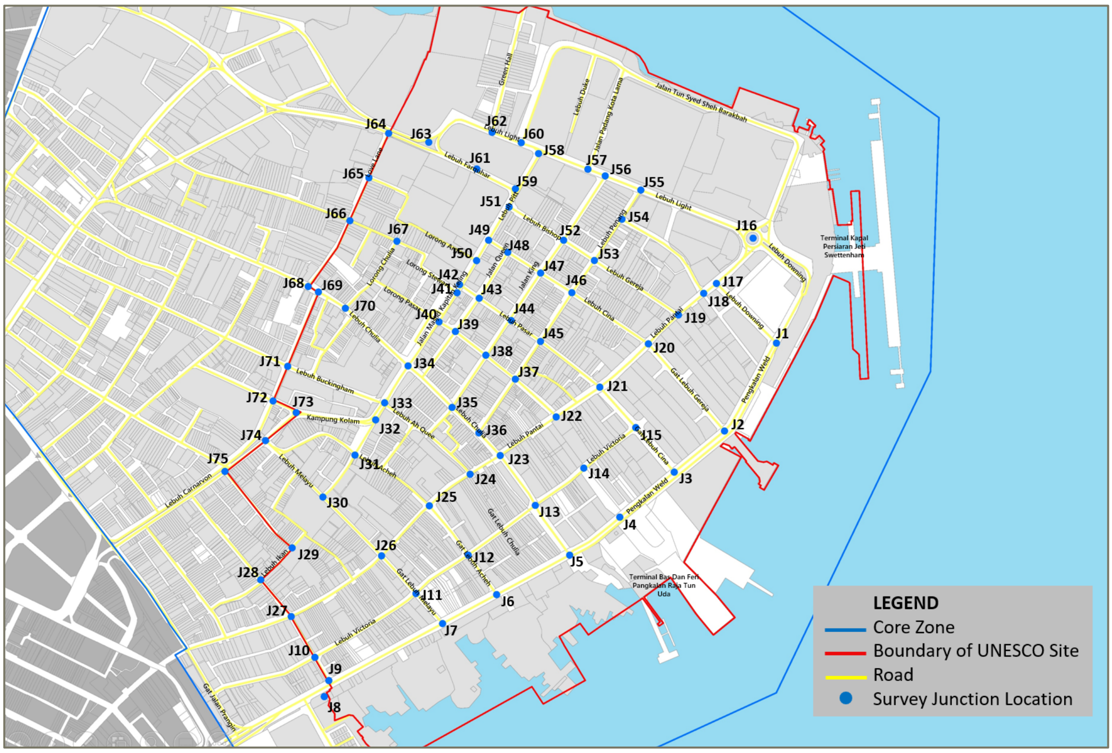


Figure 3-2 Unclassified Pedestrian / Cyclist Count Survey Junctions

3.2.3 Junction Layout and Signal Surveys

For traffic analysis and modelling, an accurate representation of network inventory is vital to the realistic reproduction of traffic conditions on site.

As a part of this survey exercise, a full record inventory has been made of existing junction and road layouts, turning movements allowed or banned, traffic signal information, traffic lane configurations, bus stops, internal parking, and public transport facilities, waiting and loading restrictions, and general site layout.

Junction layout and traffic signals have been pre-collected and verified on-site with actual situation during the site works from 9 to 11 November 2021. The following figure shows the junction layout before on-site verification. In addition, the junction layout and network inventory information also include the direction of travel along roads within the study are, which are shown in the figure below.

Figure 3-3 Junction Layout (Pre-collected before On-site Verification)

In addition, the junction layout and network inventory information also include the direction of travel along roads within the study are, which are shown in the figure below.

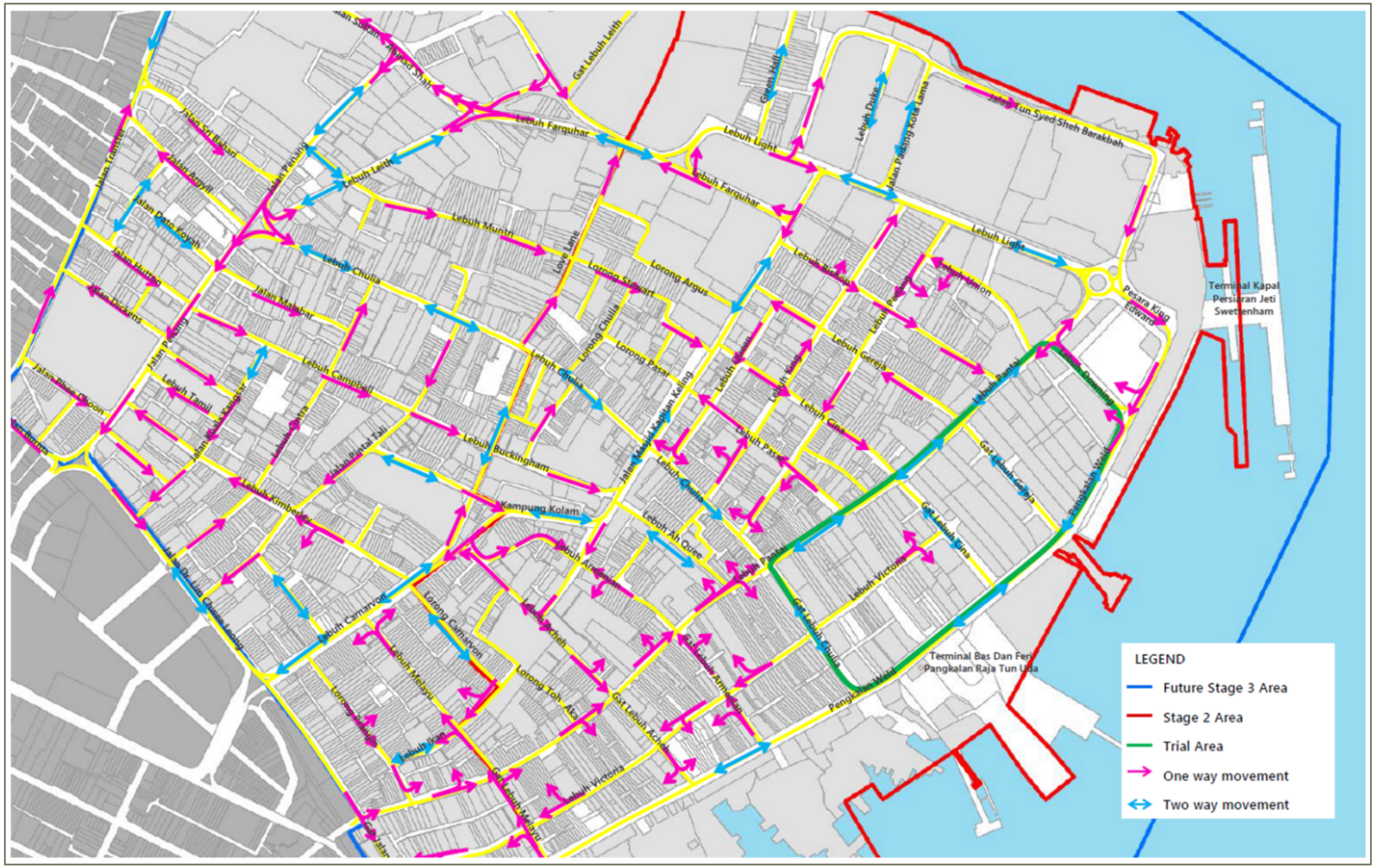


Figure 3-4 Road Movement Direction

Further survey results with on-site verification are presented below.

3.2.4 Queue Length Surveys

Together with classified vehicle traffic counts, queue length counts were also conducted during the site survey.

Queue length is an important indicator of junction performance in an urban traffic scenario. Vehicle queue is formed from delays at junction including geometry delays and signal delays. It is also a reflection of the reaction time drivers has toward traffic regulations.

Queue length information was collected at the following locations during the site survey.

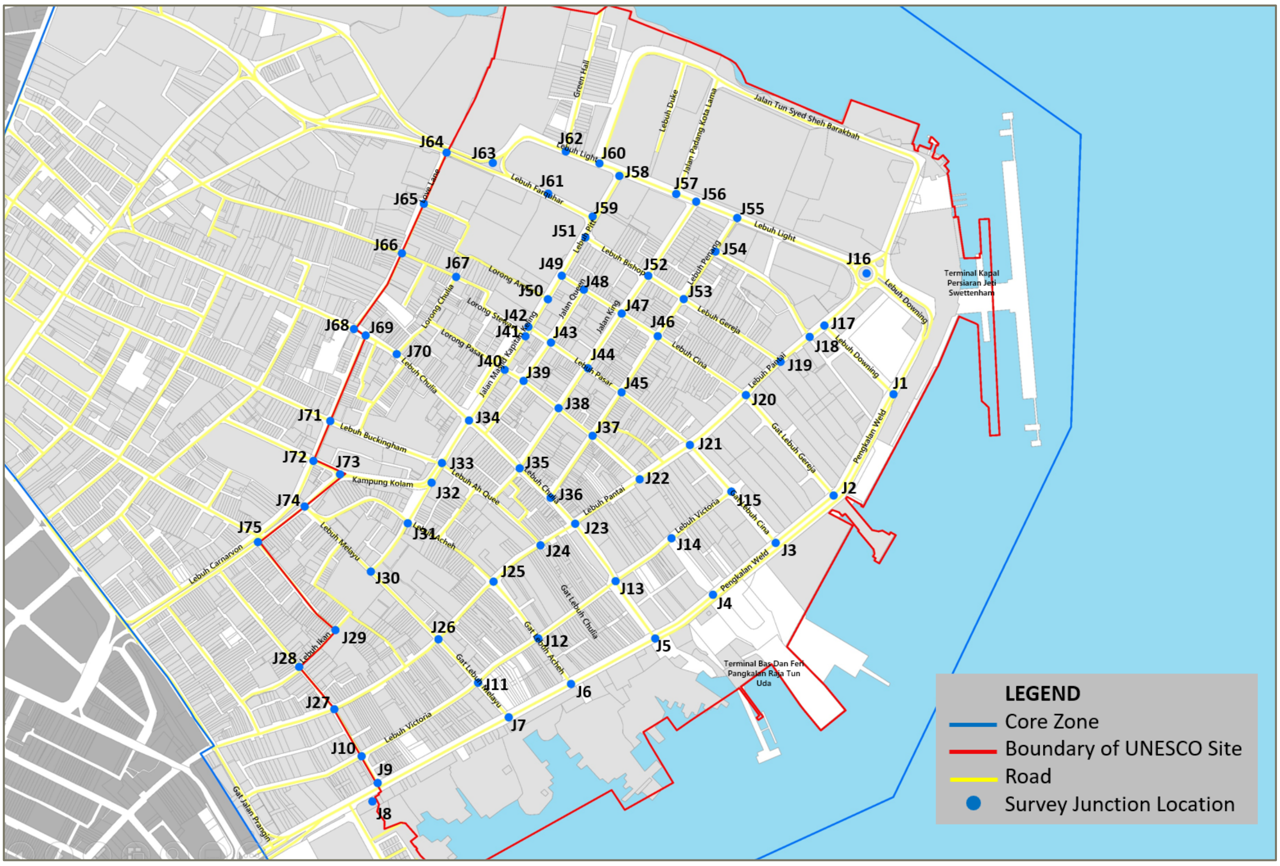


Figure 3-5 Queue Length Survey Junctions

Further survey results and their usage for site calibration were presented below.

3.3 Parking Surveys

Parking surveys have been conducted at both on-street and off-street parking facilities. On-street parking was be classified by street and midblock section. Illegal parking was also recorded. The parking survey is to gain an understanding of not just traffic flowing through the historical center of Georgetown, but also parking behavior within the study area.

For on-street parking, the following information is planned to be captured:

A. On-street Photos by survey team: Car Park Occupancy by one-hour segments of all on-street parking across the survey period.
B. On-street video surveys: Sampled arrival/departure counts and parking dwell time, by vehicle classification, at selected locations, for a period of 15 minutes within each one-hour survey period.

The following figure identifies the on-street (yellow) parking areas to be included within the parking occupancy survey (A). Selected locations for on-street parking arrival, departure, dwell time survey (B) are also indicated in purple boxes in the figure below.

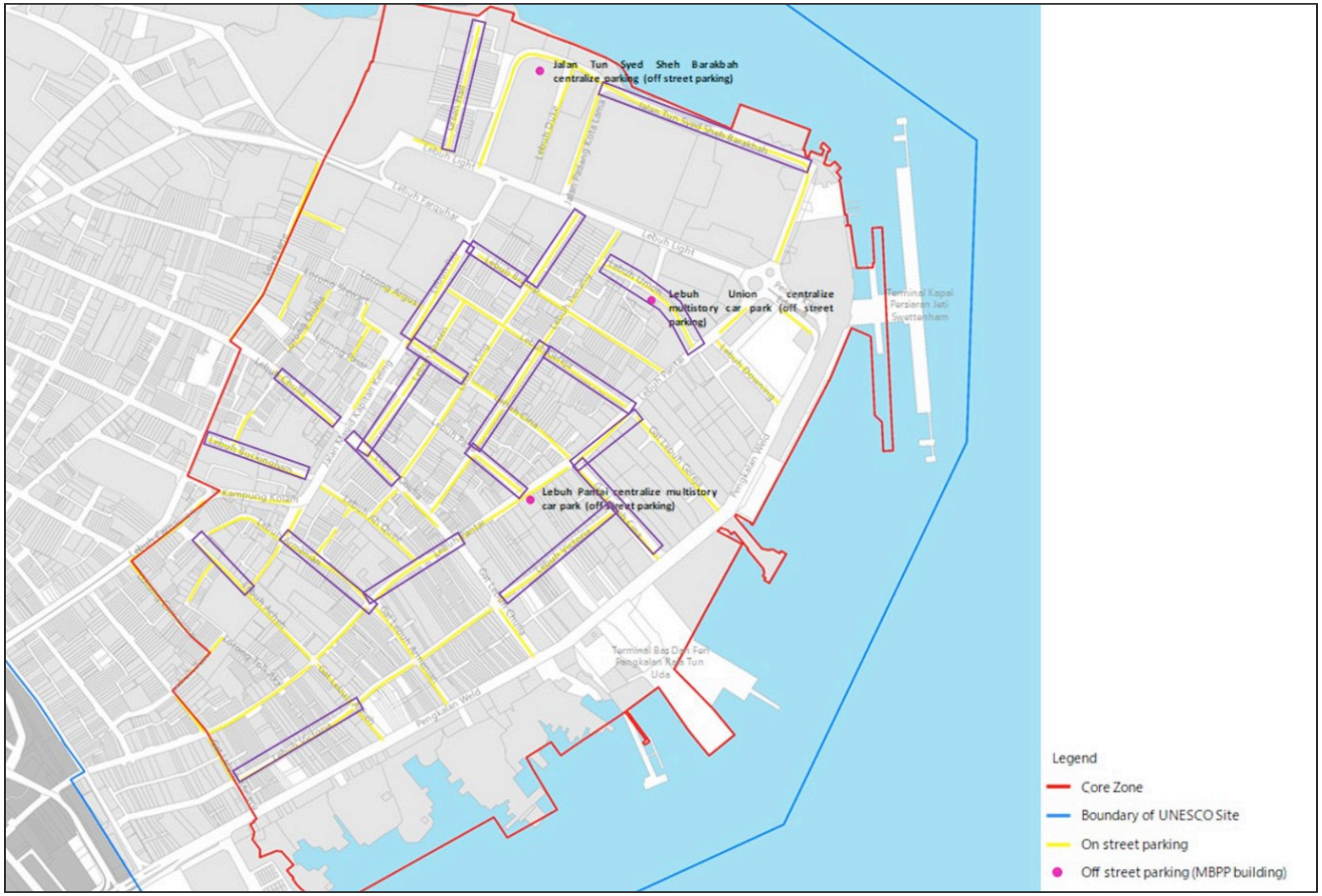


Figure 3-6 On-street Parking Survey Locations

Parking surveys have been conducted in conjunction with the surrounding junction surveys.

For off-street parking, the following information was collected:

A. Through video recording: Arrival and departure counts, by vehicle classification
B. Car Park Occupancy across the survey period

The following figure identifies the off-street parking areas marked in pink points that are to be included within the parking occupancy survey.

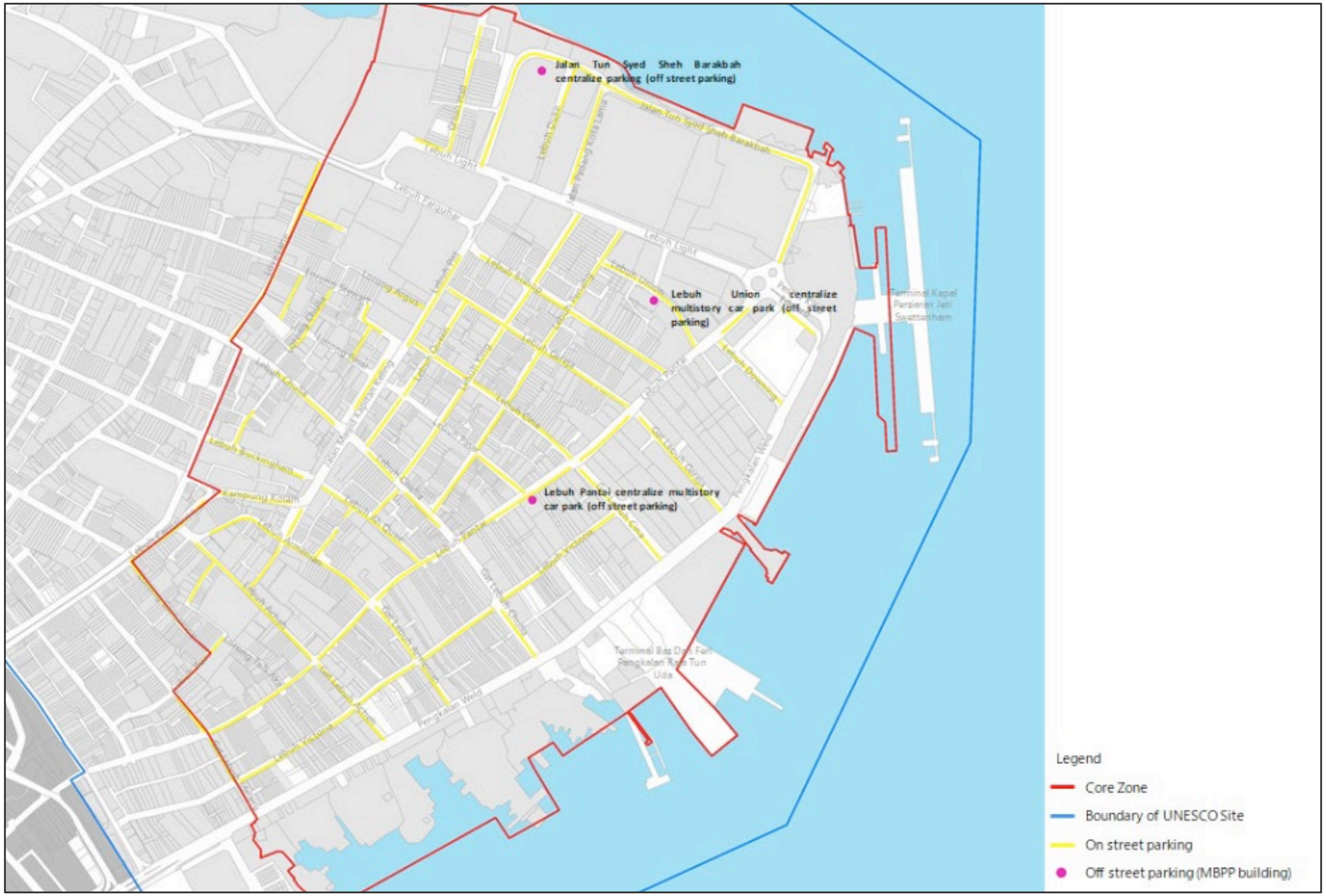


Figure 3-7 Off-street Parking Survey Locations

3.4 Origin-Destination Data Survey

GPS data to be collected for this study refer to historic data and real time data within the road network based on GPS location of vehicles on-site. This data was collected and aggregated by GPS navigation providers such as TomTom. There are two types of GPS data to be used for this study, which are travel pattern data and speed data.

Using travel pattern data, in-depth information about the distribution of the motorized traffic from various locations can be extracted to calibrate the transport models and simulations, and to better understand travel patterns.

Through speed data, bottleneck analysis of the road network can be assessed to identify significant speed reductions during peak hours, and to identify potential traffic safety issues.

The GPS data planned to be acquired to develop and calibrate the micro-simulation model includes the following components:

- Origin-destination travel pattern data; and
- Travel time and speed data

3.4.1 Origin-Destination Travel Pattern Data Collection

Origin-Destination Travel Pattern Data can be used to approximate the travel patterns within the model area for more accurate representation of the on-site condition. To generate this data, results from an online data platform named "TomTom O/D Analysis" was used to provide trip investigation based on a high volume of location data.

TomTom O/D Analysis uses advanced algorithms to analyze anonymized Floating Car Data (FCD) from 600+ million connected devices – providing the project with the authoritative view of what's happening on the road. TomTom gathers real-time FCD by combining measurements of existing infrastructure with signals from anonymous TomTom connected GPS devices. TomTom also archives this data to create a historical traffic database.

All major entry and exit points to the study area were used for collection of origin-destination travel pattern data for this simulation model. An example of the data collection process is shown in the figure below.

Figure 3-8 Example of GPS Data Collection Process

3.4.2 Travel Time & Speed Data Collection

Travel Time & Speed Data allows the modelled results to be compared with real-life data for further model calibration. Within this data, two types of analysis are used for this study:

- Route Analysis: to define a specific route and generate average speeds, average travel times and sample size (number of vehicles that traversed a segment).
- Speed & Density Analysis: focused analysis on sample size (number of vehicles that traversed a segment), including speed and density of the sampled vehicles.

Major arterial roads within the study area were used for data collection of travel time and speed information. The travel time and speed data collection occurred at the same time as the traffic survey to ensure consistency between datasets.

Datasets were compiled to aggregate data analyzed over one day.

3.5 Model Traffic Survey Input and Stage 2 Survey Update

As proposed and presented to the client, traffic counts at existing junctions were conducted to obtain the current background road network demand.

Below junctions are considered for full area Vissim study.

- Junction 1: Pengkalan Road/Lebuh Downing
- Junction 2: Pengkalan Road/Gat Lebuh Gereja
- Junction 3: Pengkalan Road/Gat Lebuh China
- Junction 4: Pengkalan Road/Gat Lebuh Pasar
- Junction 5: Pengkalan Road/Gat Lebuh Chulia
- Junction 6: Pengkalan Road/Gat Lebuh Armenian
- Junction 7: Pengkalan Road/Gat Lebuh Acheh
- Junction 8: Pengkalan Road/Lintasan Pengkalan 1
- Junction 9: Pengkalan Road/Gat Lebuh Melayu
- Junction 10: Lebuh Victoria/ Gat Lebuh Melayu
- Junction 11: Lebuh Victoria/ Gat Lebuh Acheh
- Junction 12: Lebuh Victoria/ Gat Lebuh Armenian
- Junction 13: Lebuh Victoria/ Gat Lebuh Chulia
- Junction 14: Lebuh Victoria/ Gat Lebuh Pasar
- Junction 15: Lebuh Victoria/ Gat Lebuh China
- Junction 16: Lebuh Pantai/ Pesara King Edward
- Junction 17: Lebuh Pantai/ Lebuh Downing
- Junction 18: Beach Street/ Lebuh Union
- Junction 19: Beach Street/ Bishop Street
- Junction 20: Beach Street/ Gat Lebuh Gereja
- Junction 21: Beach Street/ Gat Lebuh China
- Junction 22: Beach Street/ Gat Lebuh Pasar
- Junction 23: Beach Street/ Gat Lebuh Chulia
- Junction 24: Beach Street/ Lebuh Al Quee
- Junction 25: Beach Street/ Gat Lebuh Armenian
- Junction 26: Beach Street/ Gat Lebuh Acheh
- Junction27: Beach Street/ Gat Lebuh Melayu
- Junction 28: Lorong Ikan/ Lebuh Melayu
- Junction 29: Lorong Toh Aka/ Lorong Carnavon
- Junction 30: Lebuh Acheh/Lebuh Cannon
- Junction 31: Lebuh Acheh/Lebuh Armenian
- Junction 32: Jalan Masjid Kapitan Keling/Jalan Kampung Kolam
- Junction 33: Jalan Masjid Kapitan Keling/Jalan Buckingham
- Junction 34: Jalan Masjid Kapitan Keling/Chulia Street
- Junction 35: Chulia Street/Lebuh King
- Junction 36: Chulia Street/Lebuh Penang
- Junction 37: Lebuh Pasar/Penang Street
- Junction 38: Lebuh Pasar/ Lebuh King
- Junction 39: Lebuh Pasar/ Queen Street
- Junction 40: Jalan Masjid Kapitan Keling/ Lebuh Pasar
- Junction 41: Jalan Masjid Kapitan Keling/ Lorong Stewart
- Junction 42: Jalan Masjid Kapitan Keling/ Lebuh China
- Junction 43: Lebuh China/Queen Street
- Junction 44: Lebuh China/Lebuh King
- Junction 45: Lebuh China/Lebuh Penang

- Junction 46: Lebuh Gereja /Lebuh Penang
- Junction 47: Lebuh King /Church Street
- Junction 48: Church Street/Queen Street
- Junction 49: Jalan Masjid Kapitan Keling/ Church Street
- Junction 50: Jalan Masjid Kapitan Keling/ Lorong Argus
- Junction 51: Jalan Masjid Kapitan Keling/ Bishop Street
- Junction 52: Bishop Street/Lebuh King
- Junction 53: Bishop Street/Lebuh Penang
- Junction 54: Lebuh Penang/Lebuh Union
- Junction 55: Lebuh Penang/Light Street
- Junction 56: Lebuh King/Light Street
- Junction 57: Lebuh Light/Jalan Padang Kota Lana
- Junction 58: Lebuh Light/Jalan Masjid Kapitan Keling
- Junction 59: Jalan Masjid Kapitan Keling/Lebuh Farquhar
- Junction 60: Lebuh Light/Jalan Tun Syed Sheh Barakbah
- Junction 61: Lebuh Farquhar/Local road
- Junction 62: Lebuh Light/Jalan Green Hall
- Junction 63: Lebuh Light/ Lebuh Farquhar
- Junction 64: Lebuh Light/ Love Ln
- Junction 65: Love Ln/Lorong Argus
- Junction 66: Love Ln/Mountri Street
- Junction 67: Lorong Stewart/Lorong Chulia
- Junction 68: Love Ln/Chulia Street
- Junction 69: Chulia Street/Lebuh Carnavon
- Junction 70: Chulia Street/Lebuh Chulia
- Junction 71: Lebuh Campbell/Lebuh Carnarvo
- Junction 72: Pesara Claimant/Lebuh Carnarvon
- Junction 73: Jalan Kampung Kolam/Lebuh Carnarvon
- Junction 74: Lebuh Carnarvon/Lebuh Acheh
- Junction 75: Lebuh Carnarvon/Lebuh Kimberley

The locations of surveyed junctions are shown in the figure below.

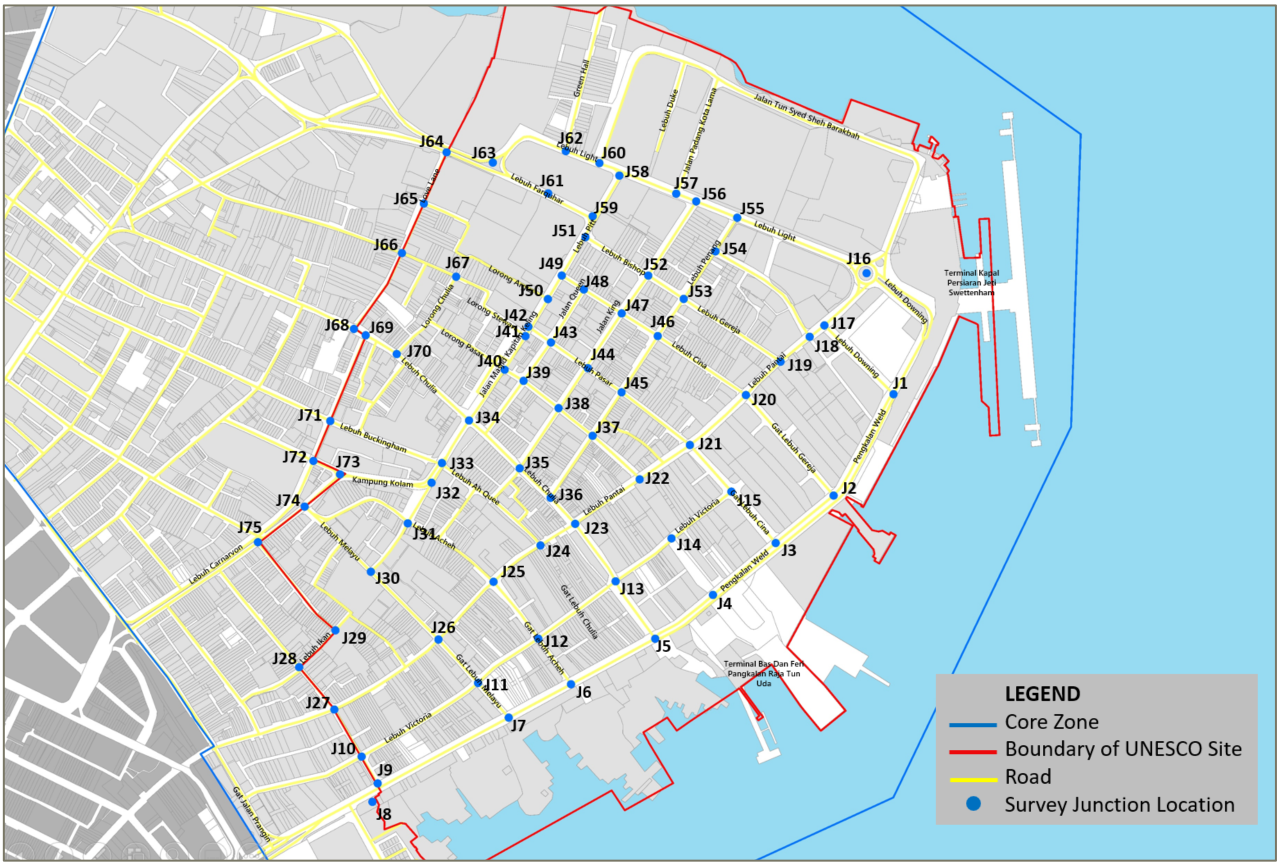


Figure 3-9 Existing Junctions Surveyed in Study Area

Traffic counts results were analyzed to determine the peak 60-minute periods within the morning and evening peak periods. All traffic flows were converted and expressed in Passenger Car Units (PCUs). PCUs are factors that convert different classification of vehicles to be equivalent to a typical car. The following PCU factors were used for the junction counts:

- Car: 1.00
- Taxi: 1.00
- Light Goods Vehicles (Lorry Kecil): 2.50
- Heavy Goods Vehicles (Lorry Besar): 3.00
- Bus: 3.00
- Motorcycle: 0.75

The peak hour traffic flows occurred during the times stated in the table below.

Table 3-3 Survey Peak Hour

Time of Day	Surveyed Time	Peak Hour Traffic
Weekday AM	07:00 to 10:00	08:15 to 09:15 (Traffic flows shown in Figure 3.10 to 3.14)
Weekday PM	16:30 to 19:30	17:00 to 18:00 (Traffic flows shown in Figure 3.15 to 3.19)

An additional survey was taken in May 2023 to collect the information needed to scale the traffic demand for Stage 2 modelling purposes. The following 11 junctions were surveyed and compared with the original surveyed volume.

- Junction 3: Pengkalan Road/Gat Lebuh China
- Junction 10: Lebuh Victoria/ Gat Lebuh Melayu
- Junction 13: Lebuh Victoria/ Gat Lebuh Chulia
- Junction 16: Lebuh Pantai/ Pesara King Edward
- Junction 20: Beach Street/ Gat Lebuh Gereja
- Junction 21: Beach Street/ Gat Lebuh China
- Junction 23: Beach Street/ Gat Lebuh Chulia
- Junction 34: Jalan Masjid Kapitan Keling/Chulia Street
- Junction 40: Jalan Masjid Kapitan Keling/ Lebuh Pasar
- Junction 59: Jalan Masjid Kapitan Keling/Lebuh Farquhar
- Junction 63: Lebuh Light/ Lebuh Farquhar

The table below provide the comparison of the traffic volume in & out of the surveyed area.

Table 3-4 11 Junctions Survey Volume Comparison

Peak Hour	Direction	Original Survey	Additional Survey
AM Peak	**Inbound**	6373 PCUs	6110 PCUs (-5%)
	Outbound	3869 PCUs	3663 PCUs (-4%)
PM Peak	**Inbound**	5922 PCUs	5561 PCUs (-6%)
	Outbound	4019 PCUs	4336 PCUs **(+8%)**

From the additional survey, no growth will be applied from the original surveyed volume for AM peak and an eight percent growth rate will be applied for PM peak.

For the respective peak hours within the surveyed timings, the corresponding traffic flow volumes (in PCUs) in the background road network are shown in the following figures.

Traffic diagrams like these are used to represent the traffic survey count data across the network with a geographic representation of intersection location. These diagrams assist in the development and calibration of the model.

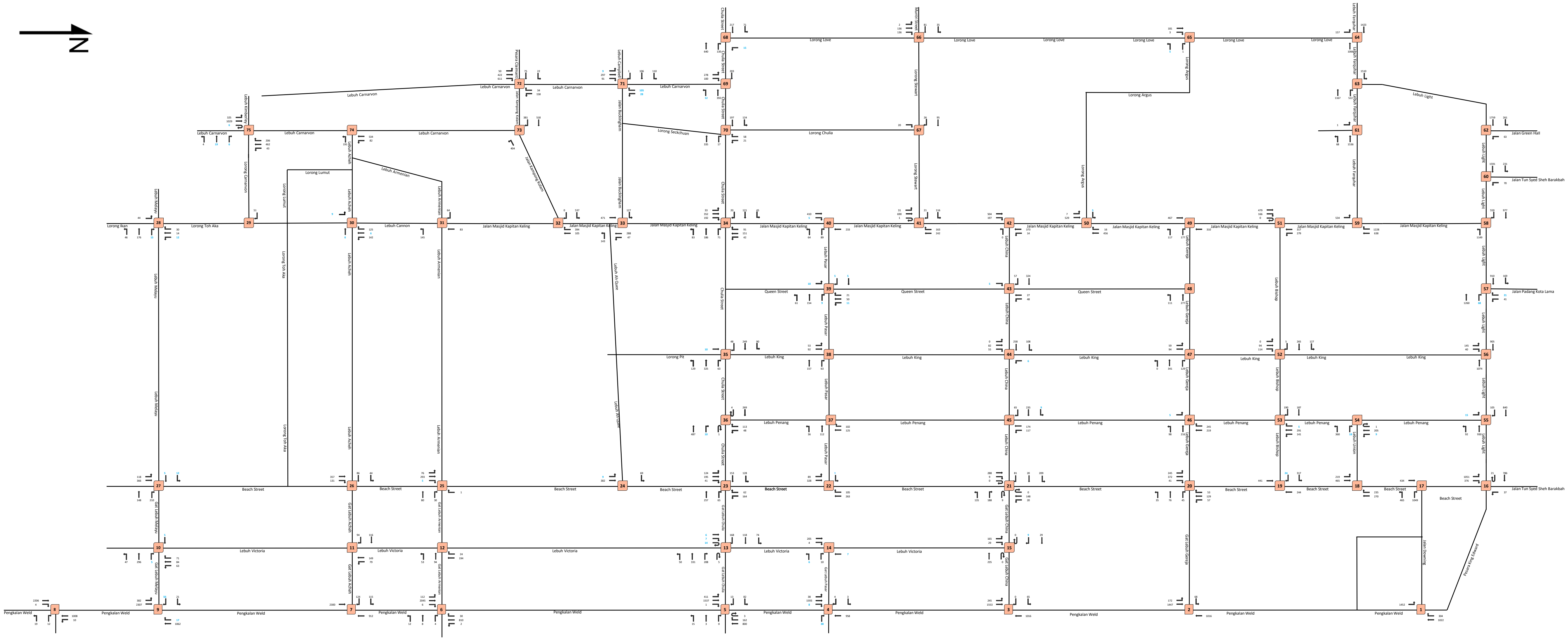


Figure 3-10 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Full

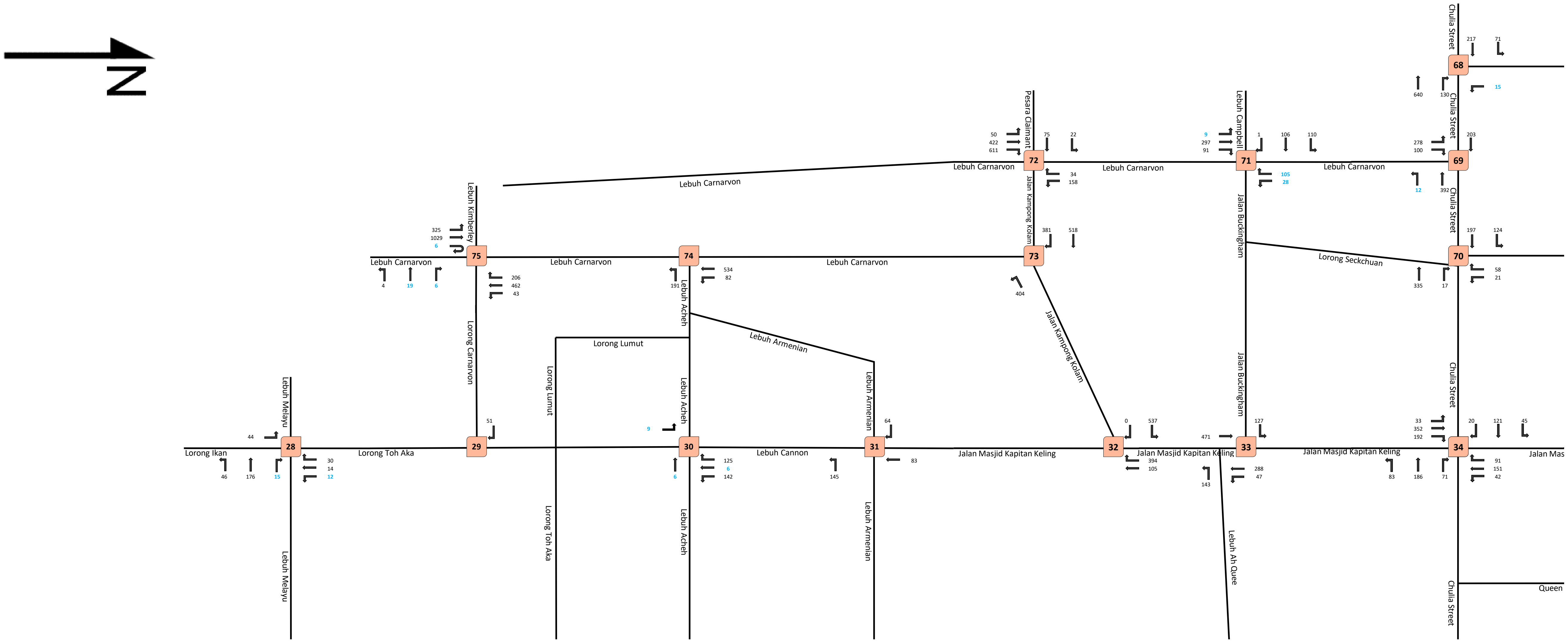


Figure 3-11 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Northwest Section

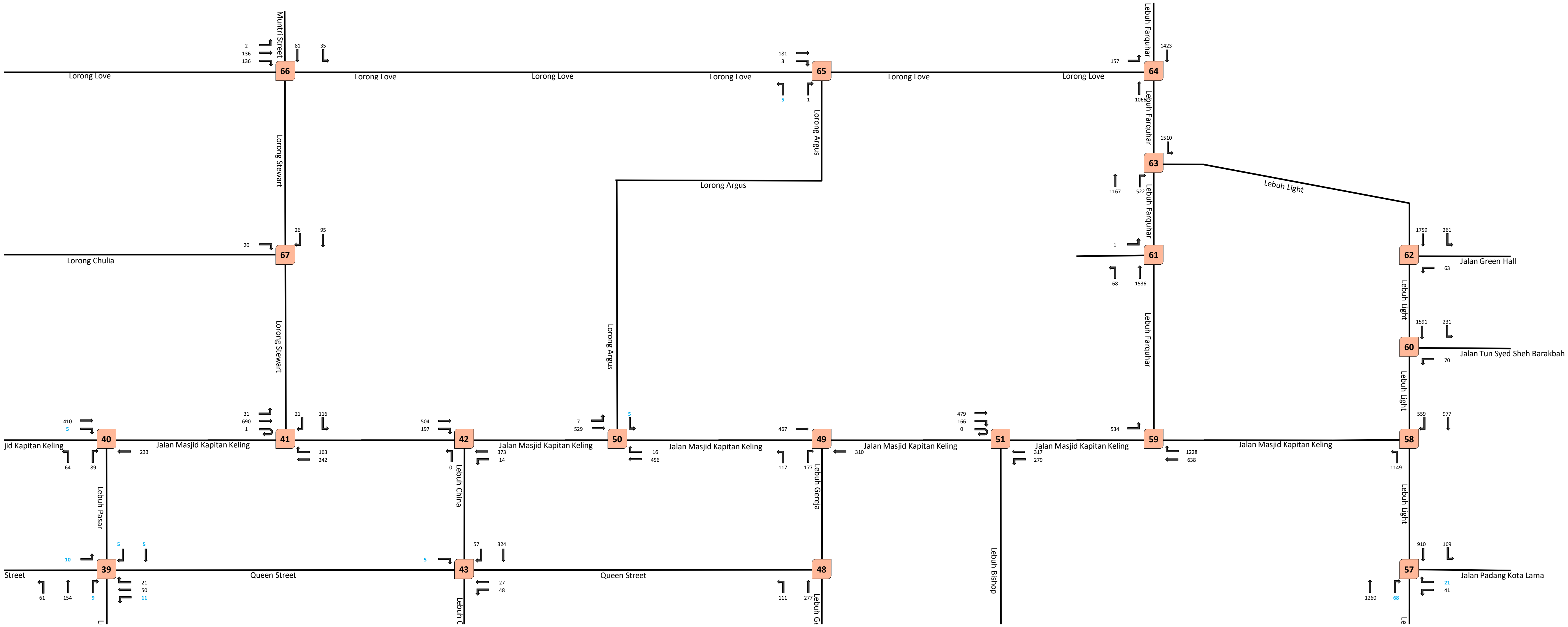


Figure 3-12 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Northeast Section

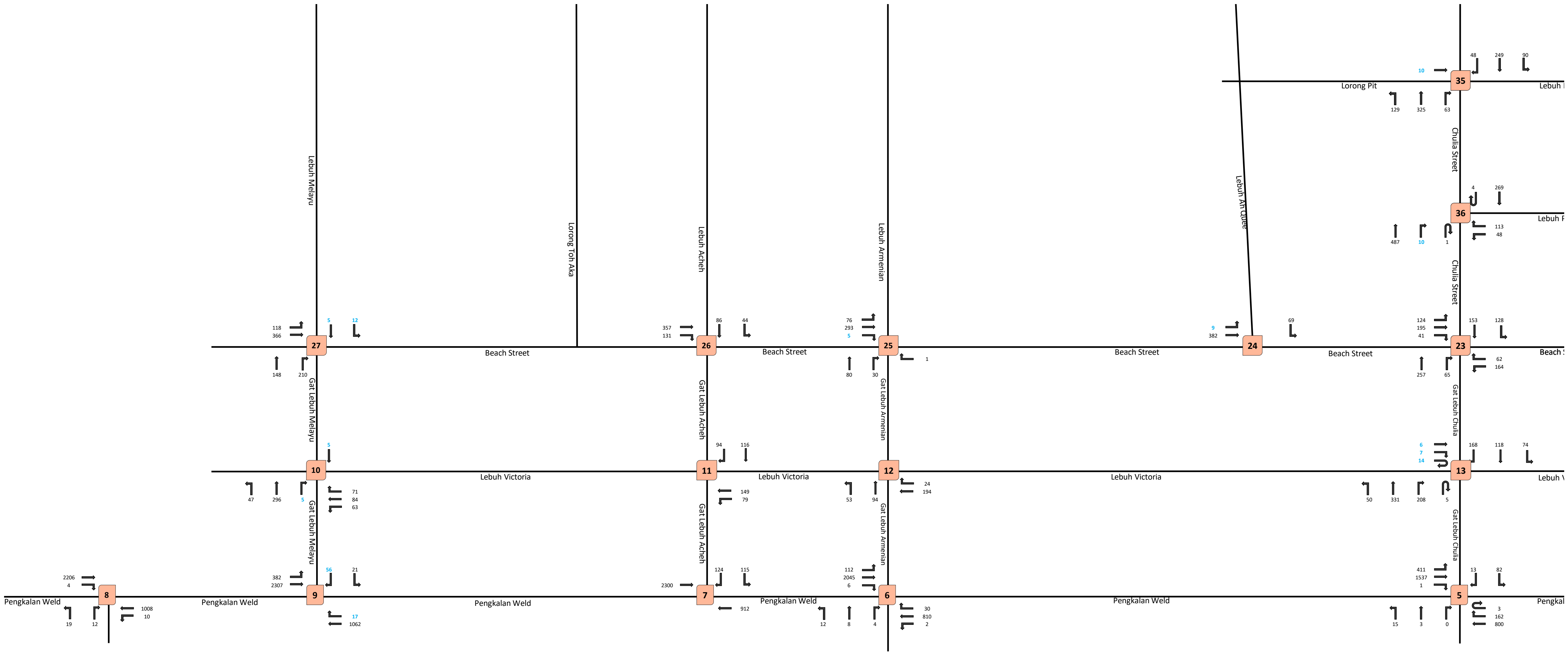


Figure 3-13 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Southwest Section

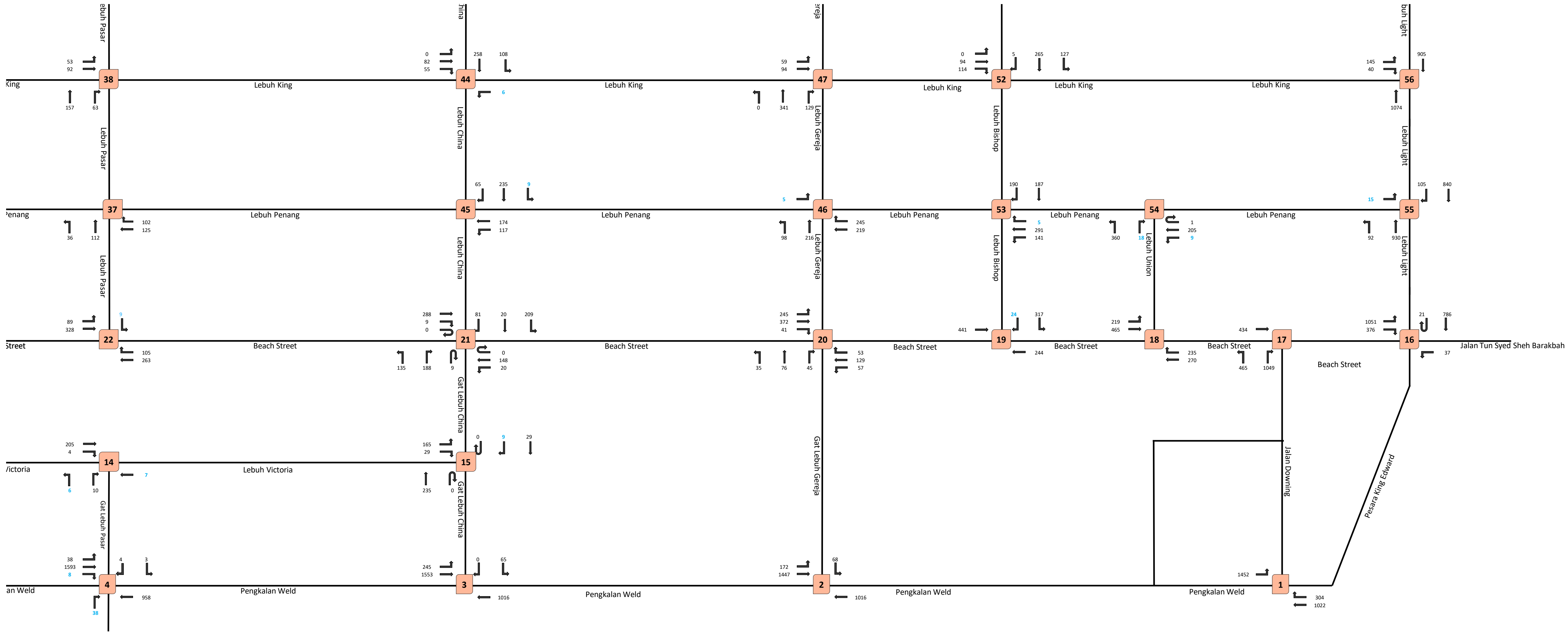


Figure 3-14 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Southeast Section

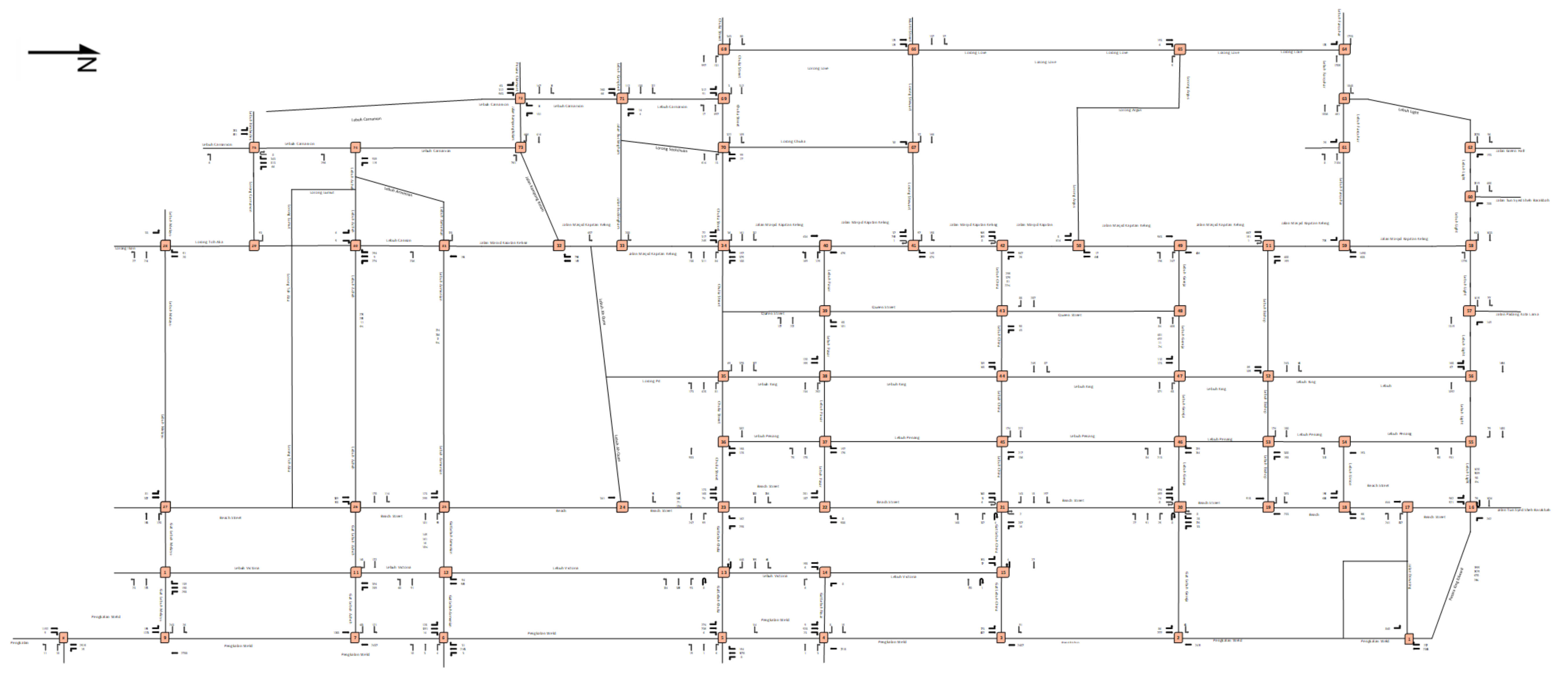


Figure 3-15 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Full

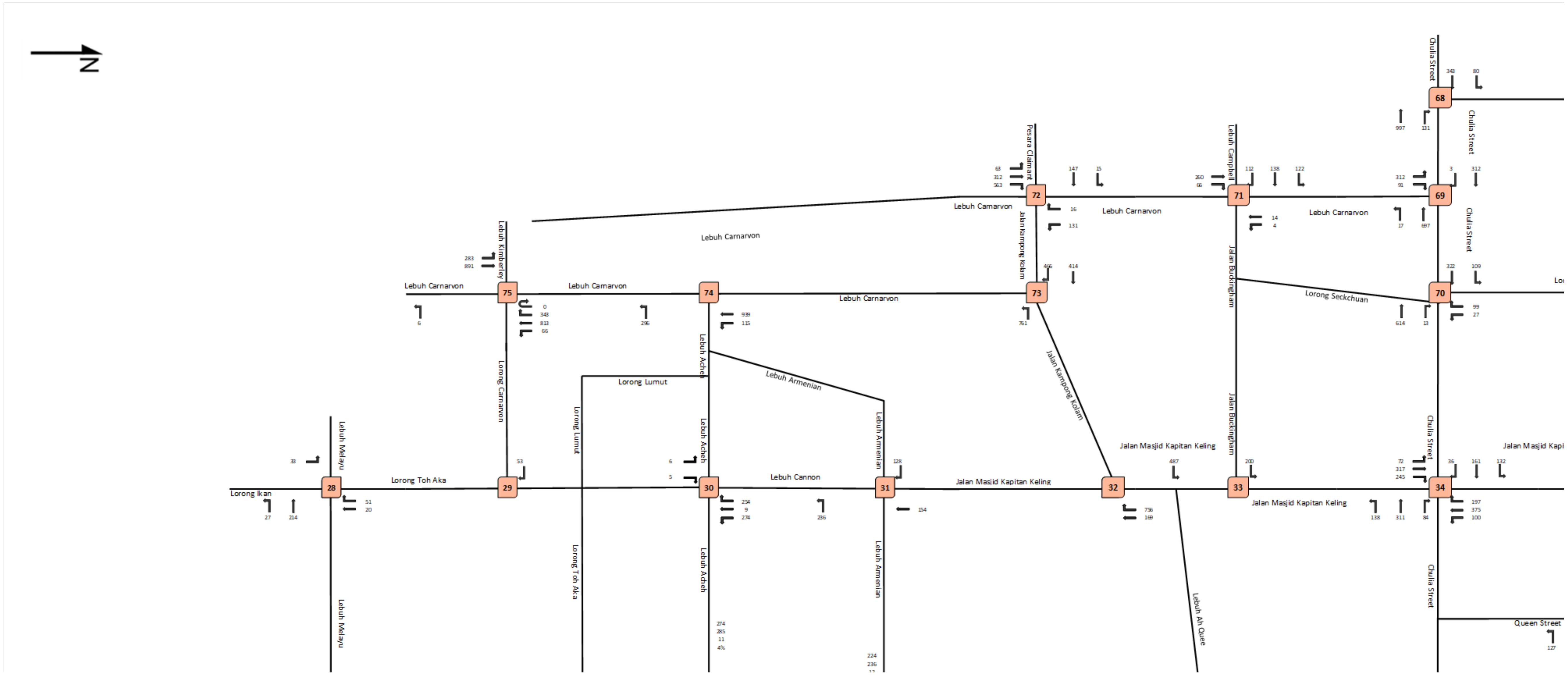


Figure 3-16 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Northwest Section

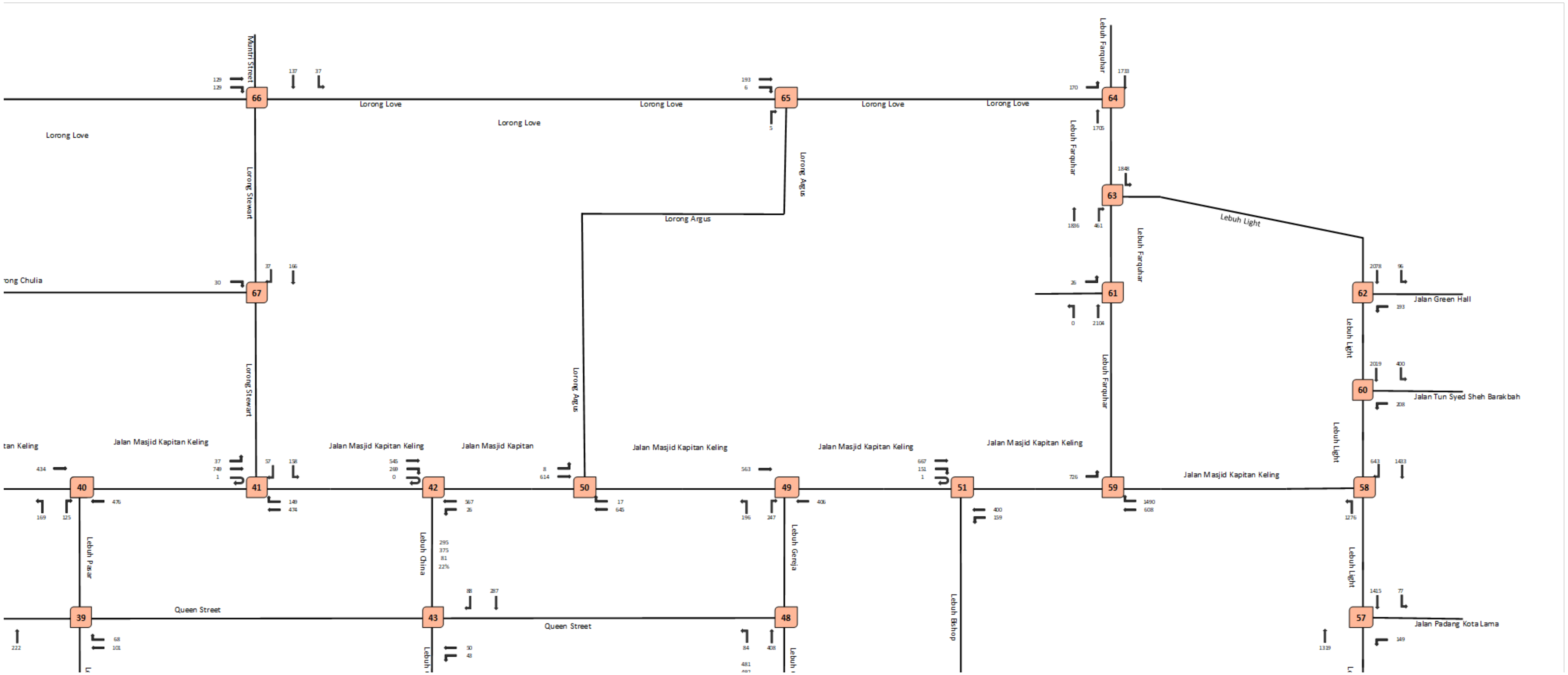


Figure 3-17 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Northeast Section

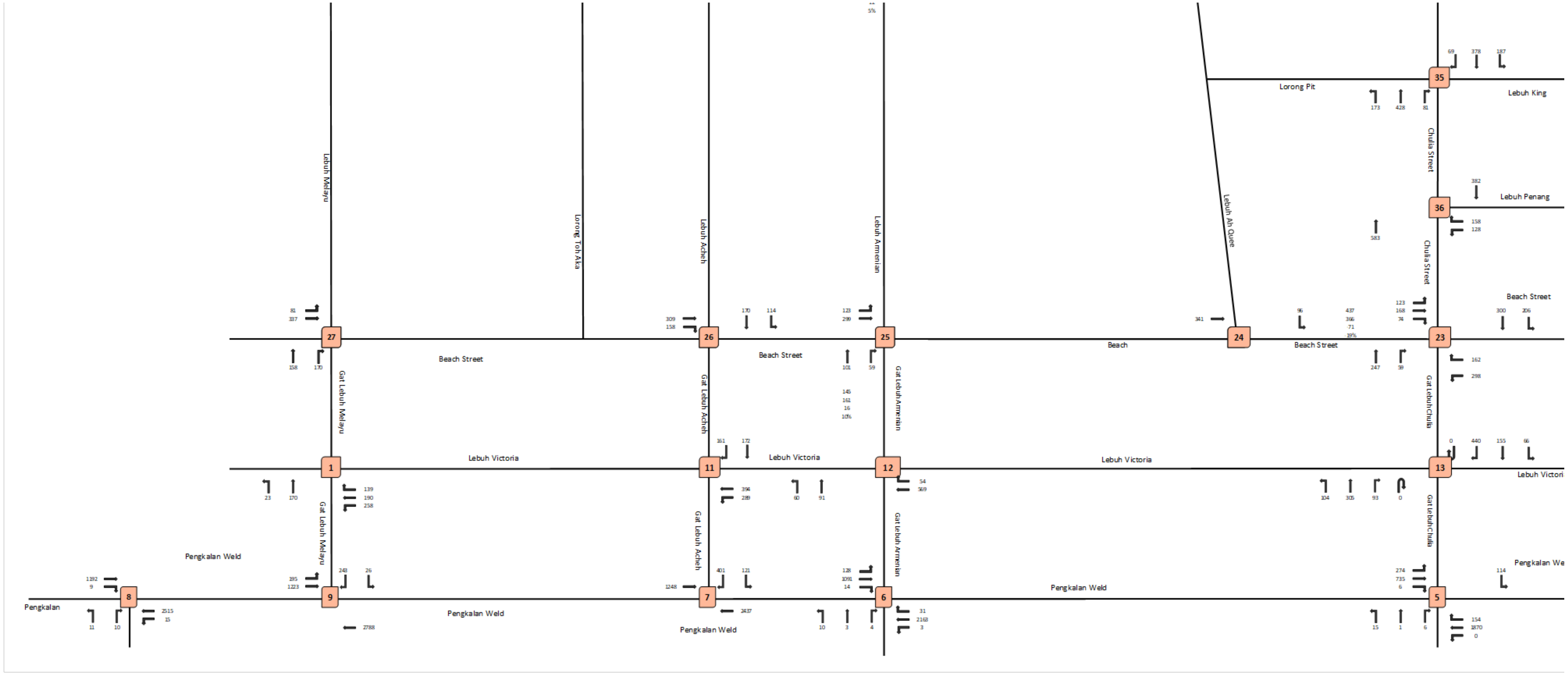


Figure 3-18 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Southwest Section

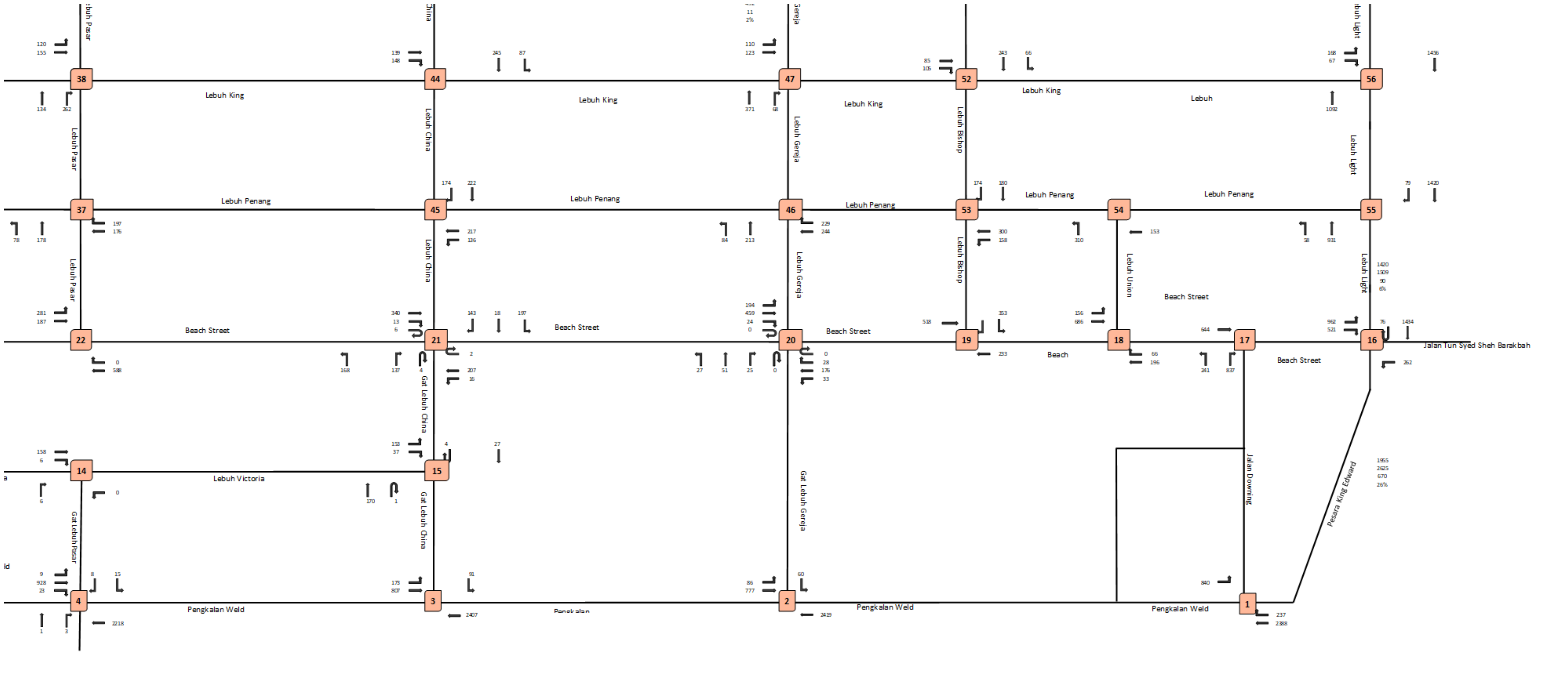


Figure 3.19 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Southeast Section

3.6 Unclassified Pedestrian / Cyclist Count Surveys

Pedestrian and cyclists were recorded at crossing point throughout the road network when they were crossing the street. The number for pedestrians and cyclists is unclassified, which means the results are in single combined class without further differentiation of user profiles (such as students, elderly, etc.). The locations of surveyed junctions are shown in the figure below.

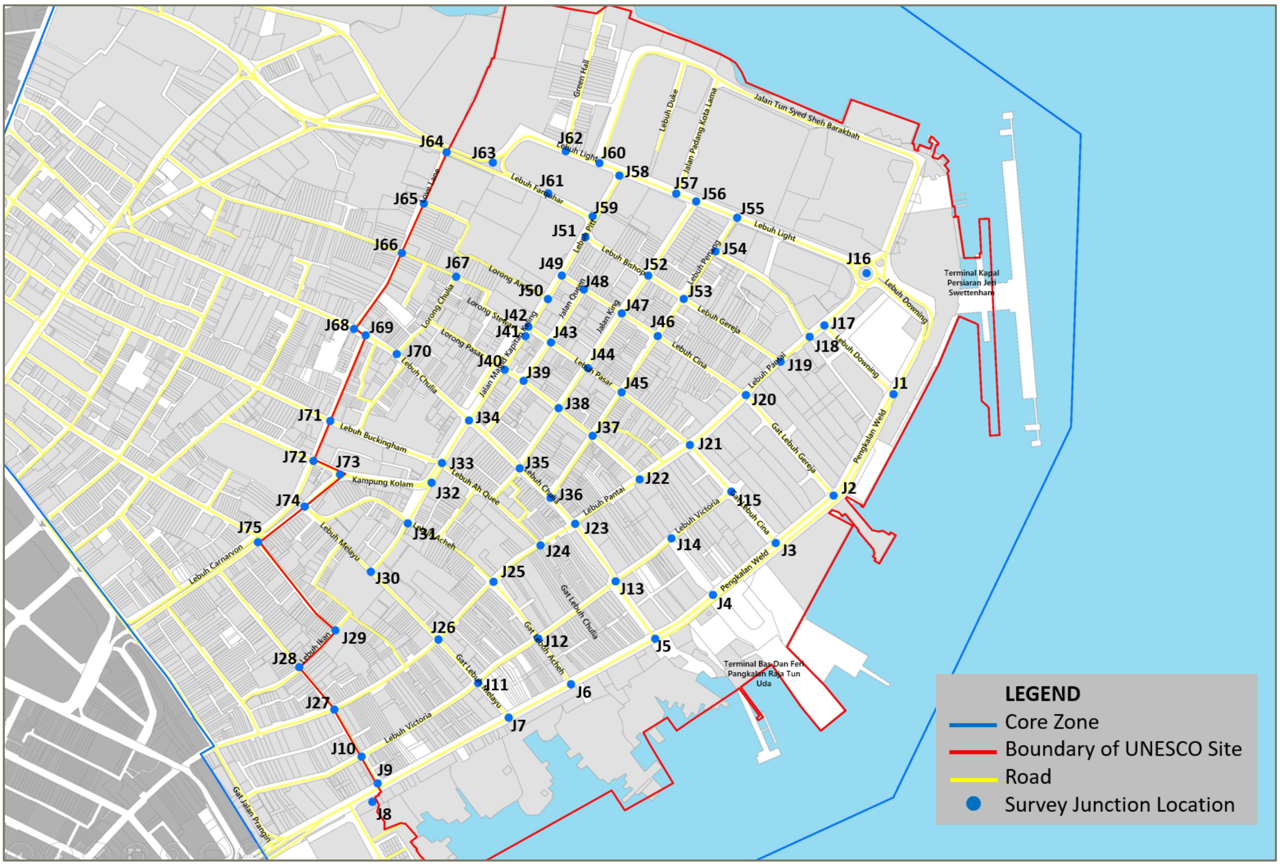


Figure 3-20 Existing Pedestrian / Cyclist Crossings Surveyed in Study Area

Pedestrian / cyclists counts results were analyzed to determine the peak 60-minute periods within the morning and evening peak periods. The peak hour pedestrian and cyclist flows follows the same period as traffic flows during the times stated in the table below.

Table 3-5 Survey Peak Hour (Pedestrian / Cyclist)

Time of Day	Surveyed Time	Peak Hour Pedestrian / Cyclists
Weekday AM	07:00 to 10:00	08:15 to 09:15 (flows shown in Figure 3.21 to 3.25)
Weekday PM	16:30 to 19:30	17:00 to 18:00 (flows shown in Figure 3.26 to 3.30)

For the respective peak hours within the surveyed timings, the corresponding pedestrian / cyclist flow volumes in the trail area road network are shown in the following figures.

Pedestrian and cyclist count data help us to calibrate road crossing activation, traffic delays and walk times through the network.

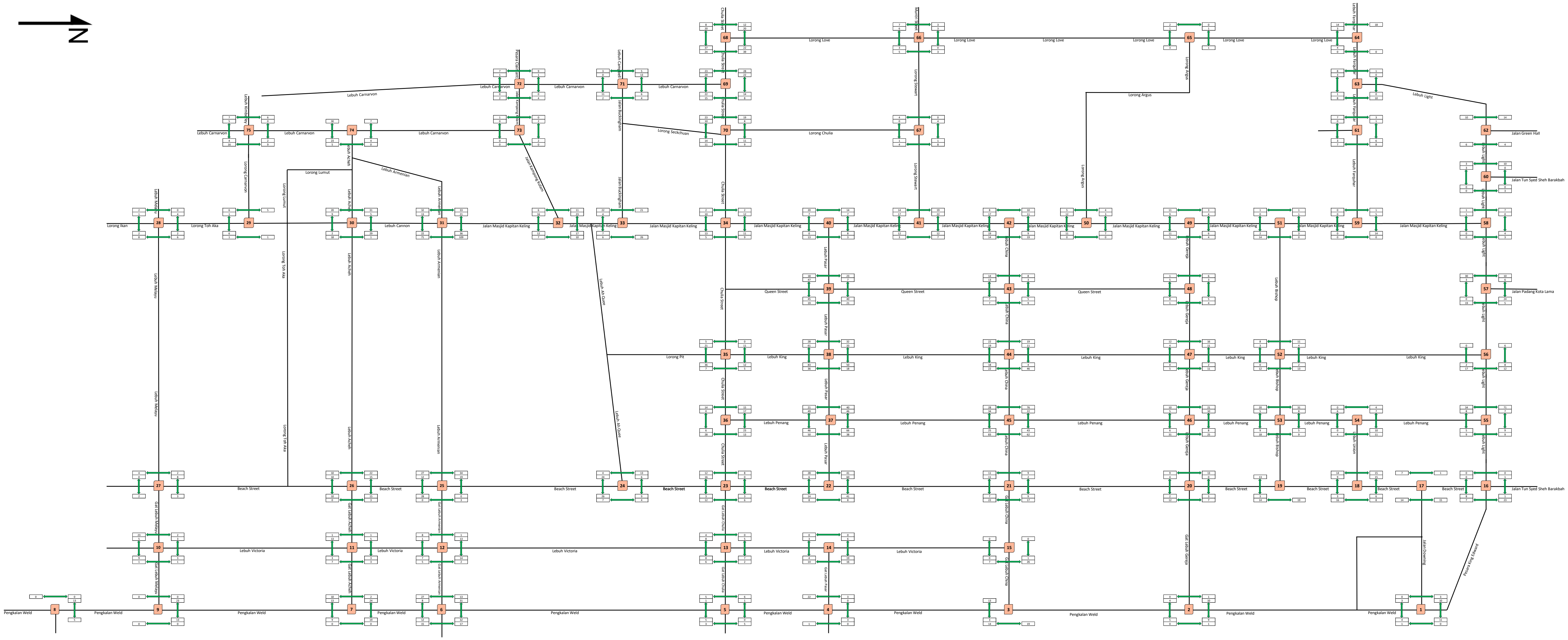


Figure 3-21 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Full

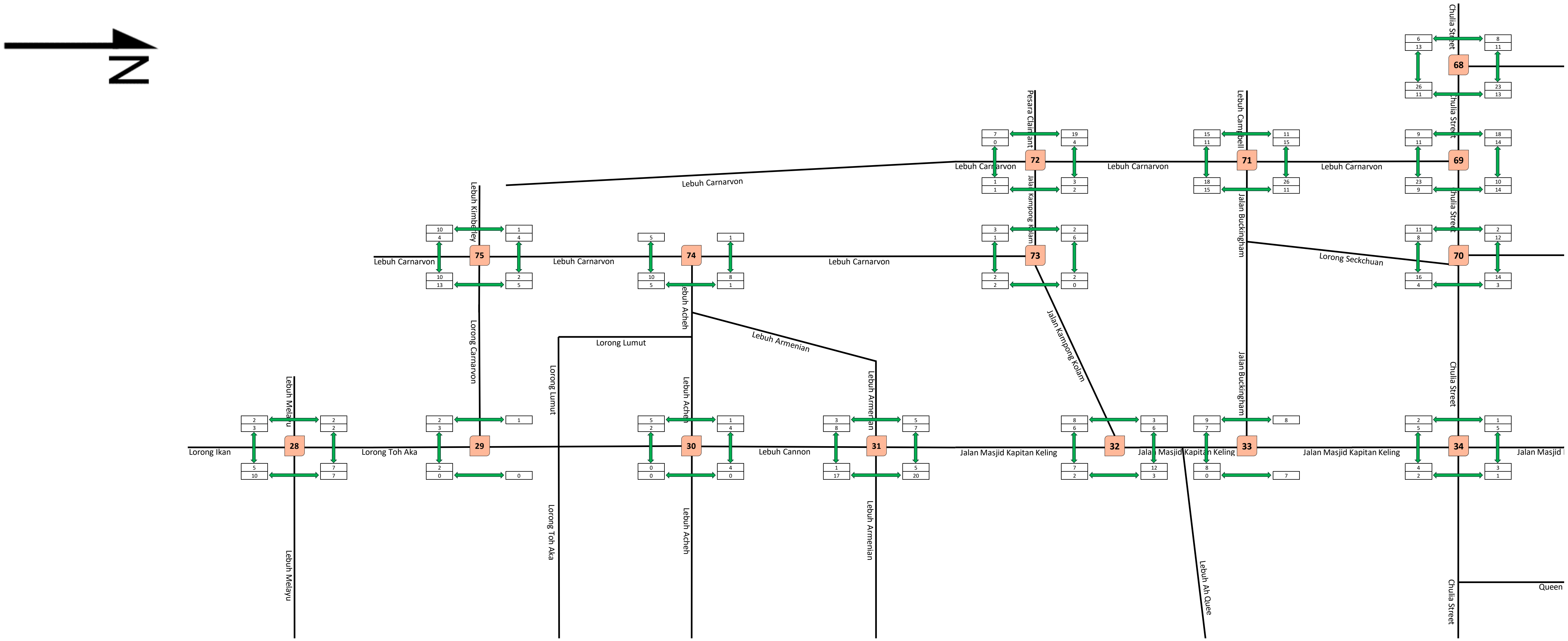


Figure 3-22 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Northwest Section

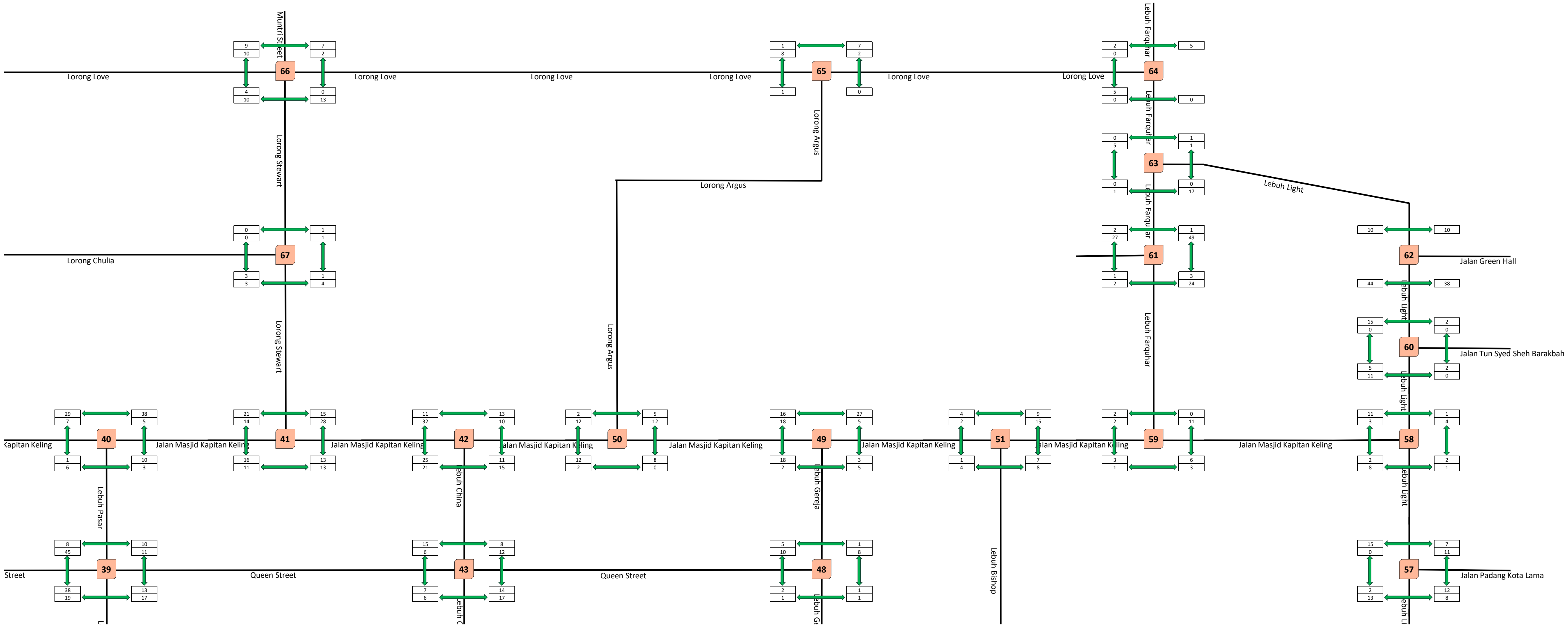


Figure 3-23 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Northeast Section

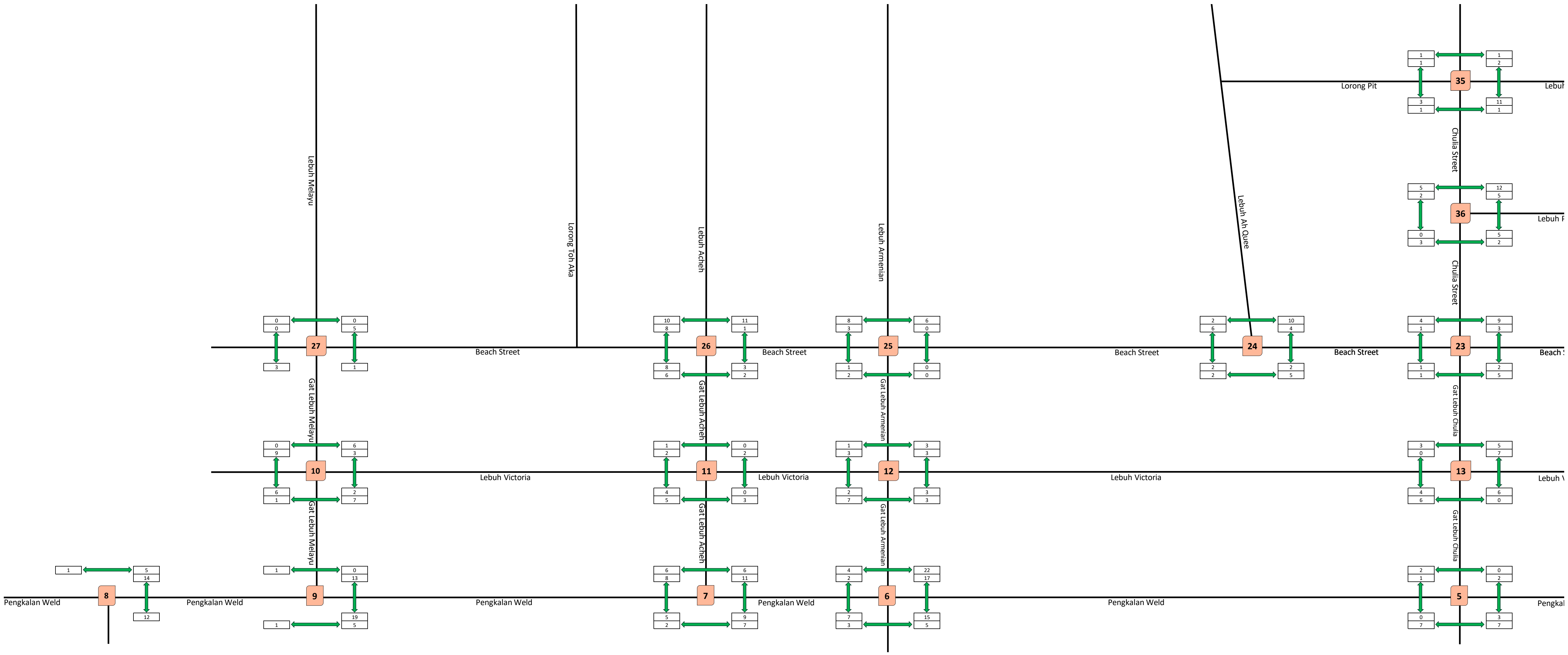


Figure 3-24 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Southwest Section

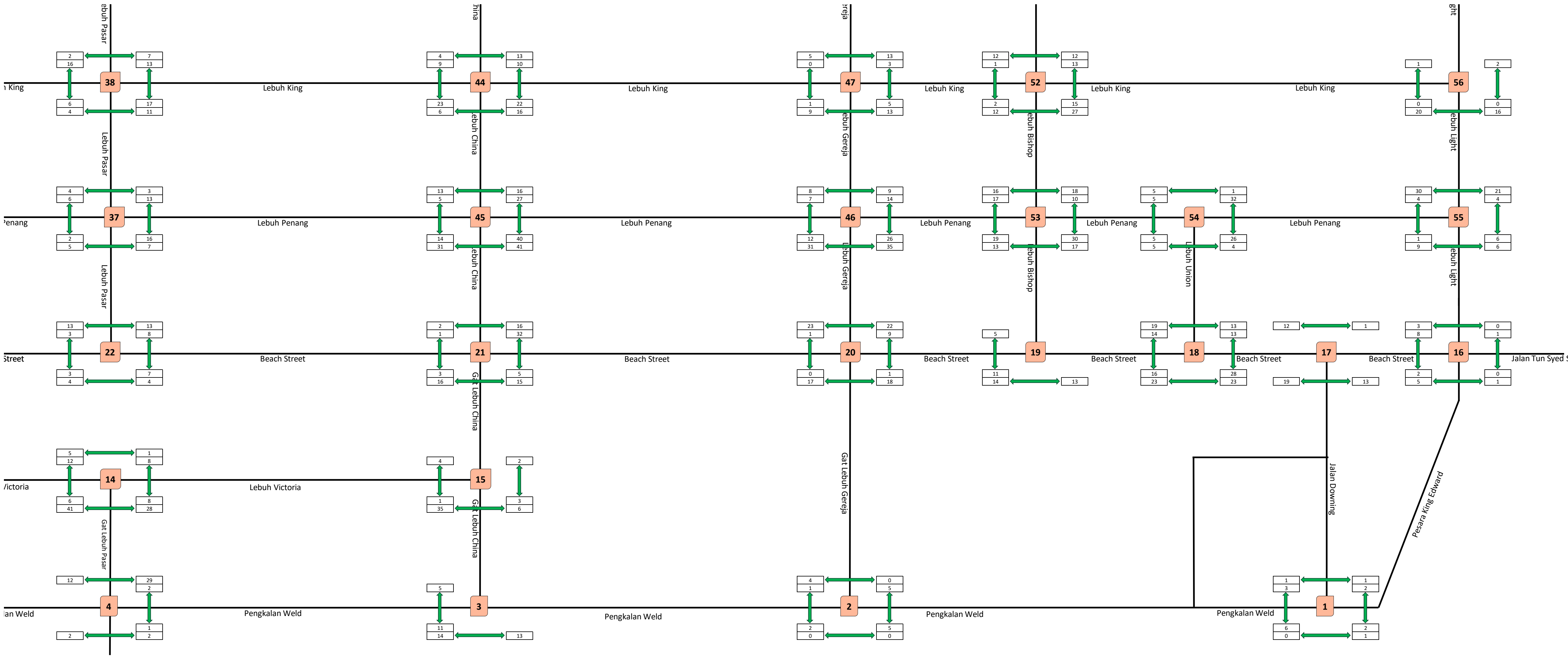


Figure 3-25 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Southeast Section

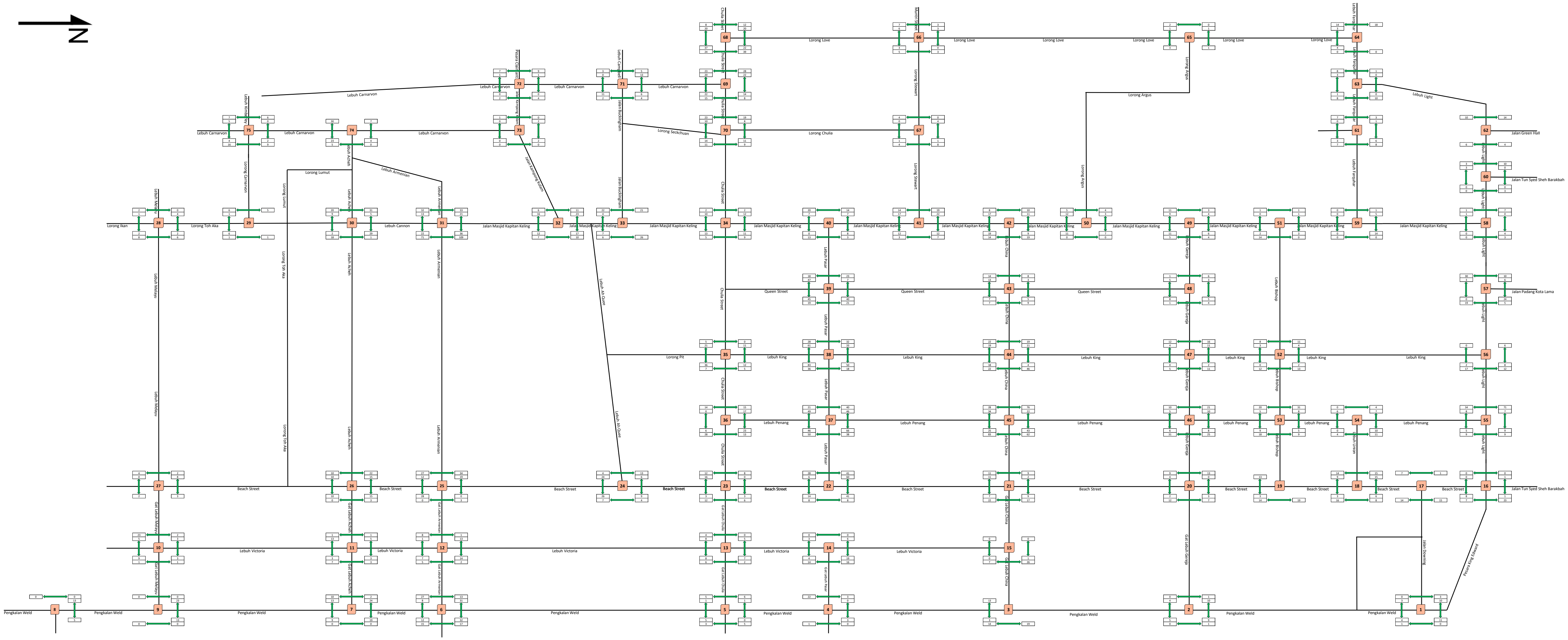


Figure 3-26 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Full

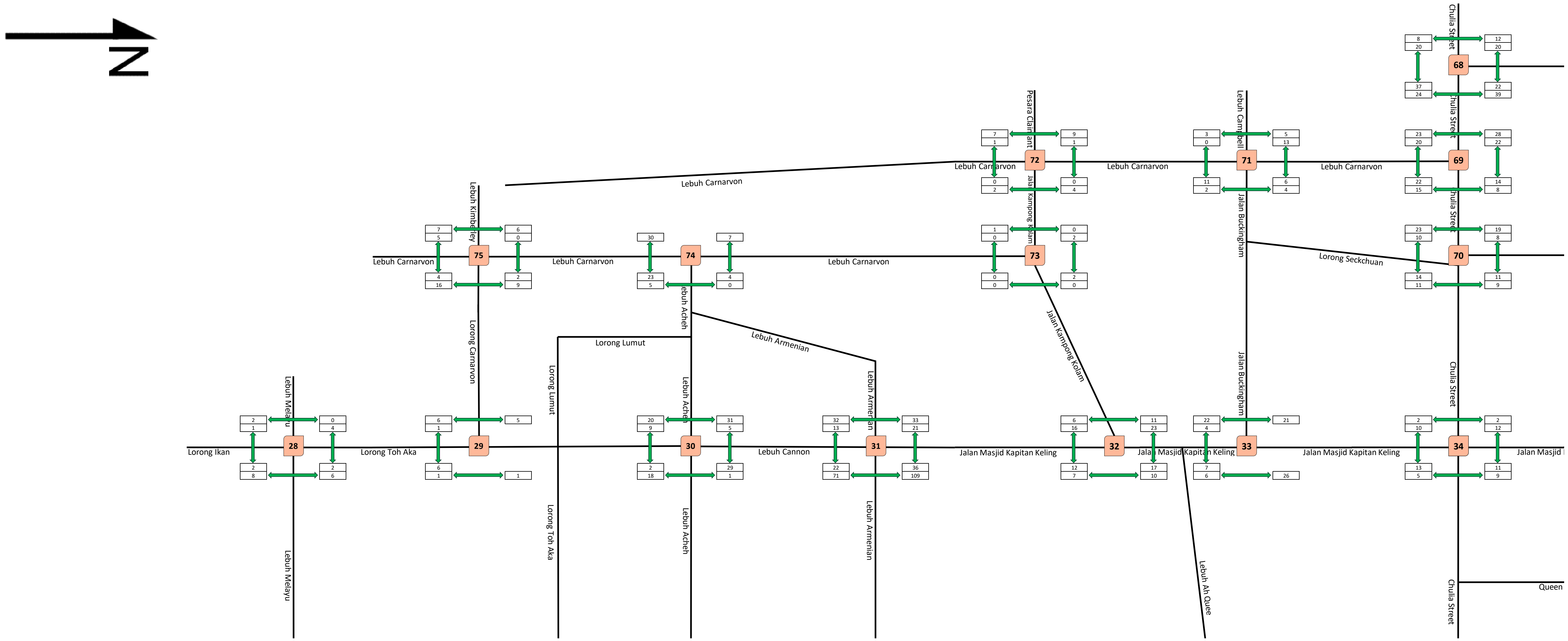


Figure 3-27 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Northwest Section

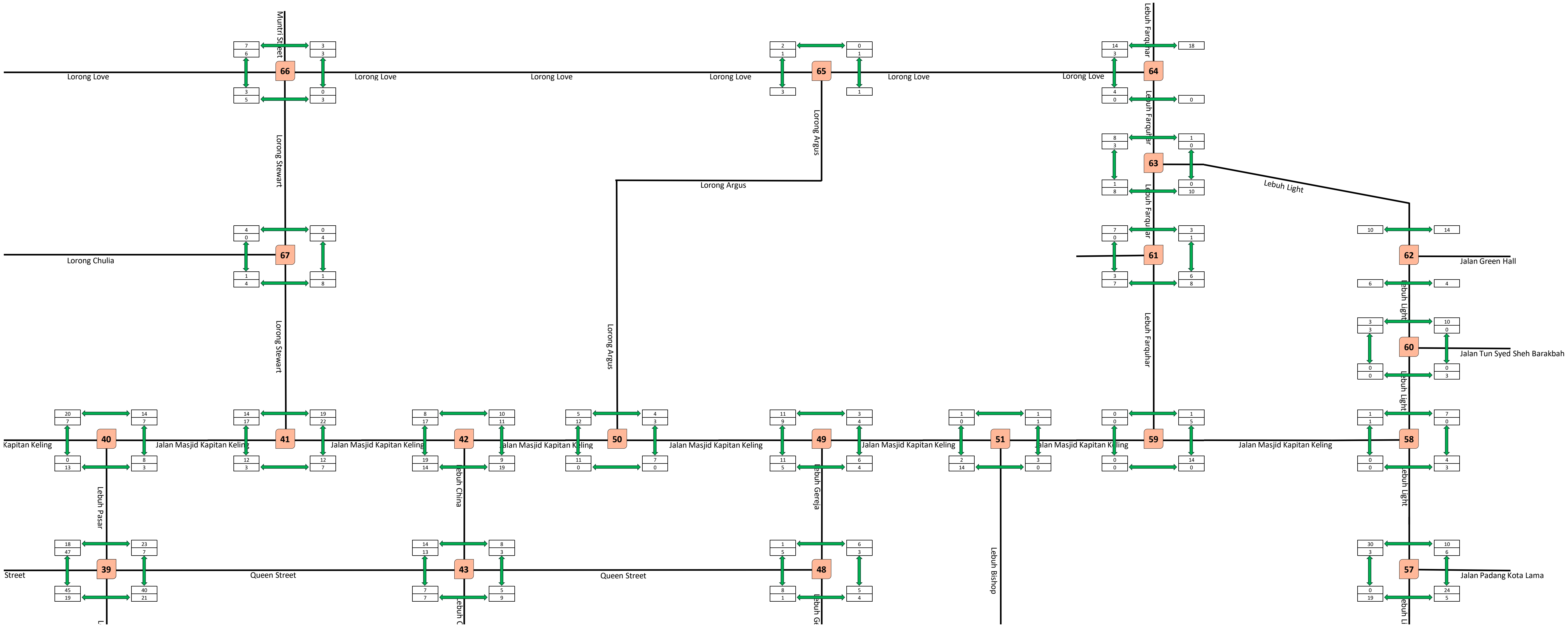


Figure 3-28 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Northeast Section

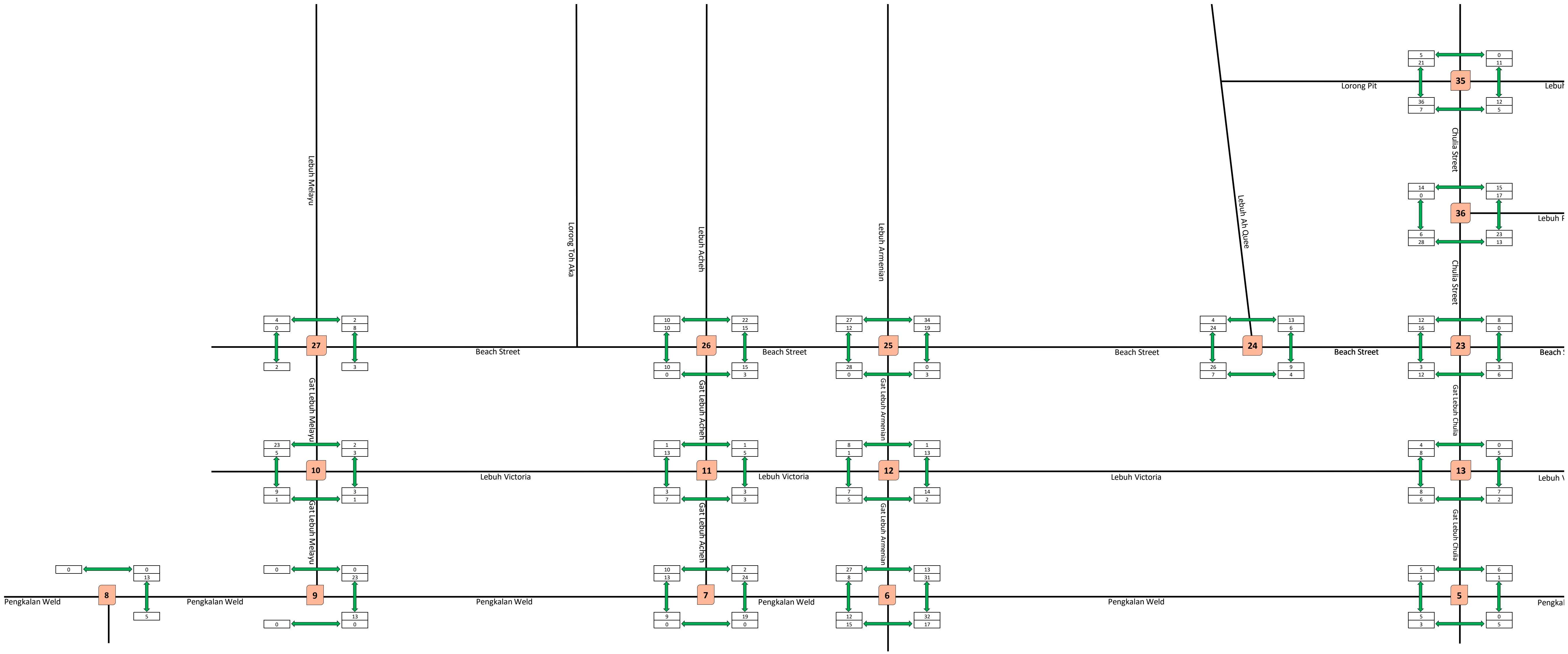


Figure 3-29 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Southwest Section

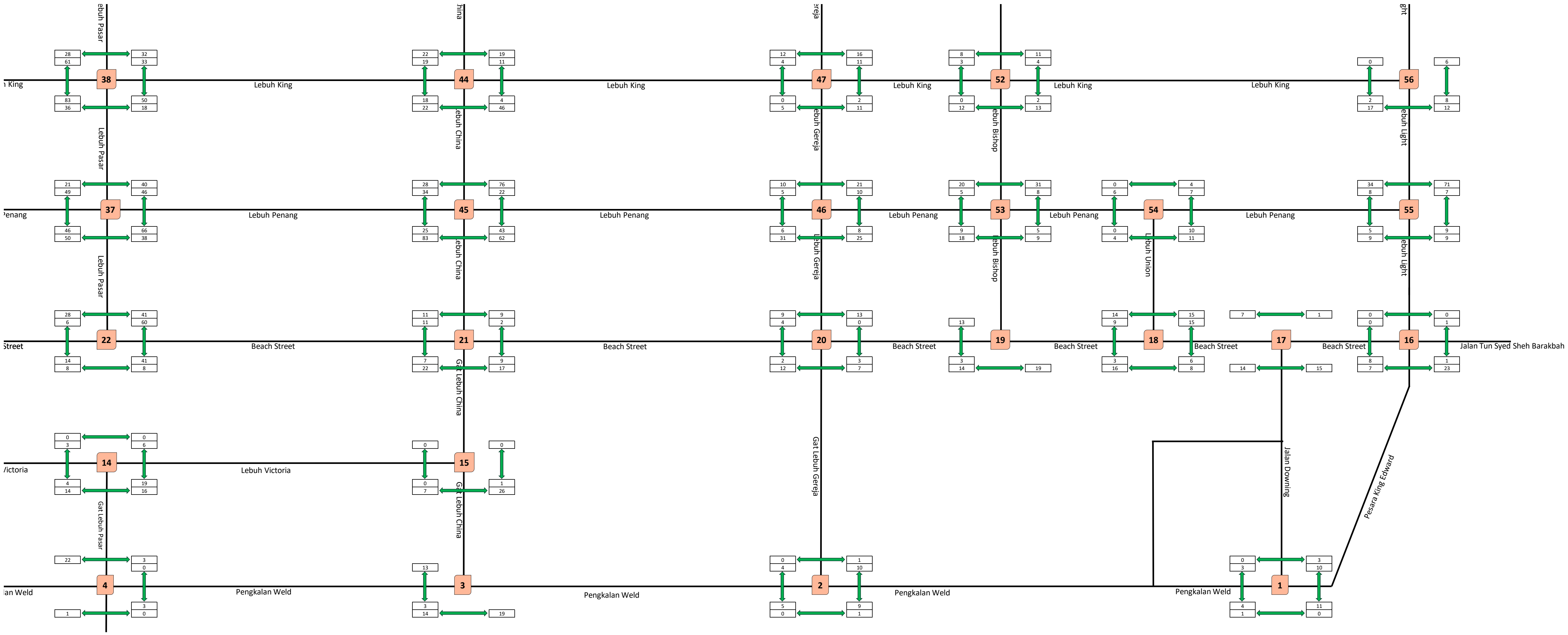


Figure 3-30 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Southeast Section

3.7 Parking Surveys

Parking surveys were conducted at both on-street and off-street parking facilities. On-street parking was classified by street and midblock section. Illegal parking was also recorded.

On-street parking surveys were conducted between junctions along the road section highlighted in both yellow and purple in the figure below.

Figure 3-31 On-street Parking Occupancy Survey Locations

The entire study area was divided into 4 areas for the survey to be conducted over a three-day period. For each of the surveyed road section between junction, occupancy data were collected every hour to understand the number of vehicles occupying the parking space at the given time.

Results reported in the table below are showing the maximum on-street parking occupancy in trail area Vissim Study.

Table 3-6 On Street Parking AM peak

Zone	Description	Side	Car Max	Bike Max	Side	Car Max	Bike Max
29	Between J1 to J17	Left	4	24	Right	2	63
30	Between J17 to J16	Left	0	11	Right	5	10
31	Between J16 to J1	Left	-	-	Right	-	-
32	Between J1 to J2	Left	-	-	Right	-	-
33	Between J2 to J20	Left	20	2	Right	14	1
34	Between J15 to J3	Left	10	0	Right	10	4
35	Between J21 to J15	Left	10	8	Right	0	0
36	Between J21 to J20	Left	9	21	Right	9	0
37	Between J5 to J13	Left	6	0	Right	11	2
38	Between J13 to J14	Left	-	-	Right	11	6
39	Between J14 to J15	Left	3	0	Right	7	0
40	Between J23 to J22	Left	5	2	Right	6	0
41	Between J22 to J21	Left	4	17	Right	9	10

Table 3-7 On Street Parking PM peak

Zone	Description	Side	Car Max	Bike Max	Side	Car Max	Bike Max
29	Between J1 to J17	Left	5	25	Right	2	50
30	Between J17 to J16	Left	10	9	Right	4	10
31	Between J16 to J1	Left	-	-	Right	-	-
32	Between J1 to J2	Left	-	-	Right	-	-
33	Between J2 to J20	Left	17	0	Right	12	1
34	Between J15 to J3	Left	11	1	Right	10	4
35	Between J21 to J15	Left	10	10	Right	0	0
36	Between J21 to J20	Left	10	27	Right	12	0
37	Between J5 to J13	Left	9	0	Right	10	1

Zone	Description	Side	Car Max	Bike Max	Side	Car Max	Bike Max
38	Between J13 to J14	Left	-	-	Right	12	1
39	Between J14 to J15	Left	10	1	Right	10	0
40	Between J23 to J22	Left	8	6	Right	10	1
41	Between J22 to J21	Left	5	18	Right	10	9

3.8 Parking Dwell Time Survey

For certain popular sections of the study area with constant movements of vehicles in and out of on-street parking locations, it is also important to record down the average time of dwell for vehicles utilizing the on-street parking. This provides an insight into the behavior of vehicle parking and the turn-around rate for the parking facility.

Road sections marked in purple in the diagram below were pre-identified as popular sections for the parking dwell time survey to take place. The road sections were labelled from DP1 to DP21. For other sections average of all parking dwell time survey is considered.

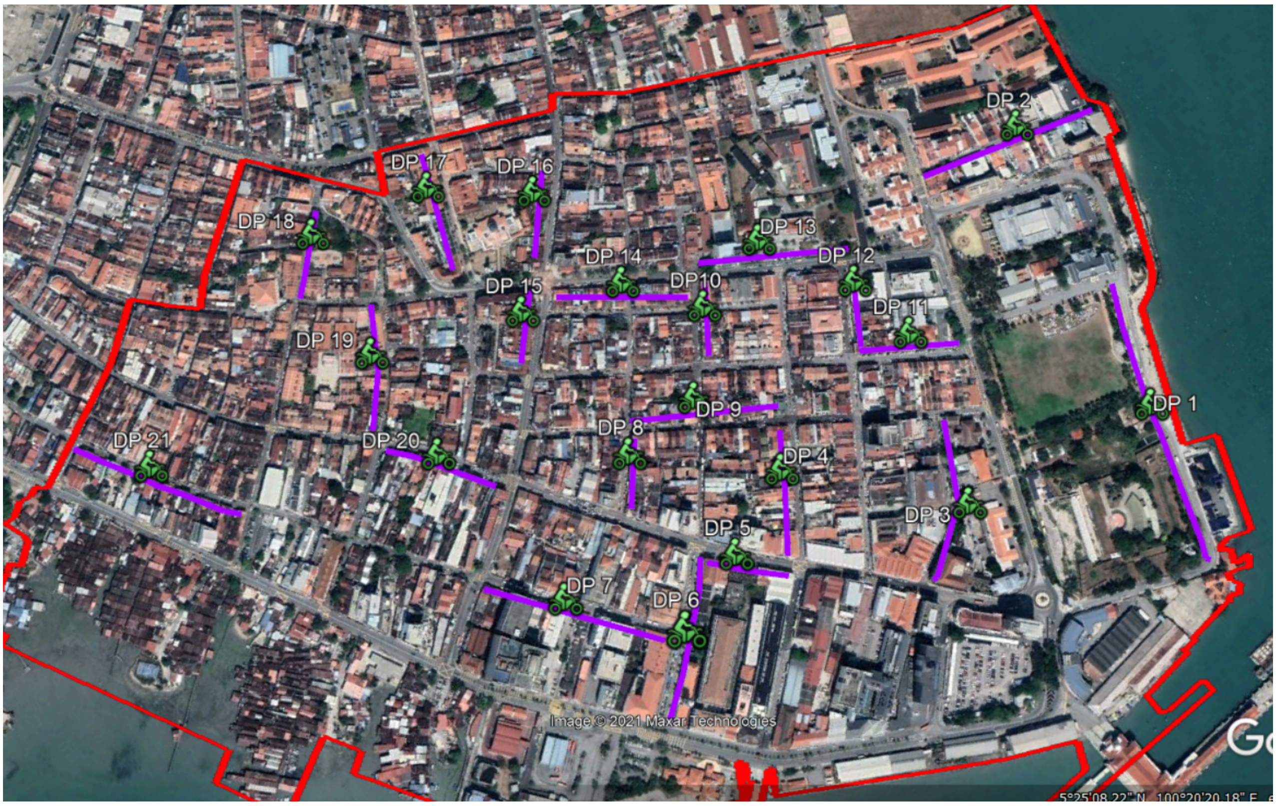


Figure 3-32 Parking Dwell Time Survey Locations

Results for parking dwell time survey are shown in the table below.

Table 3-8 Summary of Dwell Time Survey

Location	Dwell Time	Location	Dwell Time
DP1	00:00:57	DP11	00:04:50
DP2	00:02:48	DP12	00:01:03
DP3	00:02:24	DP13	00:00:31
DP4	00:01:06	DP14	00:02:58
DP5	00:00:48	DP15	00:00:56
DP6(Start Cam)	00:00:44	DP16	00:00:40
DP6(End Cam)	00:02:10	DP17	00:03:43
DP7	00:04:01	DP18	00:16:49
DP8	00:01:33	DP19	00:02:30
DP9	00:01:54	DP20	00:00:54
DP10	00:00:30	DP21	00:01:15
Average			**00:02:30**

3.9 Survey Data Utilization

3.9.1 Introduction

Site data collected are to be further processed into the format accepted in traffic analysis and modelling. These steps as documented below in the typical method how data is being utilized for large-scale urban area simulation projects, with customization made for Penang's on-site conditions.

Data collected are separated into capacity data and survey data. The types of data contained in each category are summaries in the diagram below.

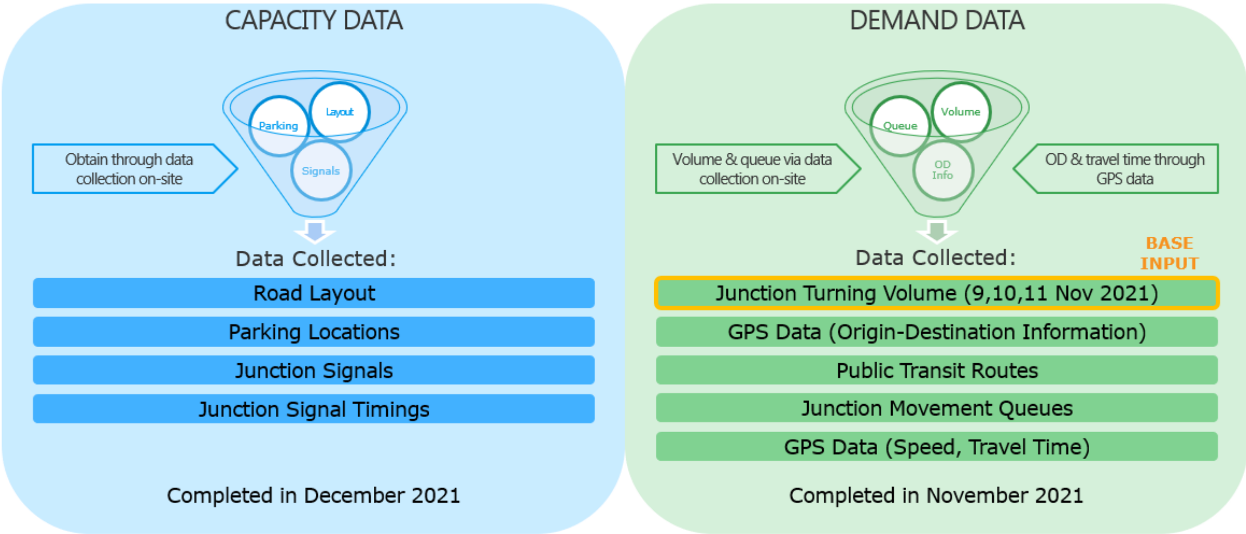


Figure 3-33 Data Categories

3.9.2 Data Conversion Process

Raw data collected from site surveys contained three hours of information, and were collected in specific classifications, in individual movements.

In order to complete a complex and dynamic traffic simulation model, the raw data need to be processed and consolidated into hourly peak data consistent of model classes and with combined movement between zones. The following steps are included to complete the process:

1. Conversion of individual vehicle classed to PCU
2. Identify peak hours during the survey period
3. Produce movement diagram from individual junctions
4. Compare movements recorded with allowable ones in road layout
5. Check flow balance between upstream and downstream junctions
6. Consolidate turn-by-turn movements to OD table

Difference between survey results and model inputs is summarized with the diagram below.

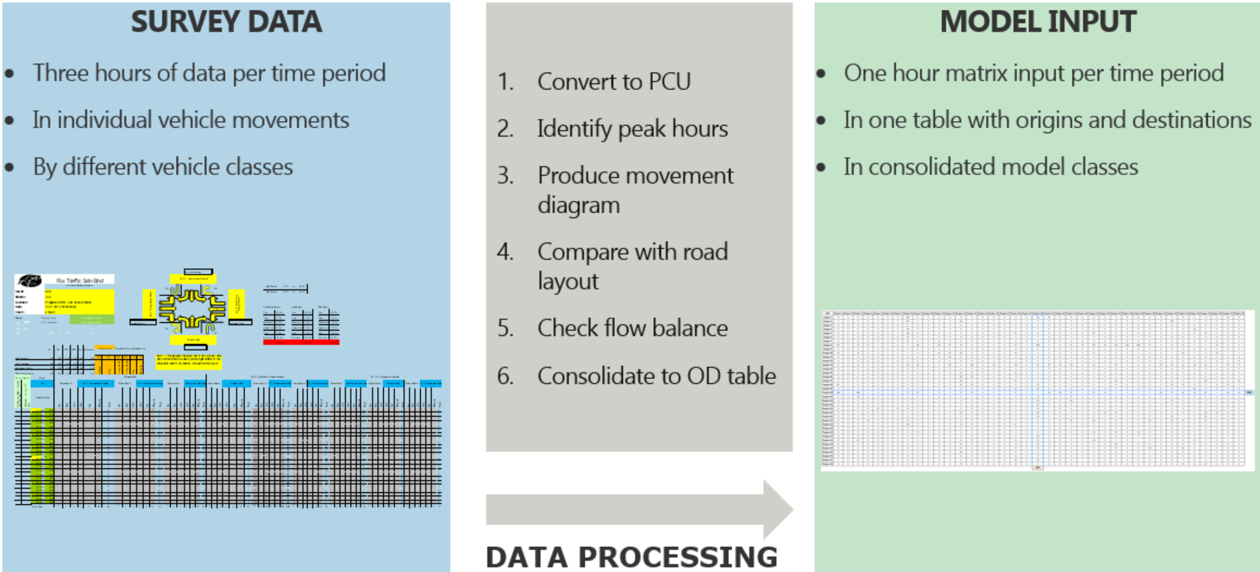


Figure 3-34 Survey Data to Model Input

For each of the tasks involved, the following section details the key considerations when completing each step.

3.9.2.1 Conversion To PCU

Traffic counts results were analyzed to determine the peak 60-minute periods within the morning and evening peak periods. All traffic flows were converted and expressed in Passenger Car Units (PCUs).[4] PCUs are factors that convert different classification of vehicles to be equivalent to a typical car. The following PCU factors were used (in accordance with Malaysian guidelines) for the junction counts:

- Car: 1.00
- Taxi: 1.00
- Light Goods Vehicles (Lorry Kecil): 2.50
- Heavy Goods Vehicles (Lorry Besar): 3.00
- Bus: 3.00
- Motorcycle: 0.75

Traffic flows from different vehicle types need to be converted into Passenger Car Unit (PCU) to be comparable. This step is usually done with Excel spreadsheet calculations with an example shown below.

[4] PCU refers to Passenger Car Unit. PCUs are factors that convert different classification of vehicles to be equivalent to a typical car.

PCU Number

Client	ADB
Site	JC 7
Day	Pengkalan Weld / Gat Lebuh Acheh
Description	10.11.2021 (Wednesday)

From	JC 6 / Jeti Ferry Georgetown														JC 11 / Carnarvon Street													
To	Direction 1			JC 8 / Pengkalan Weld				Direction 2			JC 11 / Carnarvon Street				Direction 3			C 6 / Jeti Ferry Georgetow				Direction 4			JC 8 / Pengkalan Weld			
Time Period	Car	Taxi	LGV	HGV	Bus	M'cycle	Total	Car	Taxi	LGV	HGV	Bus	M'cycle	Total	Car	Taxi	LGV	HGV	Bus	M'cycle	Total	Car	Taxi	LGV	HGV	Bus	M'cycle	Total
07.00 to 08.00	626	1	33	0	24	231	915	0	0	0	0	0	0	0	13	0	0	0	0	37	50	30	0	0	0	0	37	67
07.15 to 08.15	653	2	38	0	24	258	975	0	0	0	0	0	0	0	16	0	3	0	0	49	68	32	0	0	0	0	44	76
07.30 to 08.30	617	4	40	0	15	283	959	0	0	0	0	0	0	0	22	0	5	0	0	57	84	35	0	3	0	0	48	86
07.45 to 08.45	621	3	43	0	9	284	960	0	0	0	0	0	0	0	33	0	8	0	0	58	99	38	0	10	0	0	50	96
08.00 to 09.00	599	5	40	0	9	288	939	0	0	0	0	0	0	0	37	0	10	0	0	56	103	30	0	23	0	0	62	115
08.15 to 09.15	588	5	53	3	9	276	912	0	0	0	0	0	0	0	41	0	8	0	0	66	115	34	0	25	0	0	65	124
08.30 to 09.30	584	4	63	3	15	287	936	0	0	0	0	0	0	0	39	0	5	0	0	64	108	41	1	35	0	0	70	147
08.45 to 09.45	522	7	85	3	15	298	928	0	0	0	0	0	0	0	45	0	5	0	0	61	111	55	1	38	0	0	78	172
09.00 to 10.00	514	5	105	3	12	302	941	0	0	0	0	0	0	0	50	0	10	0	0	59	119	63	1	28	0	0	70	162
16.30 to 17.30	1295	7	128	6	3	695	2134	0	0	0	0	0	0	0	60	0	10	0	0	52	122	173	1	20	0	0	137	331
16.45 to 17.45	1316	7	125	3	6	758	2215	0	0	0	0	0	0	0	59	0	8	0	0	54	121	177	2	18	0	0	159	356
17.00 to 18.00	1343	9	105	0	6	798	2259	0	0	0	0	0	0	0	58	0	5	0	0	49	112	177	3	15	0	0	177	372
17.15 to 18.15	1358	6	90	0	6	777	2237	0	0	0	0	0	0	0	59	0	3	0	0	48	110	170	3	18	0	0	172	363
17.30 to 18.30	1300	4	68	0	6	721	2099	0	0	0	0	0	0	0	59	0	5	0	0	52	116	186	2	20	0	0	183	391
17.45 to 18.45	1286	3	53	0	6	644	1972	0	0	0	0	0	0	0	62	1	5	0	0	48	116	178	1	20	0	0	164	361
18.00 to 19.00	1185	2	48	0	9	580	1824	0	0	0	0	0	0	0	64	1	5	0	0	52	122	161	0	20	0	0	138	317
18.15 to 19.15	1098	2	58	0	6	479	1643	0	0	0	0	0	0	0	60	1	5	0	0	46	112	152	0	13	0	0	115	280
18.30 to 19.30	1008	3	63	0	9	394	1477	0	0	0	0	0	0	0	59	1	5	0	0	34	99	131	0	13	0	0	97	241
Survey Total	5342	25	435	9	63	2829	8503	0	0	0	0	0	0	0	278	1	40	0	0	290	609	613	4	103	0	0	588	1306
AM Peak	621	3	43	0	9	284	960	0	0	0	0	0	0	0	33	0	8	0	0	58	99	38	0	10	0	0	50	96
PM Peak	1343	9	105	0	6	798	2259	0	0	0	0	0	0	0	58	0	5	0	0	49	112	177	3	15	0	0	177	372

Figure 3-35 Example of PCU Conversion

3.9.2.2 Identify Peak Hours

Peak hour is defined as the one-hour period within the survey duration with the highest total amount of traffic among all vehicle's movements of all junctions in the network.

It is identified by adding all vehicle movements counts (per 15-min interval) in PCU values together and being picked as the period with highest volume.

Example of the calculation steps are shown below.

Junction 75 / PCU Number / Directions																Total	Total PCU Per 60 min
Direction 1	Direction 2	Direction 3	Direction 4	Direction 5	Direction 6	Direction 7	Direction 8	Direction 9	Direction 10	Direction 11	Direction 12	Direction 13	Direction 14	[illegible]	[illegible]		
0.0	3.0	2.3	3.3	40.5	26.8	0.0	0.0	0.0	35.5	93.8	0.8	0.0	0.0	[illegible]	[illegible]	[illegible]	
0.8	0.8	0.0	1.0	56.5	22.3	0.0	0.0	0.0	35.8	135.0	0.0	0.0	0.0	0.0	1.8	16399	
1.5	0.8	0.8	4.8	72.0	45.5	0.0	0.0	0.0	39.5	168.0	0.8	0.0	0.0	0.0	0.0	17921	
1.5	2.3	0.8	6.8	34.5	81.0	0.0	0.0	0.0	61.5	171.0	0.8	0.0	0.0	0.0	0.8	20433	68341
0.0	6.8	3.8	9.5	74.5	51.0	0.0	0.0	0.0	72.3	197.0	0.0	0.0	0.0	0.0	0.0	20860	75612
0.0	3.8	1.5	9.5	101.3	38.0	0.0	0.0	0.0	64.3	222.0	1.5	0.0	0.0	0.0	1.5	24466	83679
1.0	7.5	1.5	12.0	120.3	52.8	0.0	0.0	0.0	94.3	285.8	0.0	0.0	0.0	0.0	1.5	23859	89617
1.5	6.0	0.8	11.3	123.5	62.0	0.0	0.0	0.0	80.8	274.0	0.8	0.0	0.0	0.0	1.5	24081	93266
0.8	1.5	1.5	10.0	116.5	52.5	0.0	0.8	0.0	85.8	247.3	0.8	0.0	0.0	0.0	1.5	22471	94877
3.8	6.0	2.3	13.3	106.0	45.3	0.0	0.0	0.0	92.0	212.3	0.0	0.0	0.0	0.0	0.8	21693	92104
2.3	3.0	1.5	10.0	140.5	72.8	0.8	0.0	0.0	102.0	218.0	0.0	0.0	0.0	0.0	0.8	21300	89545
0.0	4.5	2.3	7.0	131.3	53.8	0.0	0.0	0.0	101.8	243.8	0.0	0.0	0.0	0.0	1.5	21902	87366
0.8	5.3	1.5	13.8	186.5	62.8	0.0	0.0	0.0	64.3	210.5	0.0	0.0	0.0	0.0	2.3	24815	89710
1.8	3.0	1.5	10.8	152.8	48.5	0.0	0.0	0.0	60.3	252.3	0.0	0.0	0.0	0.0	0.0	25496	93513
0.8	1.5	1.5	8.5	187.8	74.5	0.0	0.0	0.0	65.0	208.3	0.0	0.0	0.0	0.0	0.8	28715	100928
2.3	1.5	1.5	15.0	184.3	81.5	0.0	0.0	0.0	70.0	203.5	0.0	0.0	0.0	0.0	0.0	27300	106326
1.5	3.0	1.5	23.5	208.0	81.5	0.0	0.0	0.0	66.8	234.3	0.8	0.0	0.0	0.0	0.0	26547	108058
0.8	0.0	0.0	14.0	174.0	80.5	0.0	0.0	0.0	60.3	179.5	0.8	[illegible]	[illegible]	[illegible]	0.0	26075	108637
0.0	0.8	0.0	12.0	227.3	75.8	0.0	0.0	0.0	76.8	204.5	0.0	[illegible]	[illegible]	[illegible]	0.8	24456	104377
0.0	3.0	1.5	9.0	180.8	73.5	0.0	0.0	0.0	59.3	188.0	0.8	[illegible]	[illegible]	[illegible]	0.8	24406	101484
0.0	3.8	0.8	9.5	148.8	52.5	0.0	0.0	0.0	68.0	187.3	0.8	[illegible]	[illegible]	[illegible]	0.8	22223	97159
0.0	0.8	0.0	6.5	151.8	65.3	0.0	0.0	0.0	52.3	179.3	0.0	[illegible]	[illegible]	[illegible]	0.0	20997	92082
0.8	3.0	0.0	12.5	142.8	38.5	0.0	0.0	0.0	43.8	152.5	0.8	[illegible]	[illegible]	[illegible]	0.8	19378	87004
1.5	3.0	0.0	7.3	115.3	44.5	0.0	0.0	0.0	47.5	162.0	0.8	[illegible]	[illegible]	[illegible]	0.8	19146	81744

Sum of PCUs for each 15 minute interval

Rolling peak sum. Maximum represents the peak hour

Figure 3-36 Example of Peak Hour Identification

3.9.2.3 Produce Movement Diagram

Once peak hours are identified, the vehicle movements are put in a diagram to show the spatial relations between movements. Movement diagrams produced from this survey have been included in Section 3.2 of this report.

3.9.2.4 Compare With Road Layout

Data collected on site contains all vehicles movement happening on-site, regardless of whether the movement is allowed by traffic regulations or not. In order to find out irregular movements, the data collected will need to be compared on individual basis with on-site layout. If any irregularities were discovered, it is to be further studied with either verifying on the counts or modifying the network layout (should the movements occur consistently and in large quantalities).

3.9.2.5 Check Flow Balance

Flow between two consecutive junctions is compared to ensure upstream and downstream junctions have consistent flows between themselves. Example of the calculation steps are shown below.

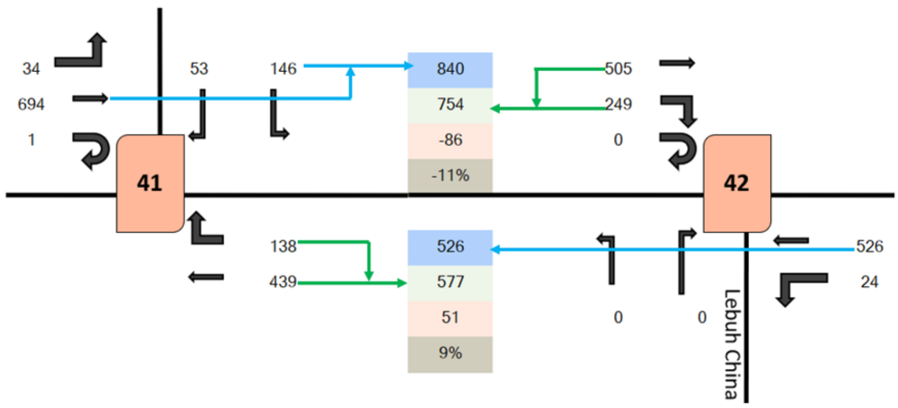


Figure 3-37 Example of Flow Balance Comparison

3.9.1 Consolidate To OD Table

At the final step, flow data were input to OD table. Example of data sources of the table is shown below.

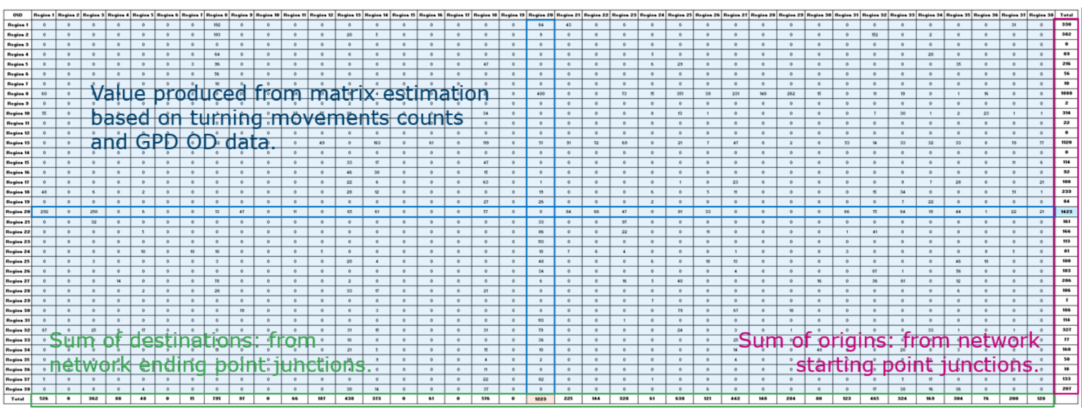


Figure 3-38 Example of OD Table Data Source

4. STAGE 1 MODEL AND SCENARIOS

The following section outlines the development of intervention scenarios to be tested in the Stage 1 Pilot Area micro-simulation model development.

The working group (Ramboll, JA Consult, Digital Penang and MBPP) have held a number of meetings to discuss the intervention scenarios that will be tested in the Stage 1 Trial Micro-Simulation model. The basis for developing intervention options was the outcomes derived from the Penang Transport Masterplan 2030 (PTMP) and the Penang Green Transport Plan (PGTP), the latter gave a number of specific proposals for the Georgetown area which have broadly been adopted in the scenarios outlined below.

Four scenarios have been developed each with a different focus. The scenarios are tested in the calibrated pilot area micro-simulation model. Following completion of the Task Order/Pilot Project intervention, the models will be given to Digital Penang and MBPP who can then test further interventions in the future.

The intervention scenarios include:

- Scenario 1: Pedestrian and Cyclist Priority
- Scenario proposed for this study focuses on providing priority pedestrian and cyclist corridors in the core area of Georgetown
- Scenario 2: Traffic Improvements
- In this scenario, emphasis is given to understand the change in overall road network performance after adopting proposed road network improvements.
- Scenario 3: Public Transport Improvements
- Main objective of this scenario is to understand the impact of implementation of dedicated public transport lanes on some sections of the study area on the road network performance.
- Scenario 4: Traffic Impact of New Development
- Impact of additional traffic on road network due to new proposed developments is tested in this scenario.

Proposed detailed interventions in each scenario have been outlined below. Scenario development for Stage 2 will be conducted following the completion and presentation of Stage 1 in order to give stakeholders a clear understanding of the micro-simulation modelling strengths and capabilities.

4.1 Study Area and Boundary for Stage 1

Trail study area contains 16 junctions in total and details are as below:

- Junction 1: Pengkalan Road/Lebuh Downing
- Junction 2: Pengkalan Road/Gat Lebuh Gereja
- Junction 3: Pengkalan Road/Gat Lebuh China
- Junction 4: Pengkalan Road/Gat Lebuh Pasar
- Junction 5: Pengkalan Road/Gat Lebuh Chulia
- Junction 13: Lebuh Victoria/ Gat Lebuh Chulia
- Junction 14: Lebuh Victoria/ Gat Lebuh Pasar
- Junction 15: Lebuh Victoria/ Gat Lebuh China
- Junction 16: Lebuh Pantai/ Pesara King Edward
- Junction 17: Lebuh Pantai/ Lebuh Downing
- Junction 18: Beach Street/ Lebuh Union
- Junction 19: Beach Street/ Bishop Street
- Junction 20: Beach Street/ Gat Lebuh Gereja
- Junction 21: Beach Street/ Gat Lebuh China
- Junction 22: Beach Street/ Gat Lebuh Pasar

- Junction 23: Beach Street/ Gat Lebuh Chulia

The junctions are shown in the figure below, with the wider area model boundary in red and the Stage 1 Trial Model area in green.

Figure 4-1 Model Area

Trial study area model has been coded using information obtained from on-site surveys. Junction configurations and geometry was also validated during on-site traffic surveys and the model was updated to reflect any on-site changes observed.

4.2 Stage 1 Model Zoning System

The zoning system that is adopted for the trail study area is as shown in the figure given below. Zones represent the entry and exit points of traffic models, where vehicular traffic arrives and departs the network. Other zones represent parking areas where vehicles will dwell for a period of time after entering the network, prior to departing from the network.

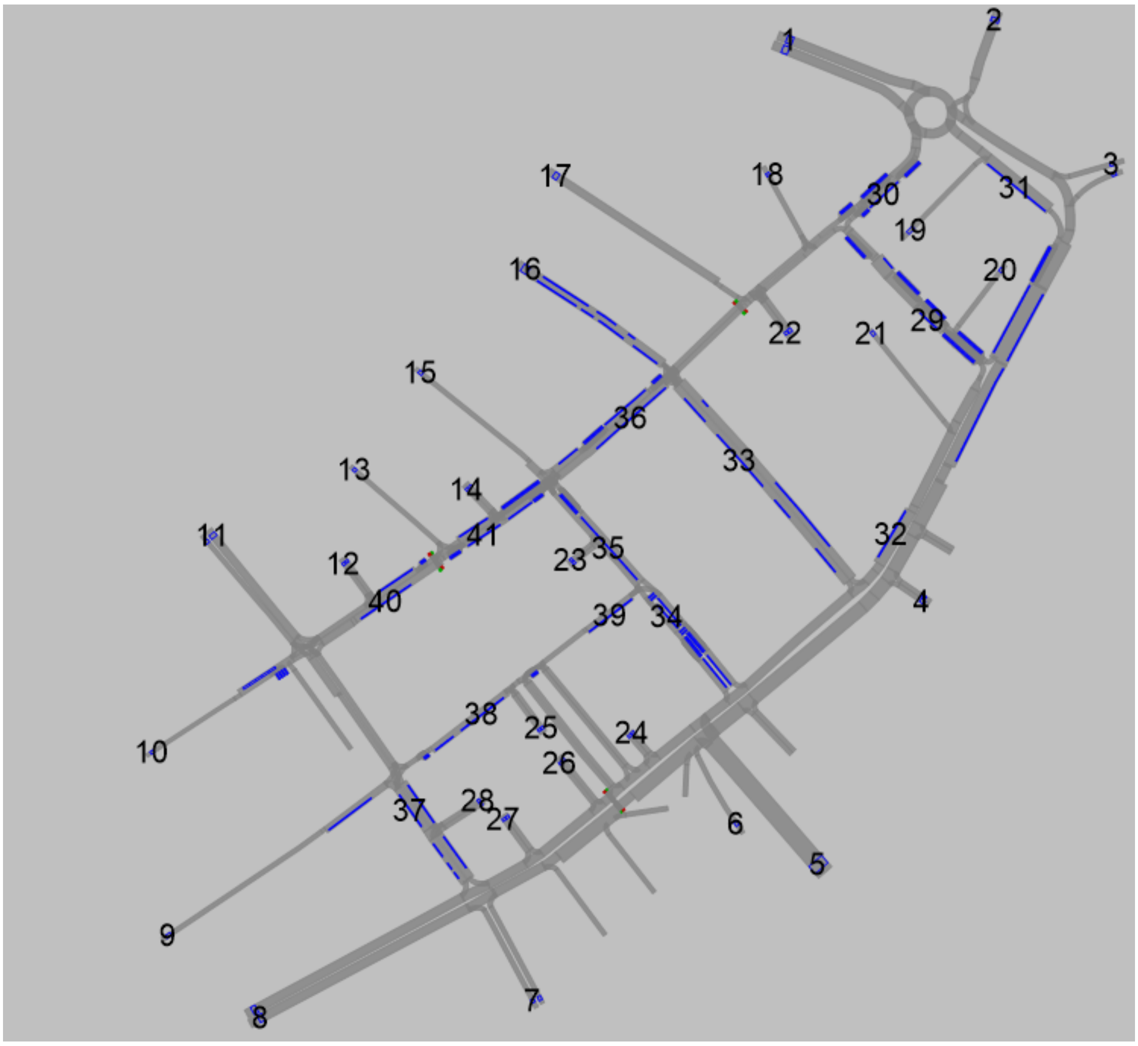


Figure 4-2 Zoning System

The figure above shows the location of zones bringing traffic into and out of the model, as well as parking areas. The following table gives a description of zone purpose.

4.3 Study Methodology

In developing a transport model, the aim is to accurately reflect on-site traffic behaviors, volumes routing and congestion levels. Traffic volumes at junctions will be collected in both morning (AM) and afternoon (PM) peak hours through video-surveys, and a process of matrix estimation is undertaken to translate traffic volumes to a matrix representing the origins and destinations of all vehicles into and out of the network.

Date and processed as contained in this Calibration Report is aimed at developing a base year simulation model which accurately represents the trip characteristics and observed volume on the ground. This base year model, once properly calibrated, would provide the project with a good basis to test traffic schemes and future traffic volume with. The entire model development and calibration proceed contains the following steps, which are illustrated further with more details in the subsections of this report.

1. **Matrix Estimation**: to translate survey traffic volume to simulation model input. In this step, the volume collected in both AM and PM peak hours through primary surveys is converted to a unified unit called Passenger Car Unit (PCU) volumes and utilized for matrix estimation to derive matrices.
2. **Model Calibration with Turn Volume**: to ensure model value match with observed value, per each turning movements at traffic junctions.
3. **Split Matrices**: to separate the uniformed matrices based on PCU value to each individual vehicle types. It is done based on traffic proportion obtained through surveys to get individual vehicular demand.
4. **Segregate Parking Demand**: parking demand need to be added in the model due to the presence of on-street and off-street parking bays in the study are. Parking demand for cars and motorcycle are extracted from their respective matrices to replicate parking in the model.
5. **Model Calibration with Queue**: a final check of modeled value versus observed value. As traffic queues are the final results of the relationship between traffic capacity and demand, it is most suitable to be selected as the final check, once all inputs to the model are completed.

Detailed description is provided in below sections. Methodology adopted for Stage 1 area Vissim model is outlined in the flow chart given below.

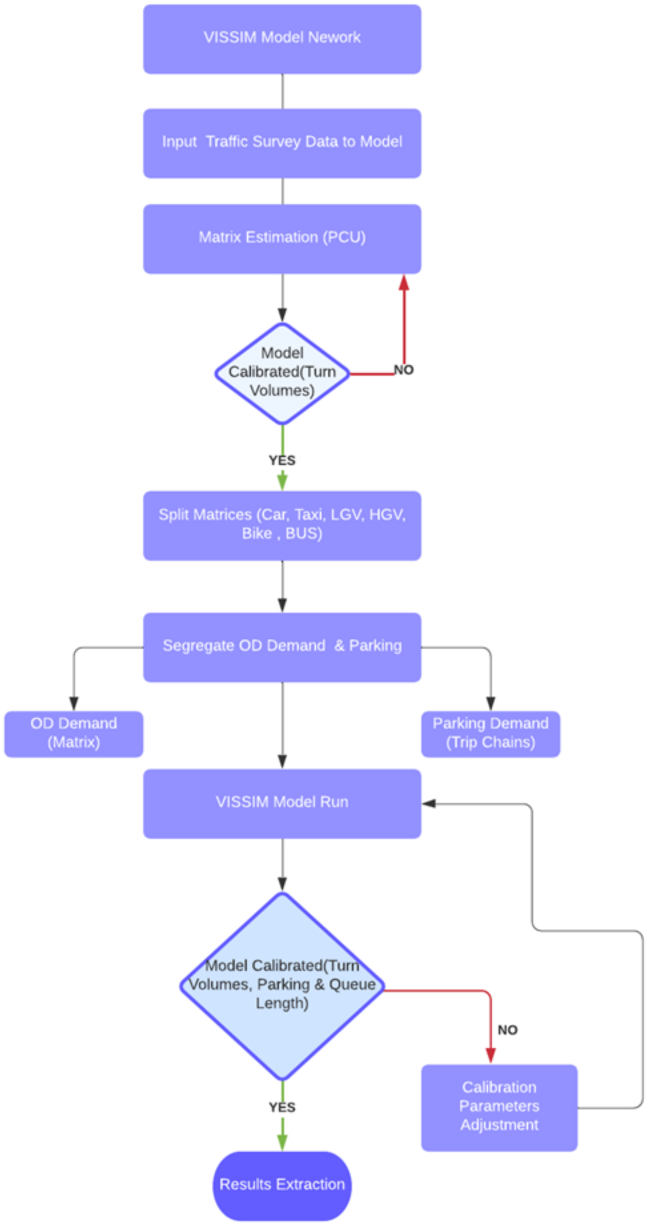


Figure 4-3 Study Methodology

4.3.1 Matrix Estimation

Matrix estimation module in Vissim is used along with the observed volume from surveys to derive matrices in both AM and PM peak. Unit matrix as a start is used to estimate the final matrices based on the observed counts as turn volumes. Several iterations are run in the process to arrive at the final matrix to be adopted for the model.

Vissim uses the least squares method in the matrix estimation procedure. The total of squares of the difference between the count data and volumes, and the total of squares of the differences between the original and corrected matrix values is minimized. Using ‘squares’ allows negative and positive differences to be treated equally. Origin-Destination pairs with a volume of zero is not adjusted.

As an example, AM PCU Matrix derived from matrix estimation using turn counts from surveys is shown in figure below.

The matrix has “Origins”, which means the zone the trip is departing from, in rows. While, “Destinations”, which means the zone the trip is arriving at, are in columns.

Taking the cell marked in green in the table below, this value refers to the number of trips traveling from Zone 2 to Zone 3.

Table 4-1 PCU Matrix AM Peak

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0	0	135	83	0	117	36	206	1	0	1	23	0	0	0	24	0	0	0	102	22	1	0	0	42	0	0	15
2	122	0	0	0	0	0	0	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	72	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	124	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	96	0	1	0	0	1	0	89	0	0	0	0	0	0	0	0	0	21	0	0	0	0	19	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	221	0	100	49	0	83	17	0	4	0	244	50	12	35	0	75	0	144	0	68	45	152	147	125	159	135	135	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	1	29	0	129	51	88	61	0	1	0	0	0	0	0	0	0	0	0	0	0	16
11	0	0	0	0	0	0	0	0	54	0	0	16	55	26	0	6	0	0	0	0	0	43	14	0	0	12	12	41
12	0	0	0	0	0	0	0	0	0	0	0	0	38	9	0	60	0	0	0	0	0	59	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	21	0	19	43	1	0	0	51	0	17	0	0	0	61	0	0	0	0	0	7
15	0	0	0	0	0	0	0	0	18	0	16	40	1	1	0	80	0	39	0	0	0	91	0	0	0	0	0	5
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
17	132	0	11	0	0	0	0	83	0	0	0	0	0	0	0	0	0	84	0	0	0	9	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	125	0	0	0	0	0	0	75	12	0	0	29	0	0	0	30	0	74	0	0	41	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	62	0	34	0	0	0	74	0	0	0	0	0	0
24	96	0	0	0	0	0	0	47	0	0	0	0	0	0	0	0	0	20	0	0	0	0	21	0	0	0	0	0
25	0	0	0	0	0	0	0	0	24	0	22	46	0	0	0	0	0	0	0	0	0	33	36	0	0	0	0	10
26	87	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	10	0	0	0	0	14	0	0	0	0	0
27	87	0	0	0	0	0	0	38	4	0	0	0	0	0	0	0	0	11	0	0	0	0	14	0	0	1	0	0
28	58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

4.3.2 Model Calibration with Turn Volumes

During the matrix estimation process, inputs from traffic survey data was used to correct the matrix and calibrate the model to be in line with on-site conditions.

In this process, there is a transport engineering measurement called GEH statics to be used as an important parameter is estimated for every iteration to make the matrices fit for purpose.

The GEH Statistic is designed to compare two sets of traffic volumes. Using the GEH Statistic avoids some pitfalls that occur when using simple percentages to compare two sets of volumes. This is because the traffic volumes in real-world transportation systems vary over a wide range. The GEH statistic reduces this problem because the GEH statistic is non-linear, a single acceptance threshold based on GEH can be used over a wide range of traffic volumes. The formula for GEH statistics is:

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}}$$

where M is the hourly traffic volume from the traffic model and C is the real-world hourly traffic count

An iterative procedure will be done in the calibration process until GEH for the observed and modelled data points is less than 5 and the resultant matrix with more than 85% percentage of links with GEH<5 is deemed fit-for-purpose.

An example of the model calibration with turn volumes are shown in figures below with the respective GEH values represented in the results table.

Table 4-2 Example Results before Turn Volume Calibration

2022 AM Peak											
Junction	Approach	2022 Volume	Modelled Volume	GEH	GEH<5	Junction	Approach	2022 Volume	Modelled Volume	GEH	GEH<5
1	J1-W-Left	1452	1455	0.08524	YES	18	J18-W-Left	145	219	7	NO
	J1-E-Right	304	280	1.41943	YES		J18-W-Through	636	465	3	YES
	J1-E-Through	1022	750	9.13802	NO		J18-E-Right	61	235	3	YES
2	J2-W-Left	172	238	4.60964	YES		J18-E-Through	182	270	1	YES
	J1-W-Through	1447	1512	1.69631	YES	19	J19-W-Through	480	441	1	YES
	J2-N-Left	68	73	0.59549	YES		J19-N-Left	327	317	7	NO
	J2-E-Through	1016	1082	2.03777	YES		J19-E-Through	216	244	9	NO
3	J3-W-Left	245	245	0.01598	YES	20	J20-W-Left	180	245	0	YES
	J3-W-Through	1553	1564	0.27232	YES		J20-W-Through	425	372	15	NO
	J3-N-Left	65	68	0.36788	YES		J20-W-Right	22	41	5	NO
	J3-E-Through	1016	1082	2.03777	YES		J20-S-Left	25	35	8	NO
4	J4-W-Left	38	0	8.7178	NO		J20-S-Through	47	76	1	YES
	J4-W-Through	1593	236	44.8733	NO		J20-S-Right	23	45	7	NO
	J4-N-Left	3	0	2.44949	YES		J20-E-Left	31	57	0	YES
	J4-E-Through	958	565	14.2416	NO		J20-E-Through	163	129	14	NO
5	J5-W-Left	411	576	7.41033	NO		J20-E-Right	26	53	0	YES
	J5-W-Through	1537	1100	12.0349	NO	21	J21-W-Through	315	288	0	YES
	J5-N-Left	82	83	0.08263	YES		J21-W-Right	12	9	4	YES
	J5-E-Through	800	930	4.40377	YES		J21-S-Left	156	135	0	YES
	J5-S-Left	15	13	0.60404	YES		J21-S-Right	127	188	19	NO
13	J13-N-Left	74	61	1.55045	YES		J21-E-Left	15	20	6	NO
	J13-N-Through	118	116	0.20812	YES		J21-E-Through	192	148	3	YES
	J13-N-Right	168	153	1.16889	YES		J21-N-Left	183	209	12	NO
	J13-S-Left	50	42	1.15047	YES		J21-N-Right	133	81	1	YES
	J13-S-Through	331	371	2.148	YES		J21-N-Through	17	20	6	NO
	J13-S-Right	208	164	3.20683	YES	22	J22-W-Through	173	248	6	NO
14	J14-W-Right	4	0	2.82843	YES		J22-W-Left	260	185	5	YES
	J14-W-Through	205	298	5.86427	NO		J22-E-Through	545	414	6	NO
	J14-N-Right	10	0	4.47214	YES	23	J22-W-Left	114	124	1	YES
15	J15-W-Left	165	190	1.89456	YES		J22-W-Through	156	195	0	YES
	J15-W-Right	29	98	8.65889	NO		J22-W-Right	69	41	5	NO
	J15-N-Through	29	98	8.65889	NO		J22-S-Through	229	257	19	NO
	J15-S-Through	235	193	2.87059	YES		J22-S-Right	55	65	0	YES
16	J16-W	1427	1541	2.94956	YES		J22-E-Left	276	164	0	YES
	J16-N	807	881	2.54719	YES		J22-E-Right	150	62	1	YES
	J16-E	37	90	6.65103	NO		J22-N-Left	191	128	1	YES
17	J17-S-Right	1049	1130	2.44655	YES		J22-N-Through	278	153	17	NO
	J17-S-Left	465	411	2.60081	YES						
	J17-W-Through	434	404	1.44759	YES						
Proportion of Turns with GEH<5											62%

It can be told from the table above that the proportion of movements with GEH value less than 5 is at 62% before the model calibration with turn volume, which does not meet the criteria set at 85% for the model to be considered fit for purpose.

The matrix estimation process is then re-run with the inputs from site surveyed traffic volumes to correct the matrix. After this iterative process, the following results can be obtained from the calibrated model. As shown in the table, the proportion of movements with GEH value less than 5 is at 92%, reaching the criteria deeming this model well-calibrated.

Table 4-3 Example Results after Turn Volume Calibration

2022 AM Peak											
Junction	**Approach**	**2021 Volume**	**Modelled Volume**	**GEH**	**GEH<5**	**Junction**	**Approach**	**2021 Volume**	**Modelled Volume**	**GEH**	**GEH<5**
1	J1-W-Left	1452	1455	0.09	YES	18	J18-W-Left	219	238	1.224521	YES
	J1-E-Right	304	280	1.42	YES		J18-W-Through	465	411	2.600811	YES
	J1-E-Through	1022	981	1.31	YES		J18-E-Right	235	193	2.870587	YES
2	J2-W-Left	172	95	6.64	NO		J18-E-Through	270	247	1.446431	YES
	J1-W-Through	1447	1512	1.7	YES	19	J19-W-Through	441	452	0.508813	YES
	J2-N-Left	68	73	0.6	YES		J19-N-Left	317	307	0.594684	YES
	J2-E-Through	1016	1082	2.04	YES		J19-E-Through	244	231	0.827112	YES
3	J3-W-Left	245	245	0.02	YES	20	J20-W-Left	245	245	0.015976	YES
	J3-W-Through	1553	1564	0.27	YES		J20-W-Through	372	426	2.691287	YES
	J3-N-Left	65	59	0.76	YES		J20-W-Right	41	14	5.148698	NO
	J3-E-Through	1016	1082	2.04	YES		J20-S-Left	35	0	8.3666	NO
4	J4-W-Left	38	0	8.72	NO		J20-S-Through	76	69	0.822108	YES
	J4-W-Through	1593	1594	0.01	YES		J20-S-Right	45	25	3.332414	YES
	J4-N-Left	3	0	2.45	YES		J20-E-Left	57	60	0.392232	YES
	J4-E-Through	958	859	3.28	YES		J20-E-Through	129	119	0.94388	YES
5	J5-W-Left	411	576	7.41	NO		J20-E-Right	53	53	0.034381	YES
	J5-W-Through	1537	1537	0.01	YES	21	J21-W-Through	288	292	0.234888	YES
	J5-N-Left	82	83	0.08	YES		J21-W-Right	9	0	4.242641	YES
	J5-E-Through	800	930	4.4	YES		J21-S-Left	135	139	0.32053	YES
	J5-S-Left	15	13	0.6	YES		J21-S-Right	188	193	0.38025	YES
13	J13-N-Left	74	61	1.55	YES		J21-E-Left	20	0	6.324555	NO
	J13-N-Through	118	116	0.21	YES		J21-E-Through	148	119	2.555574	YES
	J13-N-Right	168	153	1.17	YES		J21-N-Left	209	202	0.488306	YES
	J13-S-Left	50	42	1.15	YES		J21-N-Right	81	74	0.85332	YES
	J13-S-Through	331	371	2.15	YES		J21-N-Through	20	0	6.324555	NO
	J13-S-Right	208	164	3.21	YES	22	J22-W-Through	248	248	0.015871	YES
14	J14-W-Right	4	0	2.83	YES		J22-W-Left	185	193	0.545906	YES
	J14-W-Through	205	211	0.42	YES		J22-E-Through	414	374	2.007521	YES
	J14-N-Right	10	0	4.47	YES	23	J22-W-Left	124	115	0.86995	YES
15	J15-W-Left	165	190	1.89	YES		J22-W-Through	195	188	0.487616	YES
	J15-W-Right	29	25	0.77	YES		J22-W-Right	41	14	5.148698	NO
	J15-N-Through	29	25	0.77	YES		J22-S-Through	257	313	3.340065	YES
	J15-S-Through	235	193	2.87	YES		J22-S-Right	65	59	0.762001	YES
16	J16-W	1427	1541	2.95	YES		J22-E-Left	164	161	0.215645	YES
	J16-N	807	881	2.55	YES		J22-E-Right	62	55	0.881581	YES
	J16-E	37	36	0.11	YES		J22-N-Left	128	140	1.048559	YES
17	J17-S-Right	1049	1130	2.45	YES		J22-N-Through	153	131	1.855437	YES
	J17-S-Left	465	411	2.6	YES						
	J17-W-Through	434	404	1.45	YES						
Proportion of Turns with GEH<5											92%

In addition to GEH, there is also another statistical measurement named “R-Squared” that is used to check the how well the modeled data matches the surveyed value.

R-Squared is a statistical measure in a regression model that determines the proportion of variance in the dependent variable that can be explained by the independent variable. In other words, r-squared shows how well the data fit the regression model (the goodness of fit).

The formula for calculating R-squared is:

$$R - Squared = \frac{SS_{regression}}{SS_{total}}$$

R-squared can take any values between 0 to 1. A higher r-squared indicates a better fit for the model.

Similarly to GEH, an example of the model calibration with turn volumes are shown in figures below with the respective R-Squared graph represented in the figure below.

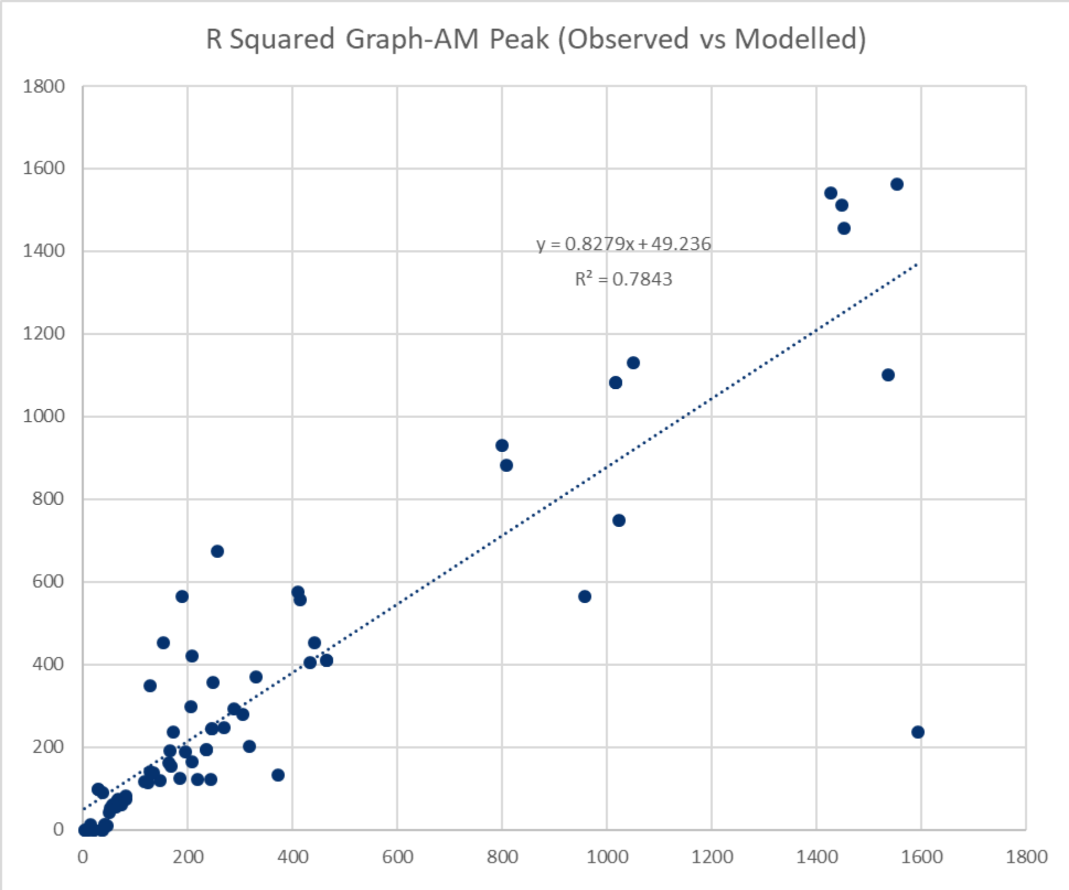


Figure 4-4 Example R-Squared Graph before Turn Volume Calibration

It can be told from the figure above that the R-Square value is at 0.7843 before the model calibration with turn volume, which indicated the modeled value is not matching the surveyed value.

The matrix estimation process as described above is then re-run with the inputs from site surveyed traffic volumes to correct the matrix. After this iterative process, the following graph can be obtained from the calibrated model. As shown in the figure, the R-Square value is at 0.992, indicating a close match between modeled values and surveyed values.

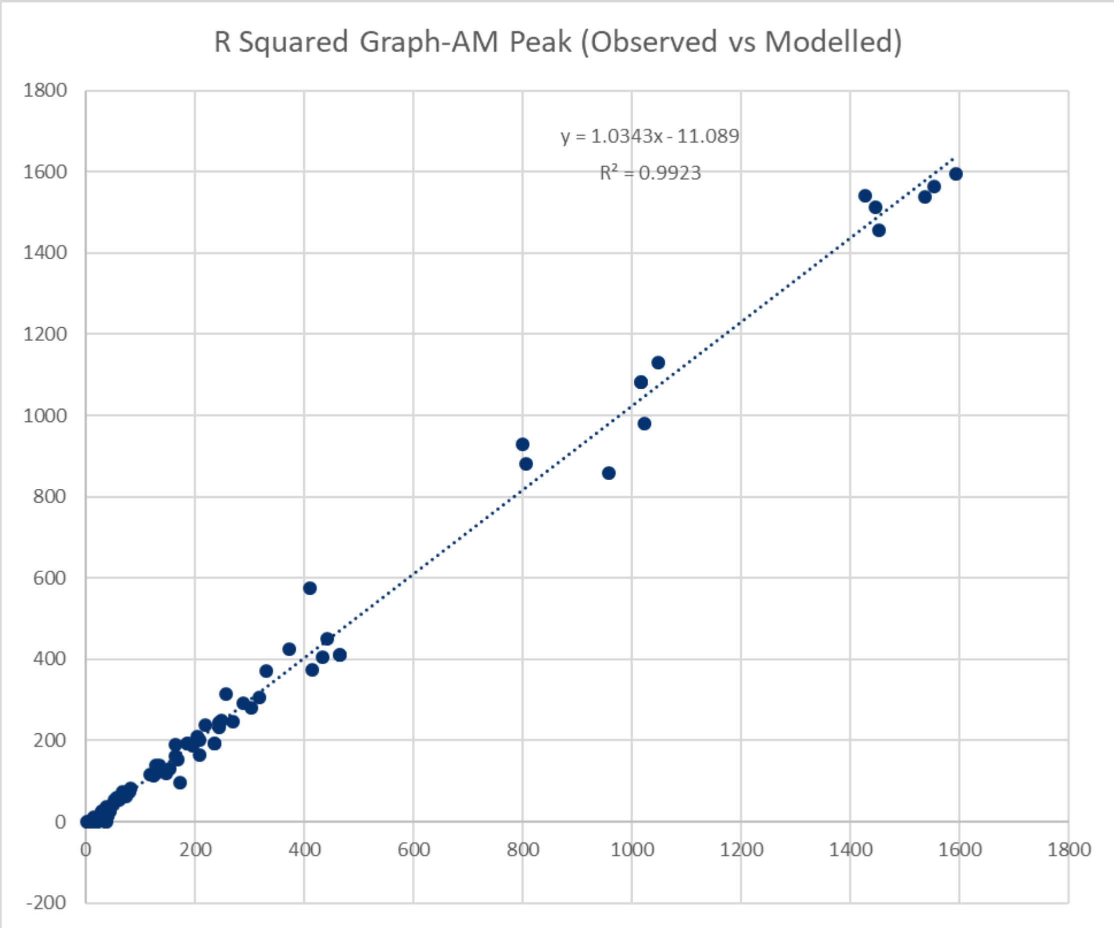


Figure 4-5 Example R-Squared Graph after Turn Volume Calibration

4.3.3 Split Matrices

Once PCU matrix is derived, it is further split into Car, Taxi, LGV, HGV and motorcycle matrices based on traffic proportion obtained from survey data as shown in figure below.

After all matrices are derived, model run is carried out and individual modelled turn counts of all the junctions are compared with surveyed turn counts and made sure that GEH requirement is met.

Table 4-4 Traffic Compositions

Junction	Mode (Total PCU)					
	Car	Taxi	LGV	HGV	Bus	Motorcycle
1	9581	146	677.5	24	969	3951
2	9169	86	587.5	24	957	3869
3	9487	118	622.5	21	972	4240
4	9346	51	595	24	873	3371.25
5	10516	67	722.5	24	795	3795.75
13	2975	19	412.5	0	759	1411.5
14	416	12	100	3	180	232.5
15	1030	20	132.5	3	180	740
16	9933	88	632.5	21	693	2649
17	6024	212	412.5	3	537	1978.5
18	3456	48	247.5	3	111	1719
19	3086	61	262.5	3	114	1875
20	3186	57	285	3	117	1486.5
21	3518	44	280	3	114	1795.5
22	2678	19	215	0	6	1710
23	4287	10	392.5	0	591	1919
Total	88688	1058	6577.5	159	7968	36744
Proportion	62.8%	0.7%	4.7%	0.1%	5.6%	26.0%

4.3.4 Segregate Parking Demand

Trip chain is used to model parking in Vissim model. After GEH requirement is met, parking demand is extracted from OD matrix of cars and motorcycles and trip chain file is created using the zone numbers, parking demand and dwell time.

Trip chain is made up of one or more trips. For example, person travelling from Home (Zone 1) to Work / Shopping / Recreation (Zone 2) and parks the vehicle there and later he travels from zone 2 to Home (Zone 3). In this example there are two activities involved and details are as below:

- Activity 1 Home to Work/Shopping/recreation
- Activity 2 Work/Shopping/recreation to Home

Trip chains combines all these trips/activities into one. In this study, real time parking is modeled through trip chains.

In order to replicate parking in model, parking spaces between the junctions is given a zone number as shown below. Trip chain file is then created using the zone numbers, parking demand and dwell time.

Detailed explanation using an example of a trip chain file for car for zone 29 in AM peak is provided below.

Table 4-5 Trip Chain example

Vehicle	Vehicle type	Origin	Departure	Destination	Coordinates	Activity	Minimum dwell time	Departure	Destinatio n	Coordinate	Activity	Minimum dwell time
1	101	8	1193	29	(-142.4540, 9.9838)	101	150	1420	1	(0.0,0.0)	102	0
2	101	8	944	29	(-142.4540, 9.9838)	101	150	1171	1	(0.0,0.0)	102	0
3	**101**	**8**	**1364**	**29**	**(-142.4540, 9.9838)**	**101**	**150**	**1591**	**1**	**(0.0,0.0)**	**102**	**0**
4	101	8	3565	29	(-105.9241, 4.7378)	101	150	3792	1	(0.0,0.0)	102	0
5	101	8	3747	29	(-105.9241, 4.7378)	101	150	3974	1	(0.0,0.0)	102	0
6	101	8	2162	29	(-105.9241, 4.7378)	101	150	2389	1	(0.0,0.0)	102	0

In the cell highlighted in above table, vehicle-3 is departing from zone **8** and is travelling to zone **29** (parking between J1 and J17). In Zone 29, vehicle will park for a time of **150** sec and later will travel to zone **1**. Similar approach is done to model all the parking spaces in the model.

Figure 4-6 Travel Pattern in Trip Chain

4.3.5 Model Calibration with Queues

After all the steps above, the model is further calibrated with queue length data recorded from the on-site traffic survey.

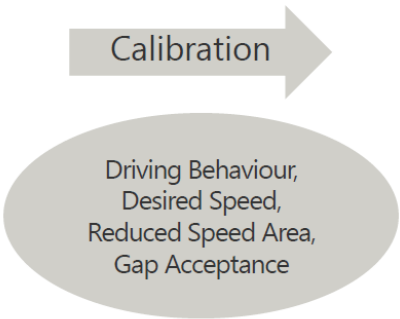
Queues are formed as a results of all the factor impacting vehicles in the network. It could be due to traffic volume, network capacity, signal configuration, vehicle speed, or driving behavior.

With traffic volume and network capacity already calibrated in the previous steps of the model calibration process described in sections above, queue calibration provides a chance for the model to be calibrated against driving behavior changes. These could include:

- Driving behavior
- Signal configuration
- Vehicle speed
- Reduction of speed at turns
- Gap acceptance

An example of the queue length calibration process is show in the figure below.

Queue Length (m)		
Before Change in Driving behaviour Parameters		
Movement	Observed	Modelled
J2-W-Through	110	40
J2-W-Right	110	40
J2-S-Left	50	20
J2-S-Right	50	20
J2-E-Left	120	80
J2-E-Through	120	80



Queue Length (m)		
After Change in Driving behaviour Parameters		
Movement	Observed	Modelled
J2-W-Through	110	105
J2-W-Right	110	105
J2-S-Left	50	50
J2-S-Right	50	50
J2-E-Left	120	125
J2-E-Through	120	125

Figure 4-7 Example of Queue Calibration

After calibration, modeled queue lengths will generate similar value to observed queue length, which indicates the model replicates the traffic situation on-site and is a good representation of the real-work traffic operations and network performance.

4.4 Scenario 1: Pedestrian and Cyclist Priority

Scenario 1 proposed for this study focuses on providing priority pedestrian and cyclist corridors in the core area of Georgetown.

These facilities would mean pedestrians and cyclists will enjoy wider space when commuting through the city and be given priorities at key junctions. Overall, these measures are designed to improve the pedestrian experience and reduce the travel time needed through the city, resulting in a larger shift from traditional private car mode to walking and cycling.

Vissim simulation model is being used to test out the effectiveness on the priority scheme, as well as the impact on vehicular traffic when these schemes are implemented. The detailed traffic scheme changes are documented as in the figure and table below.

Figure 4-8 Scenario 1 Scheme

Individual traffic schemes proposed within this scenario are outlined, based on the location in the model area, in the table below.

Table 4-6 Scenario 1 Scheme Details

Scenario 1		
Theme	**Road**	**Details (as discussed with Digital Penang)**
Pedestrian Priority	**Gat Lebuh China:** Pedestrian Walk 1 & 2	To expand the pedestrian walk with the following measurement: 1) Pedestrian walk total width: 5.5m with separation as follows: a) Walking path: 2.4m b) Small retail street: 2.1m c) Landscaping: 1m Proposed pedestrian priority facilities on Gat Lebuh China are shown in Figure 4-9 and Figure 4-10.
Pedestrian Priority	**Pengkalan Weld Street:** Pedestrian Walk 1 & 2	To expand the pedestrian walk with the following measurement: 1) Pedestrian walk total width: 4m with separation as follows: a) Walking path: 2.4m b) Landscaping: 1.5m Figure 4-11 and Figure 4-12 below provides detailed information of Pengkalan weld street in scenario-1.
Pedestrian Priority	**Pengkalan Weld Street:** Pedestrian Crossing 1	Propose to maintain the location with several upgrades as follows: i) Using Traffic Clamed Crossing with: - Actuated Signalling - Vertical speed control element set 5m to 10m from the cross. - Use pedestrian-activated warning lights, flashing beacons, or High Intensity Activated Crosswalks (HAWK) to increase motorists' awareness and improve pedestrian safety. 2) Ideally, pedestrian crossing is place at the inter-junction or at the mid-block. As existing crossing exist in the middle of Gat Lebuh Pasar, propose to close the road. Figure 4-22 provides pictorial information on vertical speed control and actuated signals.
Pedestrian Priority	**Pengkalan Weld Street:**	Pedestrian Cross location: 1) Shall place max 100m from Downing Street. If it takes a person more than 3 minutes to walk to a pedestrian

Scenario 1		
Theme	**Road**	**Details (as discussed with Digital Penang)**
	Pedestrian Crossing 2	crossing, he or she may decide to cross along a more direct, but unsafe or unprotected, route. 2) Install a pedestrian crossing where there is a significant pedestrian desire line. In this case pedestrian from Downing Street to Swettenham Pier. 3) A pedestrian crossing should be at least 3 m wide. 4) Using Traffic Clamed Crossing with: - Actuated Signalling - Vertical speed control element set 5m to 10m from the cross. - Use pedestrian-activated warning lights, flashing beacons, or High Intensity Activated Crosswalks (HAWK) to increase motorists' awareness and improve pedestrian safety. Figure 4-22 provides pictorial information on vertical speed control and actuated signals.
Pedestrian Priority	**Beach Street:** Pedestrian Walk 1 & 2	To expand the pedestrian walk with the following measurement: 1) Pedestrian walk total width: 3m with separation as follows: a) Walking path: 2.4m b) Street Light: 0.6m Proposed pedestrian priority facilities on beach street are shown in Figure 4-13 and Figure 4-14.
Pedestrian Priority	**Lebuh Victoria:** Pedestrian Walk 1 & 2	To expand the pedestrian walk with the following measurement: 1) Pedestrian walk total width: 3m with separation as follows: a) Walking path: 2.4m b) Street Light: 0.6m Figure 4-15 and Figure 4-16 below provides detailed information of Lebuh Victoria in scenario-1.
Pedestrian Priority	**Gat Lebuh Gereja:**	To expand the pedestrian walk with the following measurement:

Scenario 1		
Theme	**Road**	**Details (as discussed with Digital Penang)**
	Pedestrian Walk 1 & 2	1) Pedestrian walk total width: 5.5m with separation as follows: a) Walking path: 2.4m b) Small retail street: 2.1m c) Landscaping: 1m Proposed pedestrian priority facilities on Gat Lebuh Gereja are shown in Figure 4-17 and Figure 4-18.
Pedestrian Priority	**Downing Street:** Pedestrian Walk 1 & 2	To expand the pedestrian walk with the following measurement: 1) Pedestrian walk total width: 5.5m with separation as follows: a) Walking path: 2.4m b) Landscaping: 1.5m Pedestrian priority facilities provided on Downing Street are Shown in Figure 4-19 and Figure 4-20.
Cyclist Priority	**Gat Lebuh China:** Bike Lane 1 & 2	Bike lane to be designed using Curbside Buffered Cycle Lane type, with the measurement as follows: 1) Lane width: 1.8m 2) Demarcation width: 1m Cycle path provided is shown in Figure 4-9 and Figure 4-10
Cyclist Priority	**Pengkalan Weld Street:** Bike Lane 1 & 2	Bike lane to be design using Protected Cycle Lane type, with the measurement as follows: 1) Lane width: 2m 2) Demarcation width: 1m Figure 4-11 and Figure 4-12 shows the cycle path provided on Pengkalan weld.

The following images shows the comparison of existing and proposed schemes in street view and section view, as per location.

Figure 4-9 Scenario 1 Scheme Comparison Street View – Gat Lebuh China

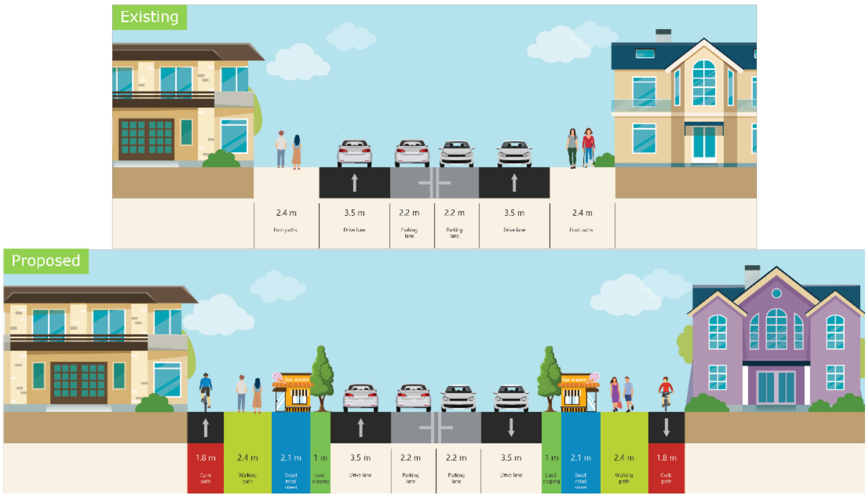


Figure 4-10 Scenario 1 Scheme Comparison Section View – Gat Lebuh China

Figure 4-11 Scenario 1 Scheme Comparison Street View – Pengkalan Weld

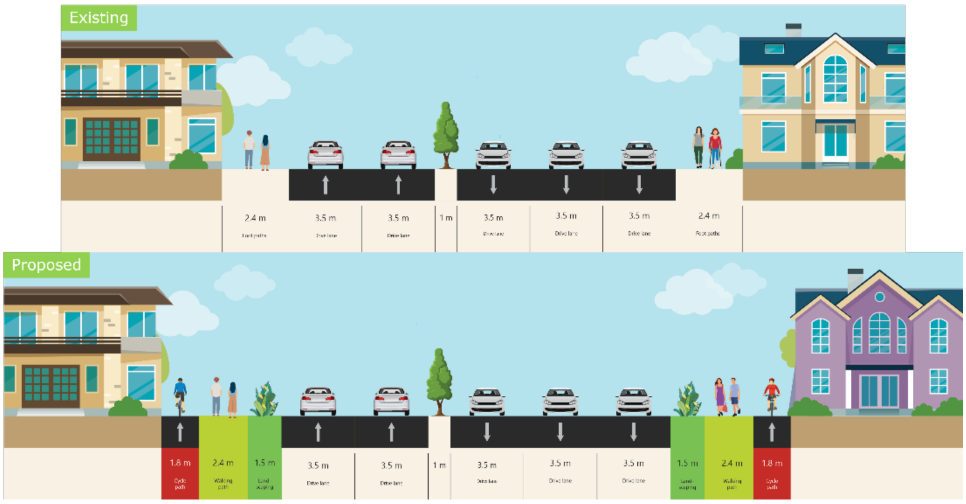


Figure 4-12 Scenario 1 Scheme Comparison Section View – Pengkalan Weld

Figure 4-13 Scenario 1 Scheme Comparison Street View – Beach Street

Figure 4-14 Scenario 1 Scheme Comparison Section View – Beach Street

Figure 4-15 Scenario 1 Scheme Comparison Street View – Lebuh Victoria

Figure 4-16 Scenario 1 Scheme Comparison Section View – Lebuh Victoria

Figure 4-17 Scenario 1 Scheme Comparison Street View - Gat Lebuh Gereja

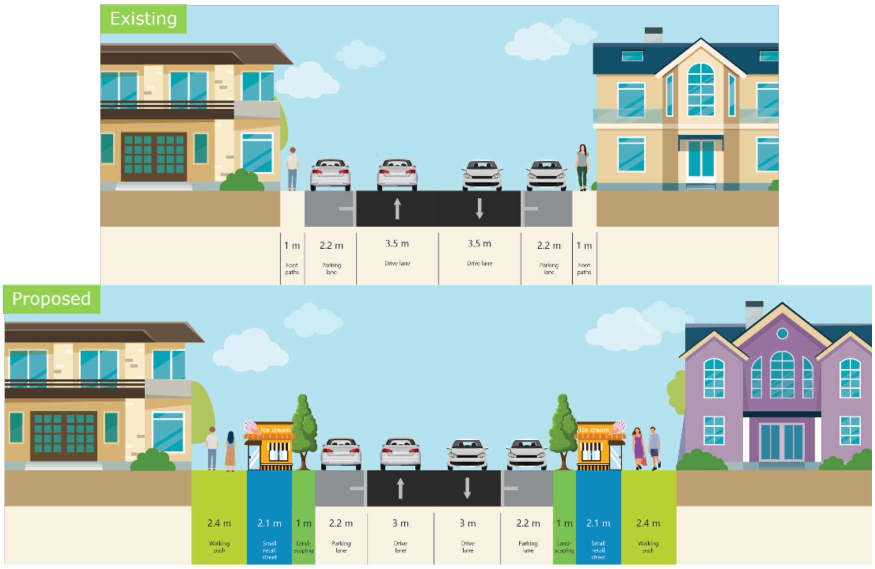


Figure 4-18 Scenario 1 Scheme Comparison Section View - Gat Lebuh Gereja

Figure 4-19 Scenario 1 Scheme Comparison Street View – Downing Street

Figure 4-20 Scenario 1 Scheme Comparison Section View – Downing Street

Main objective of this scenario is to test the impact of provision of pedestrian and cyclist priority facilities along with traffic calming measures on overall network performance. Since there is no change in vehicular demand and distribution, the OD matrix and trip chain used in this scenario is same as that of base calibrated model.

As explained, the following additional features are coded in Scenario 1:

- Walking paths on Gat Lebhu China, Pengkalan weld, Beach Street, Lebuh Victoria, Get Lebuh Gereja and Downing Street
- Small retail streets on Gat Lebhu China, Get Lebuh Gereja and Downing Street
- Landscaping on Gat Lebhu China, Pengkalan weld, Beach Street, Lebuh Victoria, Get Lebuh Gereja and Downing Street
- Actuated signals on Pengkalan weld
- Vertical speed control elements on Pengkalan weld
- Pedestrian crossings on Pengkalan weld

Below images depicts the Vissim model after inclusion of all the traffic measures for Scenario 1.

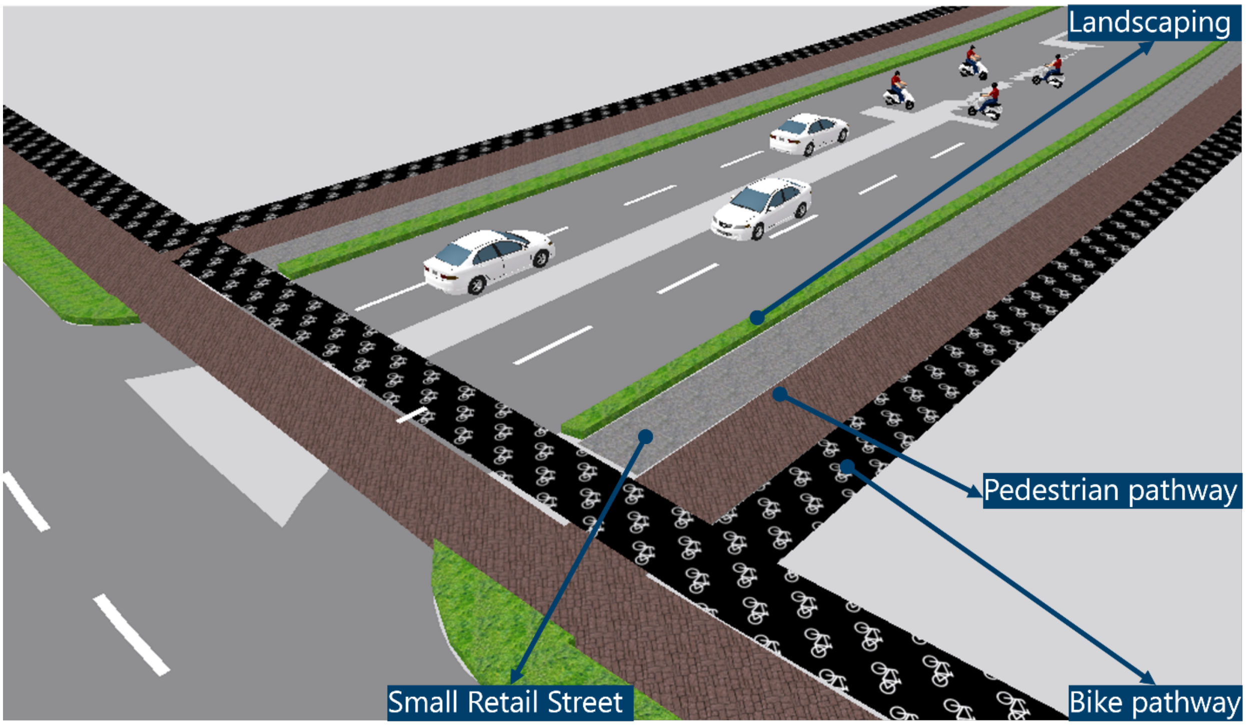


Figure 4-21 Scenario 1 - Gat Lebhu China

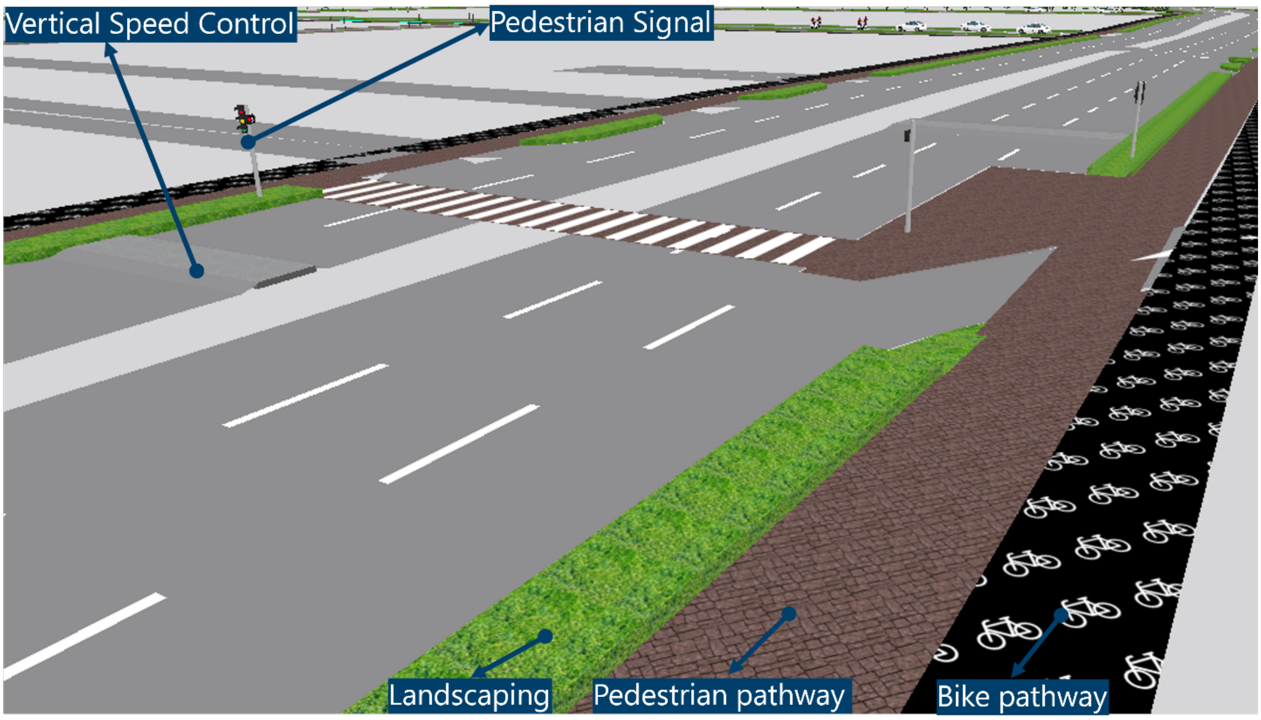


Figure 4-22 Scenario 1 - Pengkalan weld

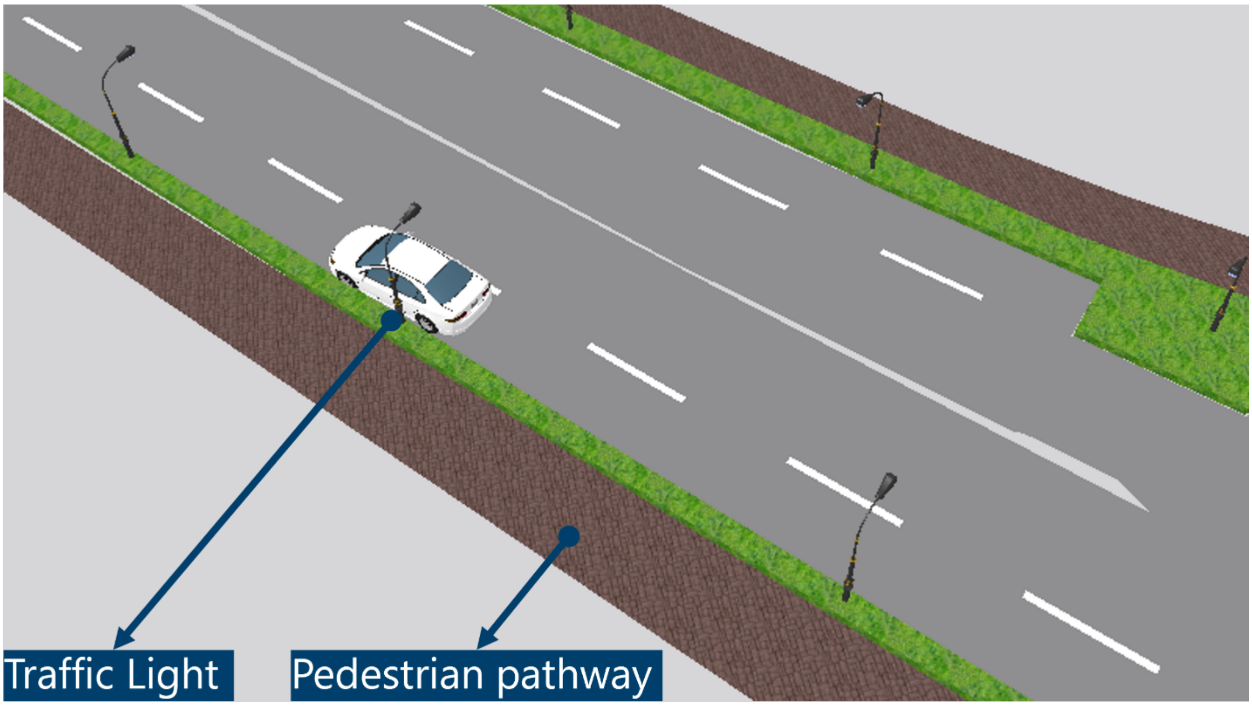


Figure 4-23 Scenario 1 - Beach Street

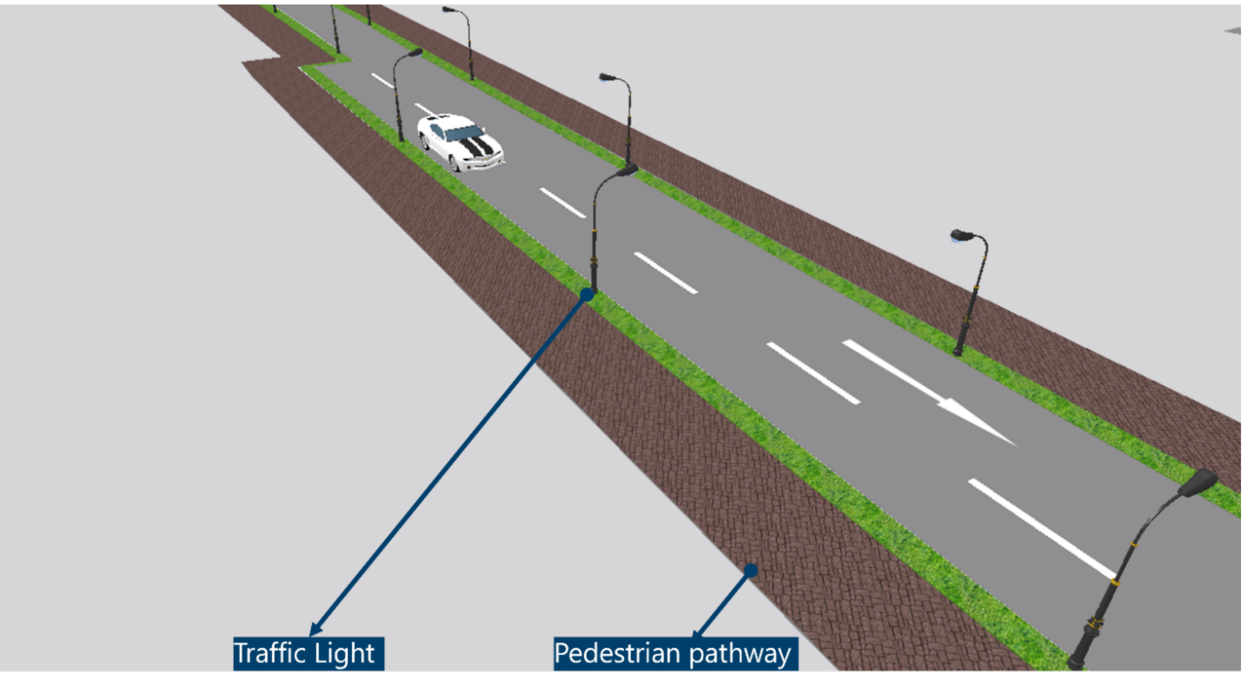


Figure 4-24 Scenario 1 – Lebuh Victoria

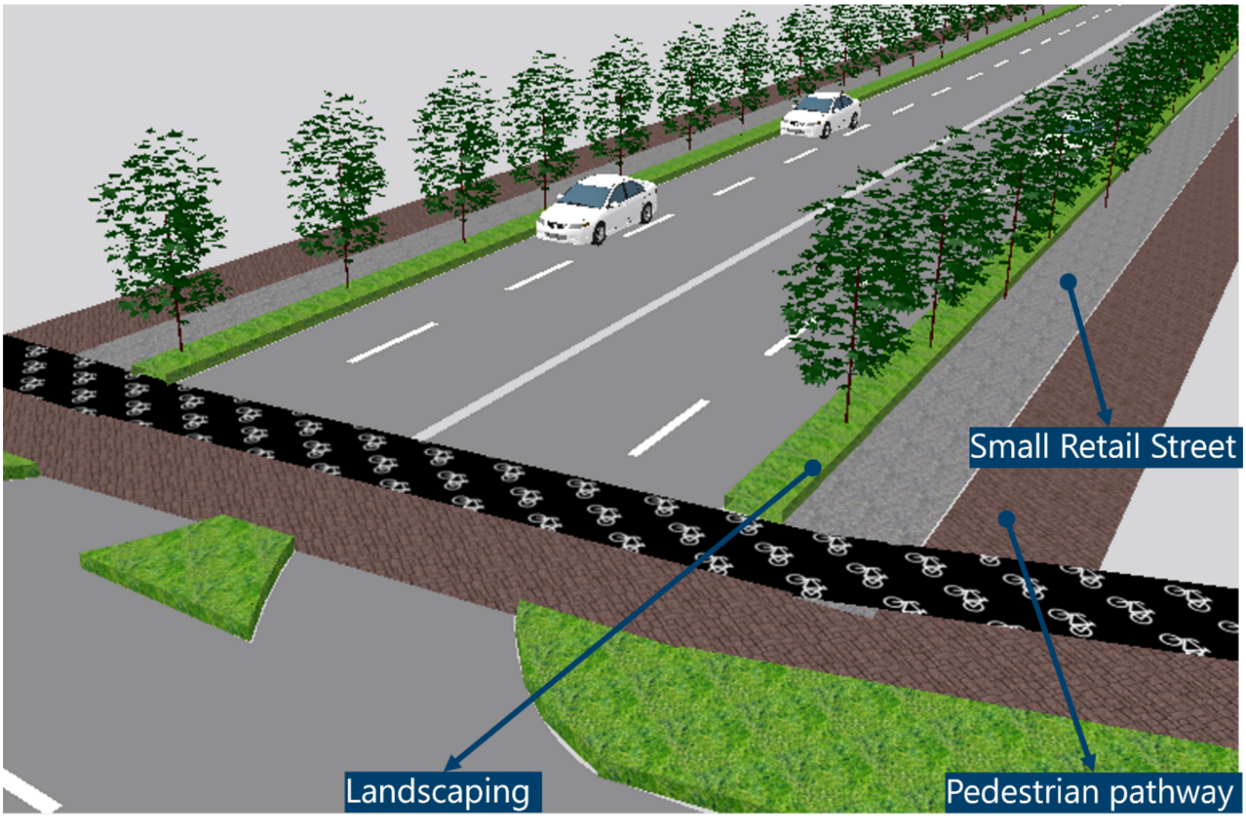


Figure 4-25 Scenario 1 – Gat Lebuh Gereja

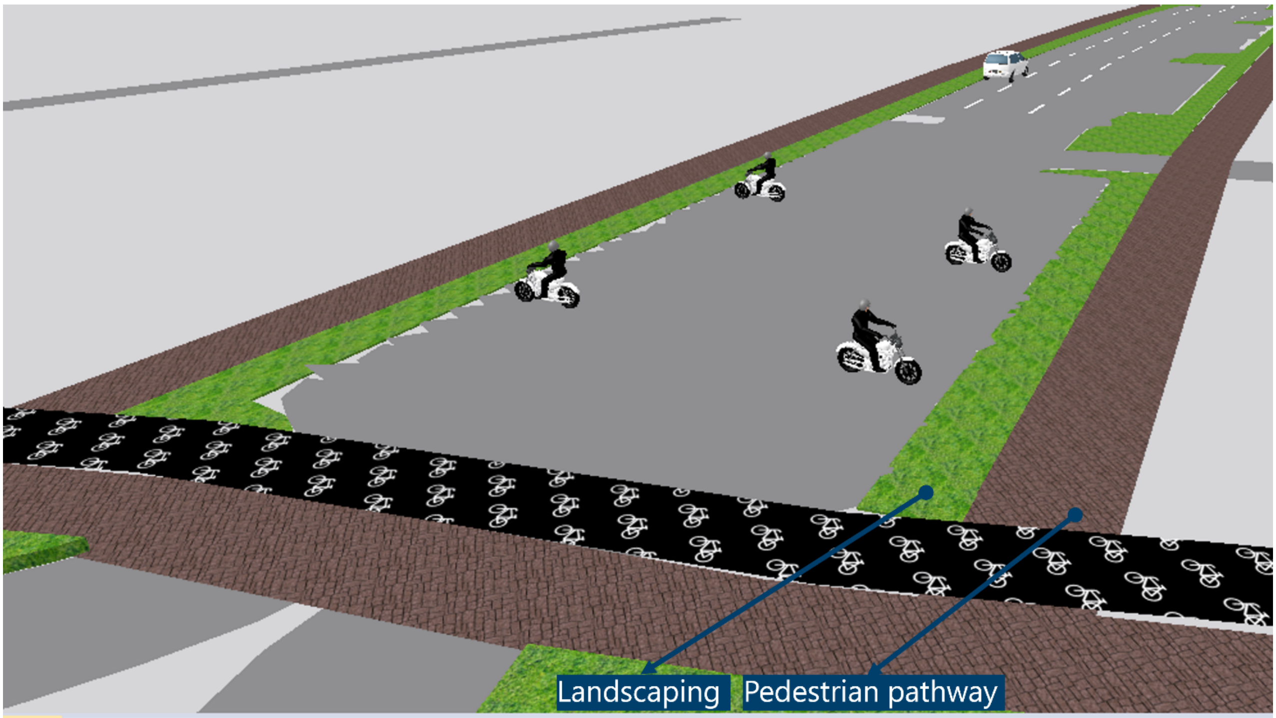


Figure 4-26 Scenario 1 – Downing Street

Because of change in road network there will be redistribution of trips and therefore there is need to develop different trip chain file for modelling parking in Vissim. Below image show the methodology adopted in Scenario 1 for Vissim model development.

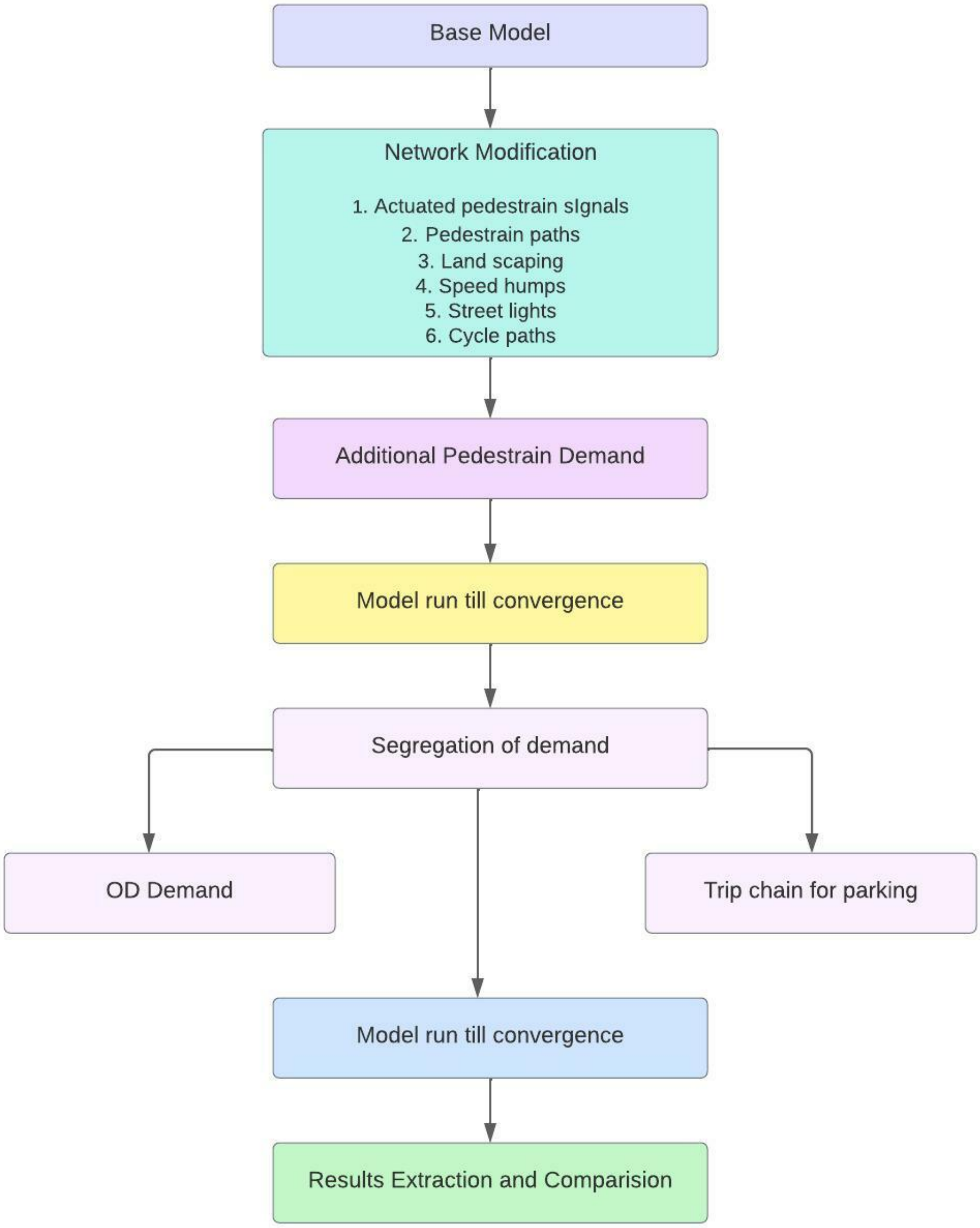


Figure 4-27 Scenario 1 – Methodology

4.5 Scenario 2: Traffic Improvements

The overall objective of this scenarios is to understand road network performance on implementation of some road network improvements. The improvements could include conversion of two-way road to one-way road, closure of road, and removal of parking.

These road network improvements are modelled in Vissim and its impact on road network performance is analyzed from model measurements of the revised model. Testing of these types of scenarios in Vissim will help decision makers to understand road network performance prior to implementation of any improvements. The detailed traffic scheme changes are documented as in the figure and table below.

Figure 4-28 Scenario 2 Scheme

Table 4-7 Scenario 2 Scheme Details

Scenario 2		
Theme	**Road**	**Details (as discussed with Digital Penang)**
Traffic Improvements	**Gat Lebuh China:** Remove Parking Spot	To remove all parking at Gat Lebuh China for giving away expansion of Pedestrian Walk with addition of space for commercial activities and landscaping. Traffic improvements proposed on Gat lebuh China in scenario-2 are shown in Figure 4-29 and Figure 4-30.
Traffic Improvements	**Beach Street:** One-Way Street	1) Introduction of 1-way street for beach street. Start from Gat Lebuh Chulia and end at Jubilee Clock Tower. 2) Widen sidewalks to provide accessibility and increased space for pedestrians and commercial activity. Alternate parking spaces with additional curb extensions, intermittent landscaping, and dedicated spaces for vendors. Figure 4-13Figure 4-14
Traffic Improvements	**Gat Lebuh Pasar:** Laneways	1) Increase the frontage area available for businesses in the city and create intimate environments by transforming laneways and alleys with active ground floor uses. 2) Maintain an accessible clear path of 3.5 m for emergency vehicle access. 3) Movable furniture can be placed in the emergency access path so long as they do not impede necessary but infrequent movements. Figure 4-33
Traffic Improvements	**Gat Lebuh Pasar:** To close	The exit of Gat Lebuh Pasar is in the middle of a pedestrian crossing. as it is a safety issue, closing of this road is proposed. Another road beside the market can be replaced as an exit road. Figure 4-33
Traffic Improvements	**Downing Street:** One-Way Street	1) Introduction of 1-way street for beach street. Start from Gat Lebuh Chulia and end at Jubilee Clock Tower. 2) Widen sidewalks to provide accessibility and increased space for pedestrians and commercial activity. Alternate parking spaces with additional curb extensions, intermittent landscaping, and dedicated spaces for vendors. Figure 4-36

The following images shows the comparison of existing and proposed schemes in street view and section view, as per location.

Figure 4-29 Scenario 2 Scheme Comparison Street View – Gat Lebuh China

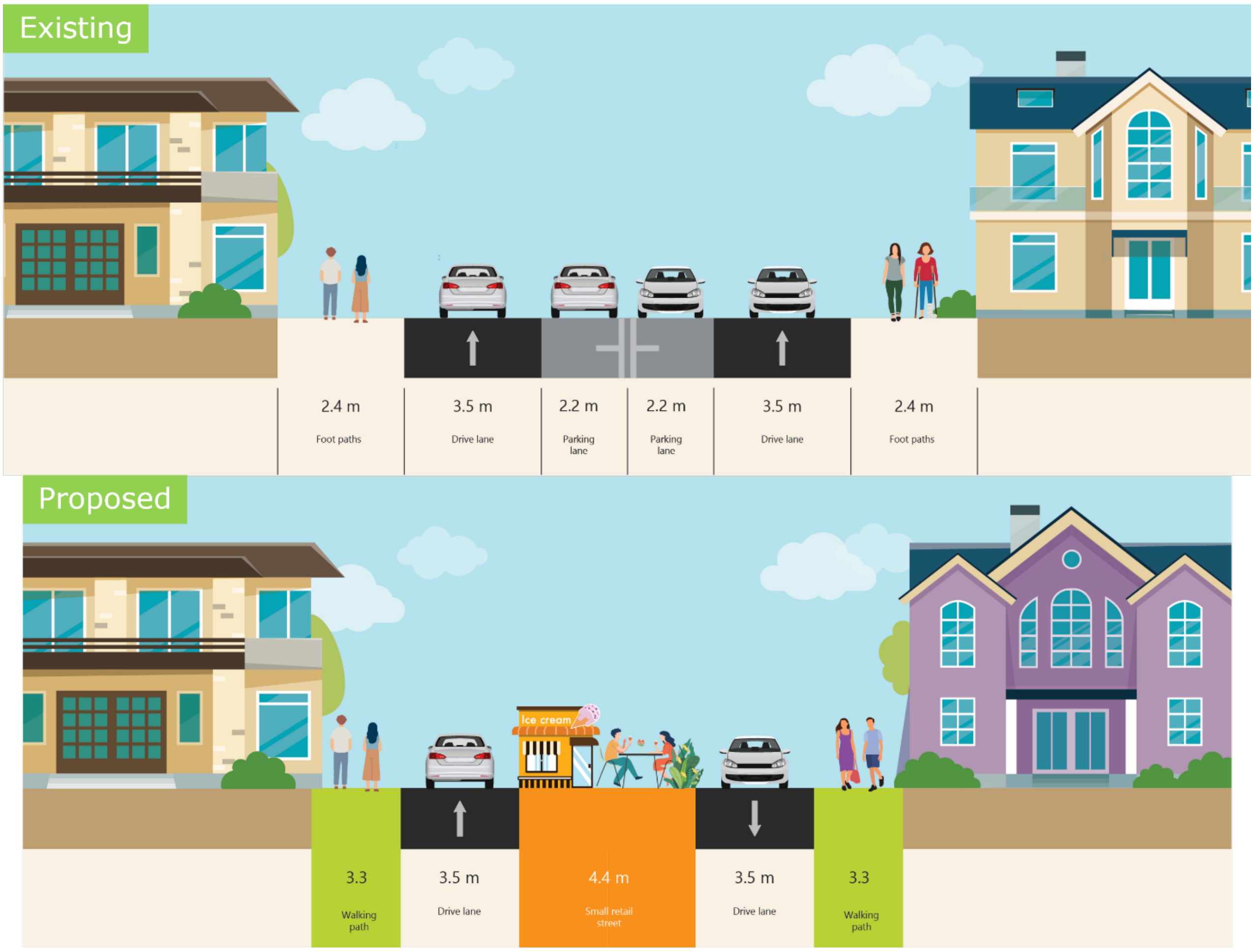


Figure 4-30 Scenario 2 Scheme Comparison Section View – Gat Lebuh China

Figure 4-31 Scenario 2 Scheme Comparison Street View – Beach Street

Figure 4-32 Scenario 2 Scheme Comparison Section View – Beach Street

Figure 4-33 Scenario 2 Scheme Comparison Street View – Gat Lebuh Pasar

Figure 4-34 Scenario 2 Scheme Comparison Section View – Gat Lebuh Pasar

Figure 4-35 Scenario 2 Scheme Comparison Street View – Downing Street

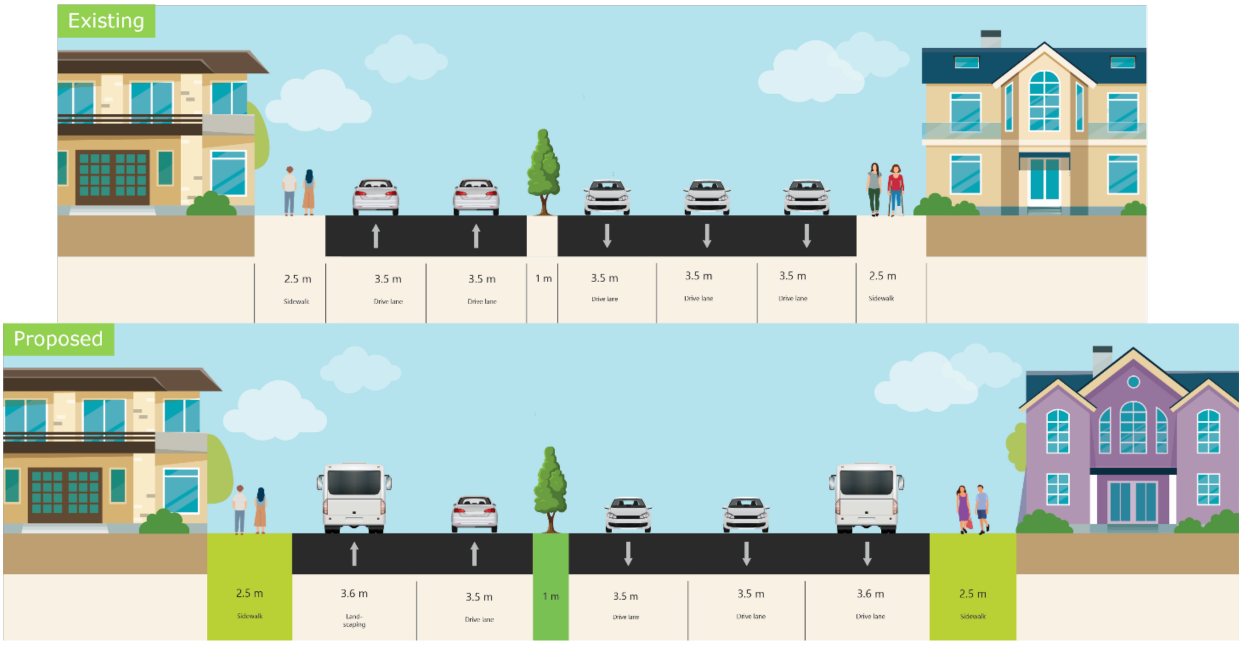


Figure 4-36 Scenario 2 Scheme Comparison Section View – Downing Street

In this scenario, emphasis is given to understand the network performance after adopting road network improvements.

As explained, following major modifications to road network are carried out in Scenario 2:

- Beach street conversion to one-way street
- Removal of parking lots on Gat lebuh China
- Closure of roads on Gat lebuh pasar

Below images depicts the Scenario 2 in Vissim after implementation of all the interventions.

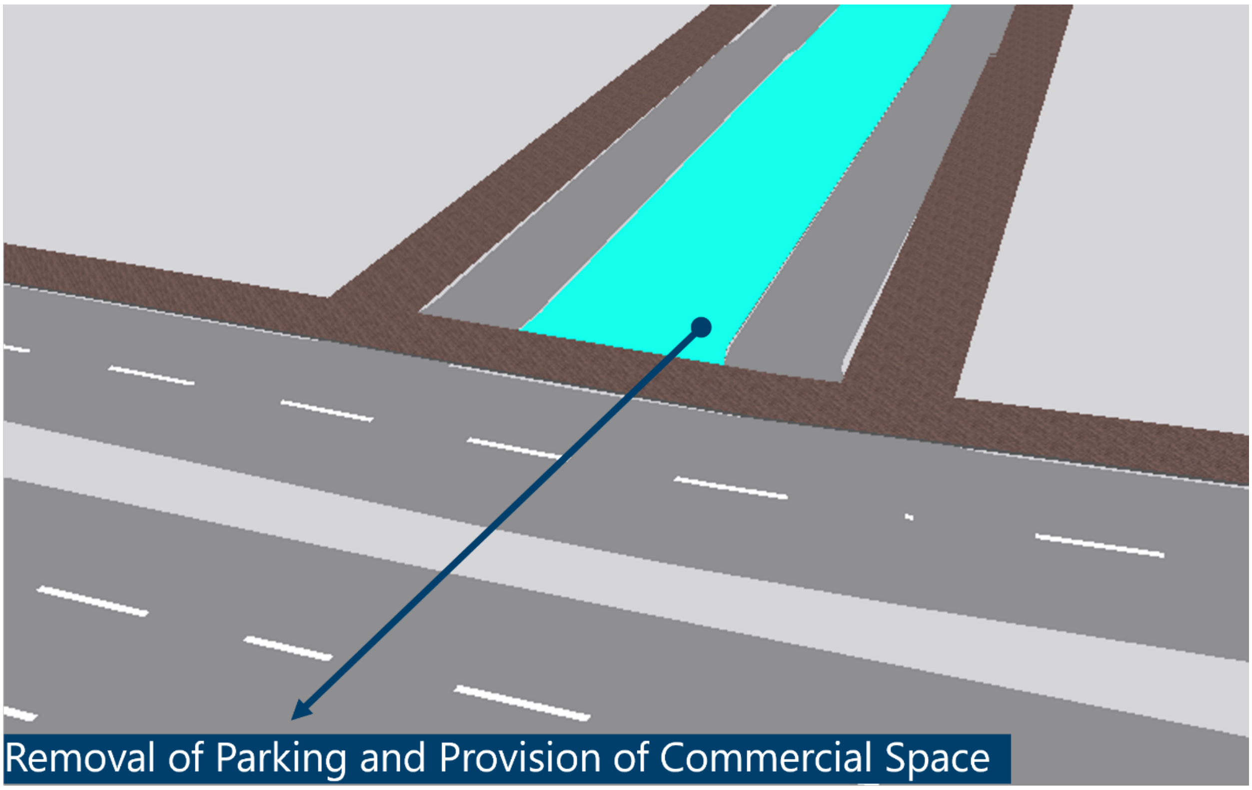


Figure 4-37 Scenario 2-Gat Lebuh China

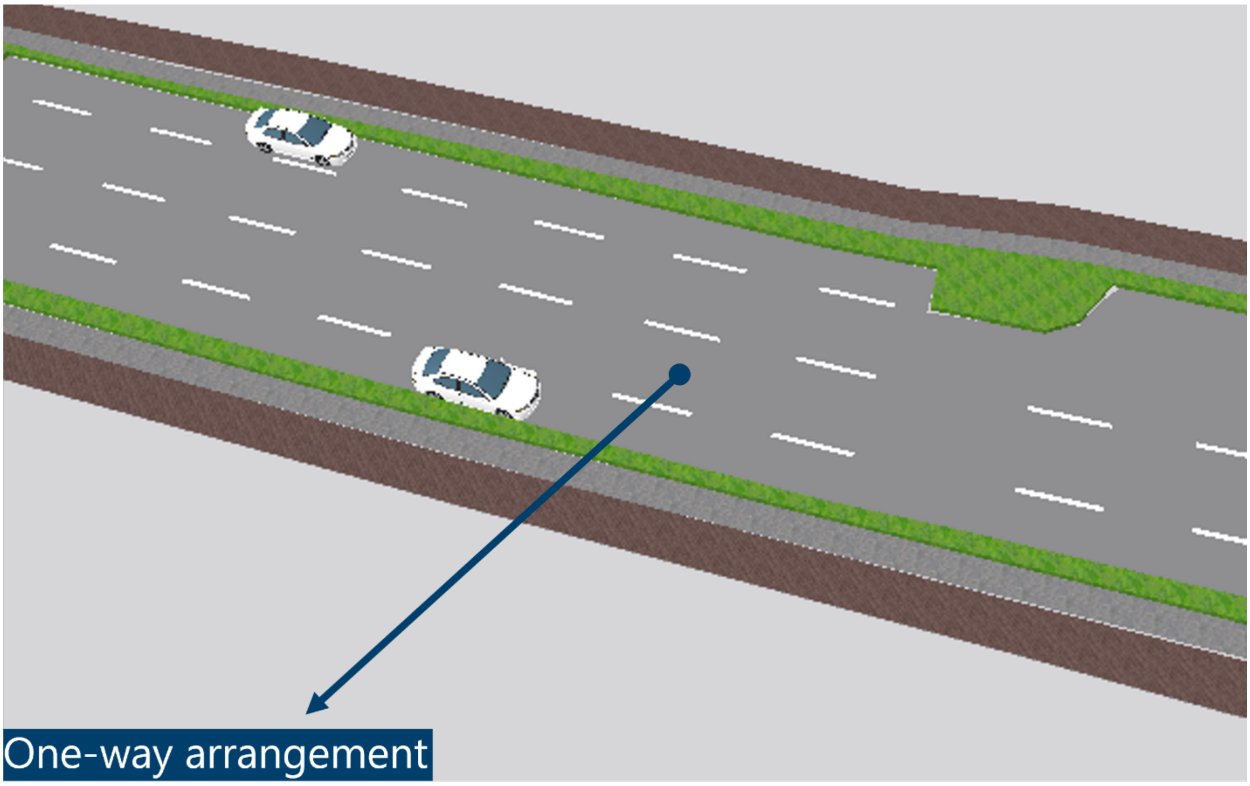


Figure 4-38 Scenario 2-Beach Street

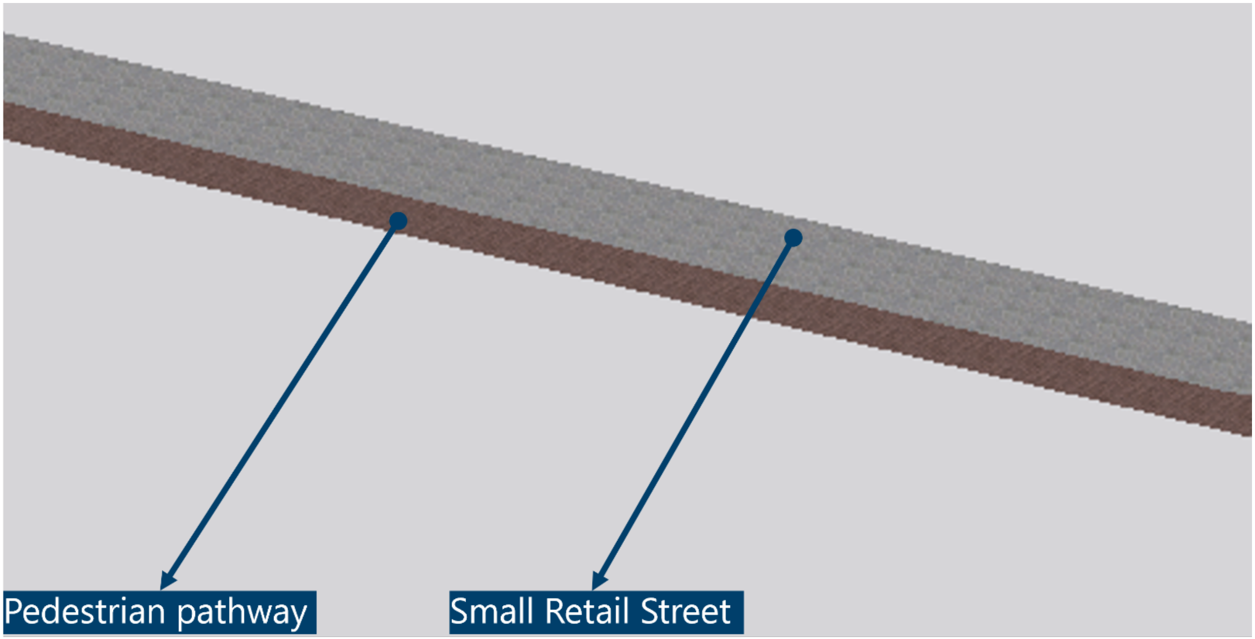


Figure 4-39 Scenario 2-Gat Lebuh Pasar

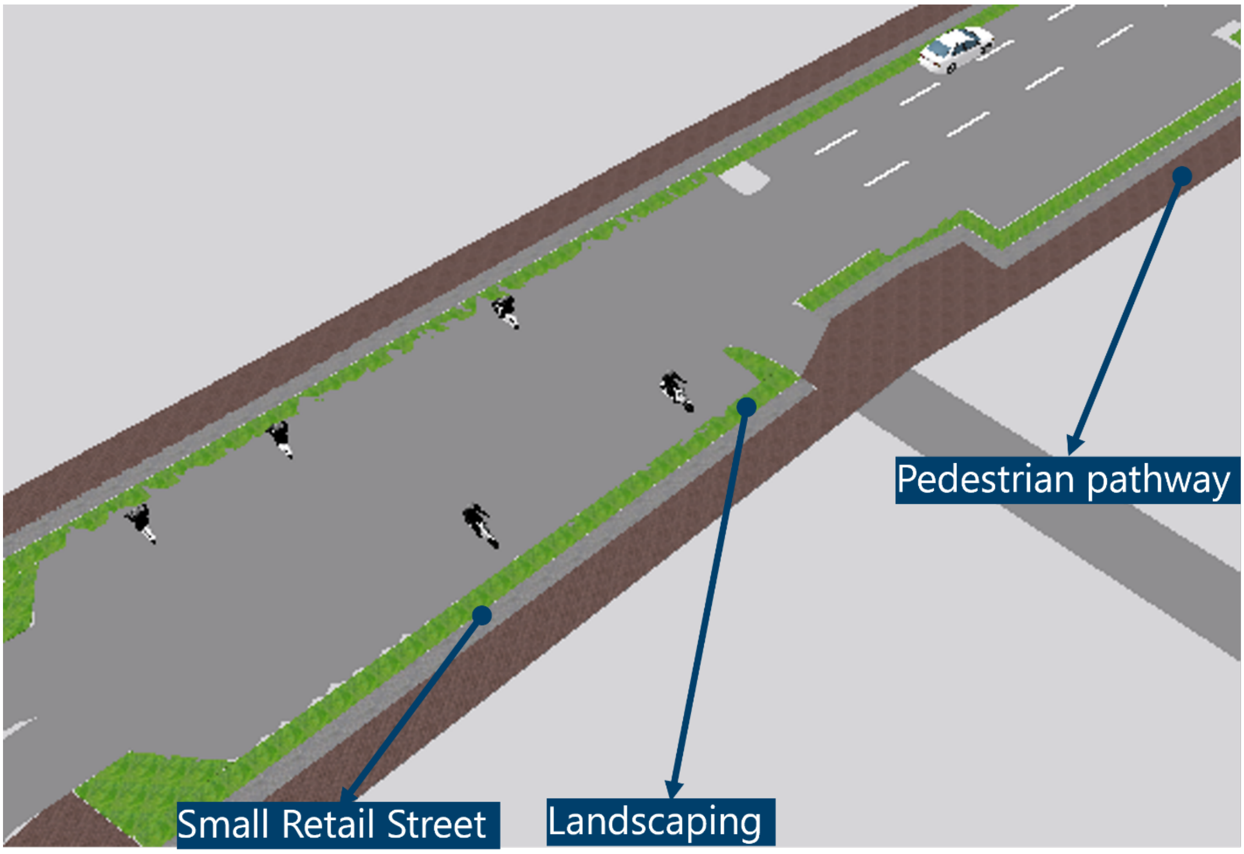


Figure 4-40 Scenario 2-Downing Street

Because of change in road network there will be redistribution of trips and therefore different OD matrix and trip chain file is derived by keeping the demand constant. Below image show the methodology adopted in Scenario 2 for Vissim model development.

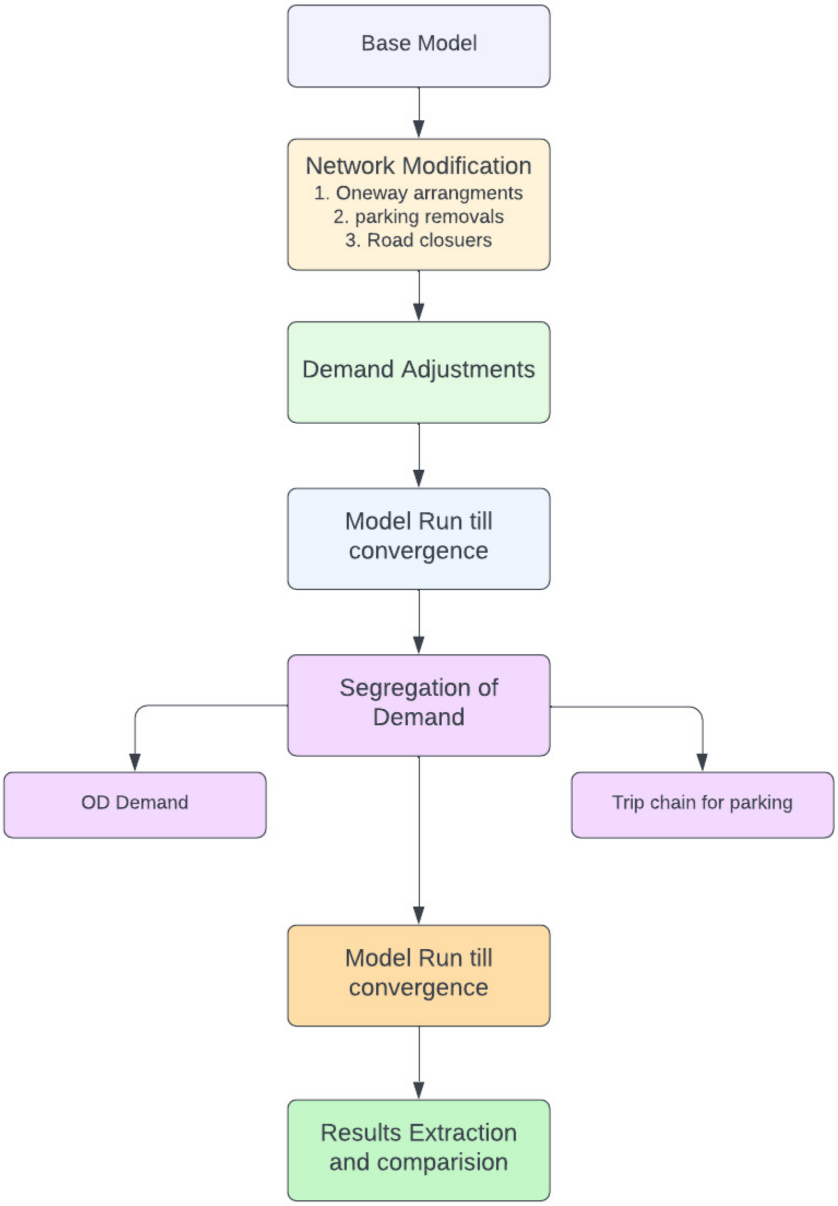


Figure 4-41 Scenario 2 – Methodology

4.6 Scenario 3: Public Transport Priority

In this scenario, emphasis is given to providing provision on dedicated bus lanes for some sections of Pengkalan Weld which in turn offers fast, comfortable, and cost-effective urban transport system.

Vissim model is being used to test out the effectiveness on the bus priority scheme, as well as the impact on vehicular traffic when these schemes are implemented. The detailed traffic scheme changes are documented as in the figure and table below.

Figure 4-42 Scenario 3 Scheme

Individual traffic schemes proposed within this scenario are outlined, based on the location in the model area, in the table below.

Table 4-8 Scenario 3 Details

Scenario 3		
Theme	**Road**	**Details (as discussed with Digital Penang)**
Public Transport Improvements	**Gat Lebuh China:** Shared Street	Design principles: 1) Must prioritize vulnerable users, ensuring that clear paths are maintained. 2) Drainage channels and permeable materials should be provided in accordance with existing curb lines and slope. 3) Provide tactile warning strips at the entrance to all shared spaces. Warning strips should span the entire intersection crossing. 4) Maintain a clear path for delivery vehicles, and mark dedicated areas for vehicular movement with a change in paving pattern or type. 5) Pedestrian walk space to maintain at least 1.8m width 6) Install signage to educate the public on how to use a shared street in the early stages of conversion.
Public Transport Improvements	**Pengkalan Weld Street:** Bus Lane 1, 2 & 3	Design using offset transit lane. The standard width for road lane is 3.3m. Benefits: 1) Offset transit lanes reduce delays due to congestion. 2) Offset transit lanes raise the visibility of high-quality services, especially rapid service. Figure 4-43 and Figure 4-44 below shows the proposed public transport lane on Pengkalan Weld road.
Public Transport Improvements	**Pengkalan Weld Street:** Bus Lane turn-in	Design using offset transit lane. The standard width for road lane is 3.3m. Benefits: 1) Offset transit lanes reduce delays due to congestion. 2) Offset transit lanes raise the visibility of high-quality services, especially rapid service.
Public Transport Improvements	**Lebuh Victoria:** Shared Street	Design principles: 1) Must prioritize vulnerable users, ensuring that clear paths are maintained. 2) Drainage channels and permeable materials should be provided in accordance with existing curb lines and slope.

Scenario 3		
Theme	**Road**	**Details (as discussed with Digital Penang)**
		3) Provide tactile warning strips at the entrance to all shared spaces. Warning strips should span the entire intersection crossing. 4) Maintain a clear path for delivery vehicles, and mark dedicated areas for vehicular movement with a change in paving pattern or type. 5) Pedestrian walk space to maintain at least 1.8m width 6) Install signage to educate the public on how to use a shared street in the early stages of conversion.
Public Transport Improvements	**Gat Lebuh Gereja:** Shared Street	Design principles: 1) Must prioritize vulnerable users, ensuring that clear paths are maintained. 2) Drainage channels and permeable materials should be provided in accordance with existing curb lines and slope. 3) Provide tactile warning strips at the entrance to all shared spaces. Warning strips should span the entire intersection crossing. 4) Maintain a clear path for delivery vehicles, and mark dedicated areas for vehicular movement with a change in paving pattern or type. 5) Pedestrian walk space to maintain at least 1.8m width 6) Install signage to educate the public on how to use a shared street in the early stages of conversion.

The following images shows the comparison of existing and proposed schemes in street view and section view, as per location.

Figure 4-43 Scenario 3 Scheme Comparison Street View – Pengkalan Weld

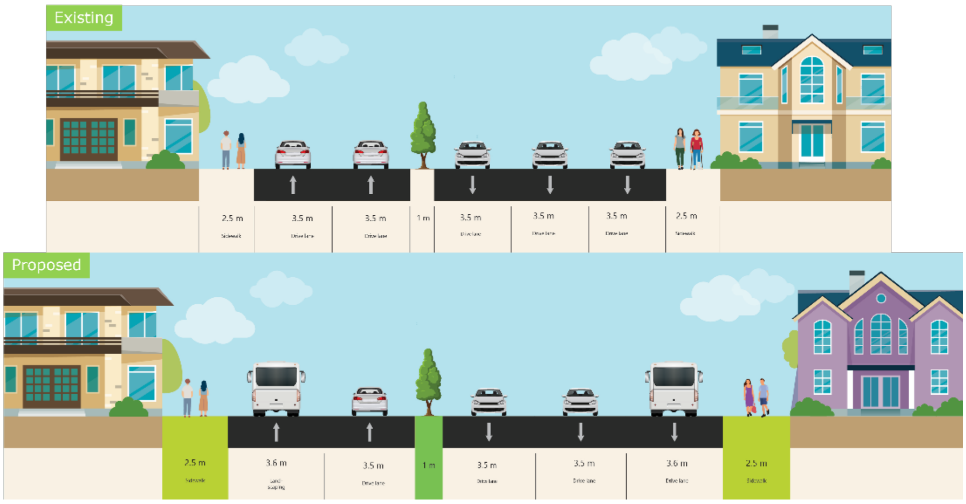


Figure 4-44 Scenario 3 Scheme Comparison Section View – Pengkalan Weld

Main objective of this scenario is to understand the impact of implementation of dedicated public transport lanes on some sections of the study area on the road network performance.

As explained, following major modifications to road network are carried out in Scenario 3

- Dedicated Public transport lane at some sections of Pengkalan Weld as shown in below image

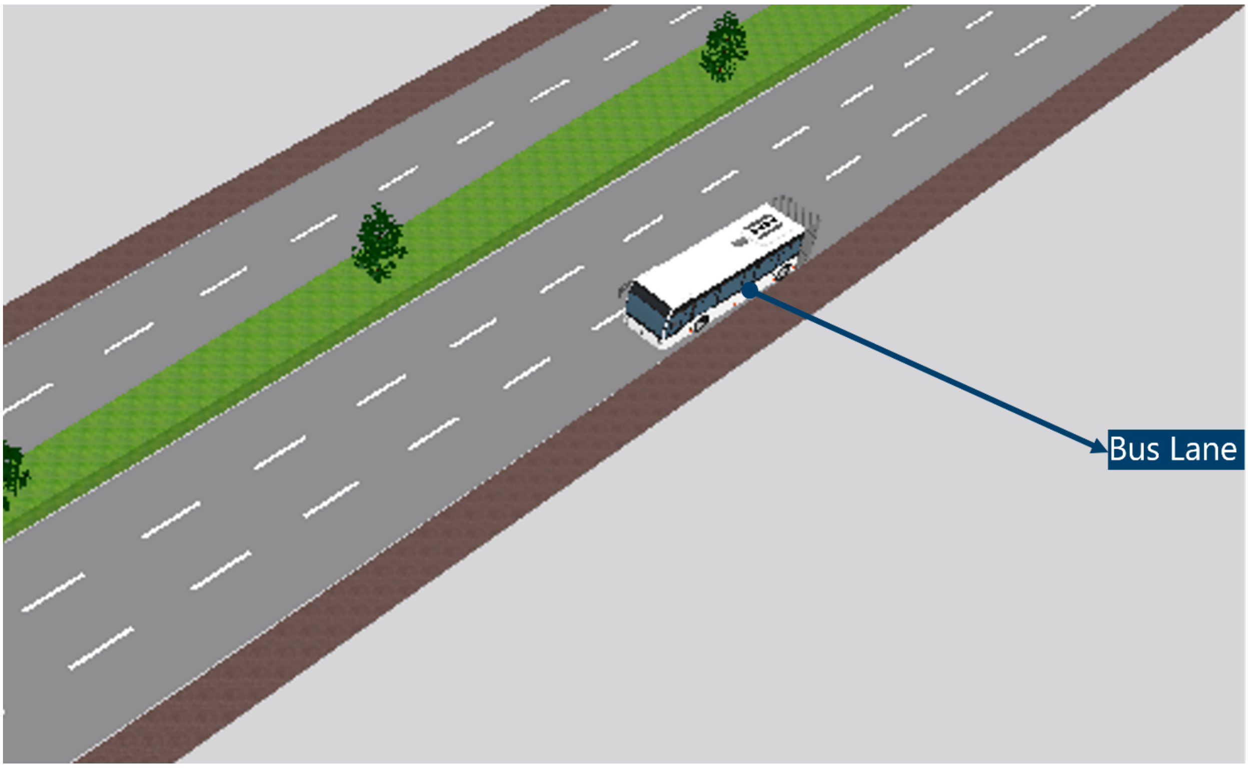


Figure 4-45 Scenario 3 - Pengkalan Weld

Since there is no change in road network in terms of road closures/circulation, vehicular and parking demand will remain same as of base calibrated model. Below image show the methodology adopted for this scenario

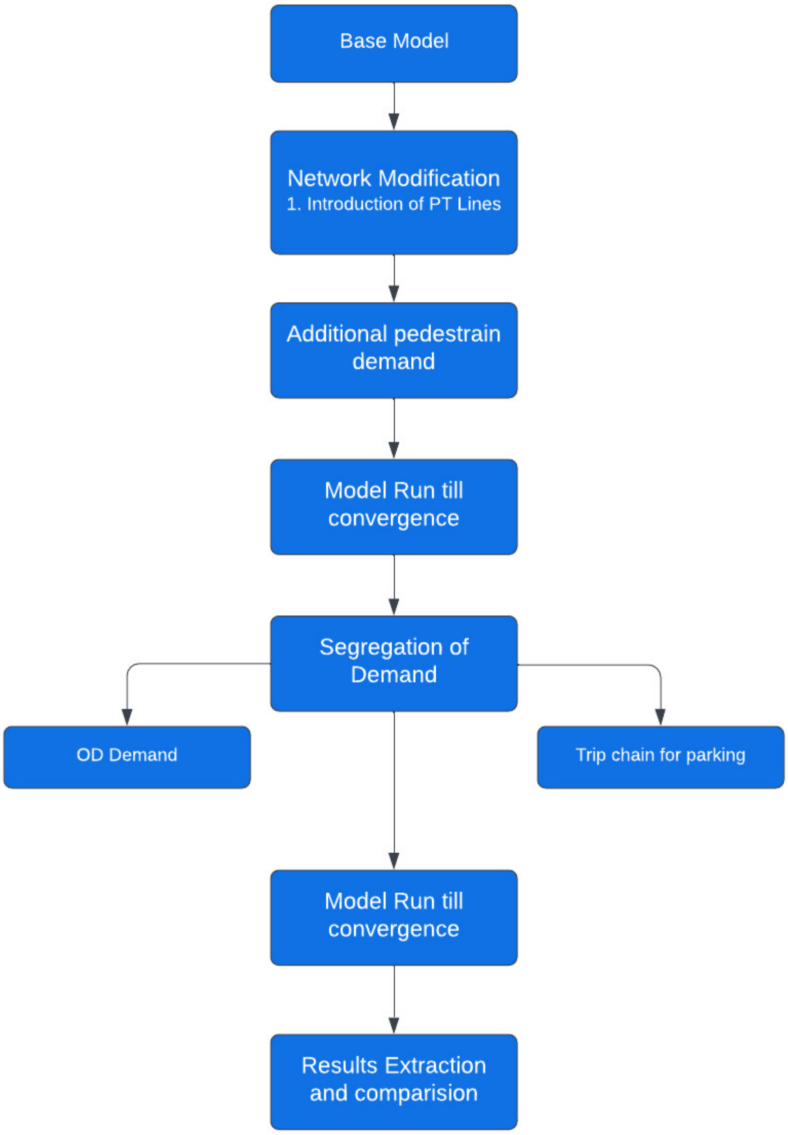


Figure 4-46 Scenario 3 – Methodology

4.7 Scenario 4: Traffic Impact of New Development

Objective of this testing scenario is to analyses the impact of additional traffic generated by a newly proposed development on existing transport system. This is in line with traffic impact assessment process to evaluate and approve the traffic impact of a new development within the city. This compares the new traffic demand with the traffic capacity of the network and will provide an insight into where traffic performance has changed, and where traffic improvement works might be required.

The detailed traffic scheme changes are documented as in the figure and table below.

Figure 4-47 Scenario 4 Interventions

Individual traffic schemes proposed within this scenario are outlined, based on the location in the model area, in the table below.

Table 4-9 Scenario 4 Details

Scenario 4		
Theme	**Road**	**Details**
Traffic Impact of New Development	**Pengkalan Weld Street or Other Road with New Development:** Planning and Construction of New Development	Digital Penang would like to study the new traffic demand and traffic impact of new on the study area. This will apply to one new development regardless of land use to be planned and constructed in the study area. On simulating and assessing the traffic impact, the following aspect will be included in the scenario: 1) Traffic impact of new demand brought by the new development on the road network 2) Traffic impact of construction road diversion and construction vehicle access

Scenario 4		
		3) Traffic operations and management measures arising from post-implementation traffic issues 4) Traffic demand management recommendations and other traffic improvement recommendations

The following images shows the comparison of existing and proposed schemes in street view and section view, as per location.

Impact of additional traffic on road network due to new proposed developments is tested in this scenario.

Digital Penang has provided land use details of the new development as shown in below table and location of the development is shown in Figure 4-48.

Table 4-10 Land use details of new development

Land use	Area (square meter)
Seafront F&B	2480
Showroom	975
E-Sports Arena	1551
Restaurants	464
Flight Simulator Training Center	4273
Remaining Area (Shops as assumed in progress meeting)	15213
Total Area	**24956**

Figure 4-48 Location of proposed new development

The number of trips generated by proposed development has been established with the use of trip generation rates that were obtained from the trip generation surveys conducted for the similar development during peak hours within Malaysia. Trip generation for the proposed new development using the trip rates is provided by JA Consult and details are as below.

Table 4-11 Trip generation of proposed development

Land use	Area (sqm)	AM In	AM out	PM In	PM out
Seafront F&B	2480	22	9	10	20
Showroom & Remaining Area	16188	444	272	471	531
E-Sports Arena	1551	4	2	5	3
Restaurants	464	12	9	9	7
Flight Simulator Training Center	4273	40	9	7	36
Total Area	24956	523	302	502	597

Due to this additional demand, base calibrated demand matrix is adjusted to reflect this additional increase of the demand. Parking demand is assumed to remain unchanged as all the parking required for proposed development is assumed to be provided within the development.

Proposed development is assumed to be accessed from the Left in out as shown in figure below.

Figure 4-49 Proposed development access

Zone 4 in the base model is assumed to be proposed development zone in Scenario 4.

Methodology adopted to develop Vissim model for Scenario 4 is shown in figure below.

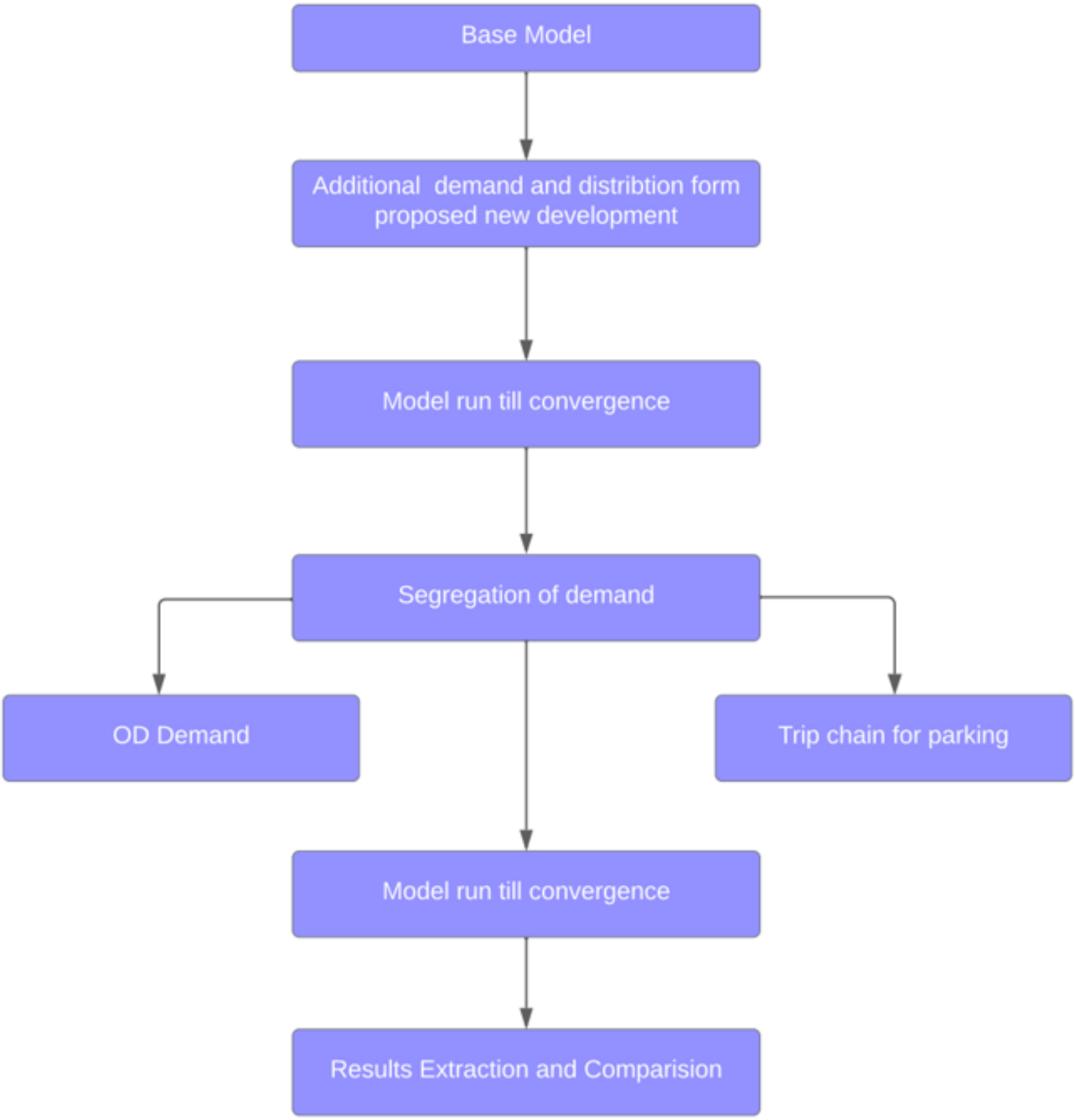


Figure 4-50 Scenario 4 – Methodology

Table 4-12 Zone Description

Zone Number	Description	Road Name	Zone Number	Description	Road Name
1	Origin/Destination Zone	Lebuh Light	22	Origin/Destination Zone	Access to parking
2	Origin/Destination Zone	Jalan Tun Syed Sheh Barakbah	23	Origin/Destination Zone	Local Road
3	Origin/Destination Zone	Access to Ferry terminal	24	Origin/Destination Zone	Access to parking
4	Origin/Destination Zone	Local road	25	Origin/Destination Zone	Access to parking
5	Origin/Destination Zone	Access to Terminal	26	Origin/Destination Zone	Access to parking
6	Origin/Destination Zone	Access to Bus stop	27	Origin/Destination Zone	Local Road
7	Origin/Destination Zone	Local Road	28	Origin/Destination Zone	Local Road
8	Origin/Destination Zone	Pengkalan weld	29	Parking Zone	Parking between J1 and J17
9	Origin/Destination Zone	Lebuh Victoria	30	Parking Zone	Parking between J17 and J16
10	Origin/Destination Zone	Beach street	31	Parking Zone	Parking between J16 and J1
11	Origin/Destination Zone	Chulia Street	32	Parking Zone	Parking between J1 and J2
12	Origin/Destination Zone	Local Road	33	Parking Zone	Parking between J2 and J20
13	Origin/Destination Zone	Lebuh Pasar	34	Parking Zone	Parking between J3 and J15

Zone Number	Description	Road Name	Zone Number	Description	Road Name
14	Origin/Destination Zone	Lorong Chee Em	35	Parking Zone	Parking between J15 and J21
15	Origin/Destination Zone	Lebuh China	36	Parking Zone	Parking between J20 and J21
16	Origin/Destination Zone	Church street	37	Parking Zone	Parking between J5 and J13
17	Origin/Destination Zone	Bishop Street	38	Parking Zone	Parking between J13 and J14
18	Origin/Destination Zone	Lebuh Union	39	Parking Zone	Parking between J14 and J15
19	Origin/Destination Zone	Access to parking	40	Parking Zone	Parking between J22 and J23
20	Origin/Destination Zone	Access to parking	41	Parking Zone	Parking between J21 and J22
21	Origin/Destination Zone	Local Road			

4.8 Model Verification

4.8.1 Model Parameter Settings

- **Simulation Resolution:** The position of vehicle on the road network of the model is recalculated in simulation second with each times step. The Simulation resolution specifies the number of time steps. In current VISSIM model simulation resolution is set as 10.

- **Vehicle Fleet:** Within the vehicle type, different model of vehicles together with their share can be defined. For example, in this model for vehicle type- car, models like Volkswagen golf, Audi A4, Mercedes C1K, Peugeot 607, Volkswagen Beet, Porsche Cayman and Toyota Yaris are used. Below image shows the vehicle type along with their fleet and share.

Car

Count: 7	Share	Model2D3D
1	0.240	1: Car - Volkswagen Golf
2	0.180	2: Car - Audi A4
3	0.160	3: Car - Mercedes CLK
4	0.160	4: Car - Peugeot 607
5	0.140	5: Car - Volkswagen Beet...
6	0.020	6: Car - Porsche Cayman
7	0.100	7: Car - Toyota Yaris

Taxi

Count: 2	Share	Model2D3D
1	0.500	7: Car - Toyota Yaris
2	0.500	1: Car - Volkswagen Golf

Bike

Count: 1	Share	Model2D3D
1	1.000	313: Bike

LGV

Count: 2	Share	Model2D3D
1	0.500	311: Lt Truck -Ford
2	0.500	312: Lt Truck- Chevrolet

HGV

Count: 1	Share	Model2D3D
1	1.000	21: HGV - EU 04

BUS

Count: 1	Share	Model2D3D
1	1.000	31: Bus - EU Standard

- **Functions and distributions:** as per default

- **Random Seed:** The use of random seeds allows for stochastic variations of traffic arrivals in Vissim, which helps account for variations in real-world traffic conditions. Value of 42 which is default is used for our current model.

4.8.2 Vehicle Speeds at Turn Movements

Generally, reduced speed areas were placed on turn movements at intersections to consider reduced speeds and geometric delays at these locations.

An even speed distribution between 20 and 25 km/h has been adopted to reflect the reduced speeds in a realistic manner. 15 km/h is used for U turns and left turns.

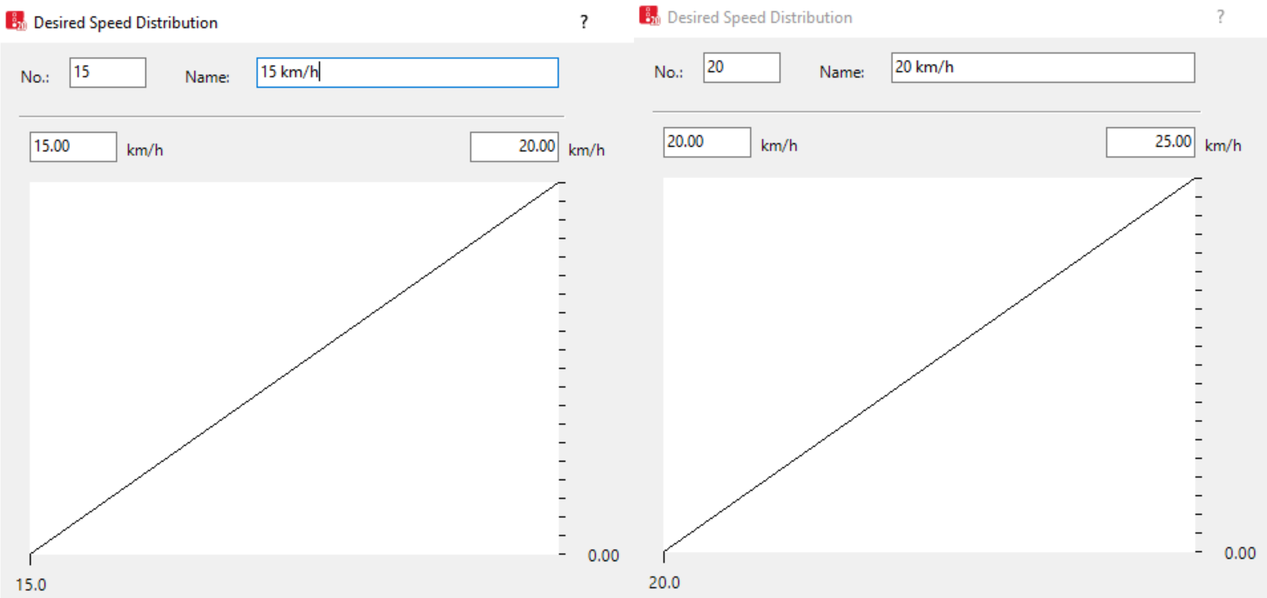


Figure 4-51 Speed Distribution at Turn Movements

The figure above shows a linear distribution of speed between the lower limit and upper limit. For example, the speed distribution of 15 km/h shows a uniformly distributed speed between 15 km/h and 20 km/h. While the speed distribution of 20 km/h shows a uniformly distributed speed between 20 km/h and 25 km/h.

Speed distribution allows for more realistic representation of vehicle in the network.

4.8.3 Modelled Speed Limits

Speed limit is the highest achievable speed a vehicle can reach at free-flow state, which means there is no interference felt by the vehicle from road network and other vehicles. Vehicles also cannot meet this speed in the model due to imperfect driving conditions, such as low-speed proceeding vehicles or traffic signal controls.

The road links modelled were assigned speeds in accordance with the posted speed limits on the roads in the study area. Predominantly, 50 km/h is utilized on majority of the road links and on minor road 40 km/h speed is utilized.

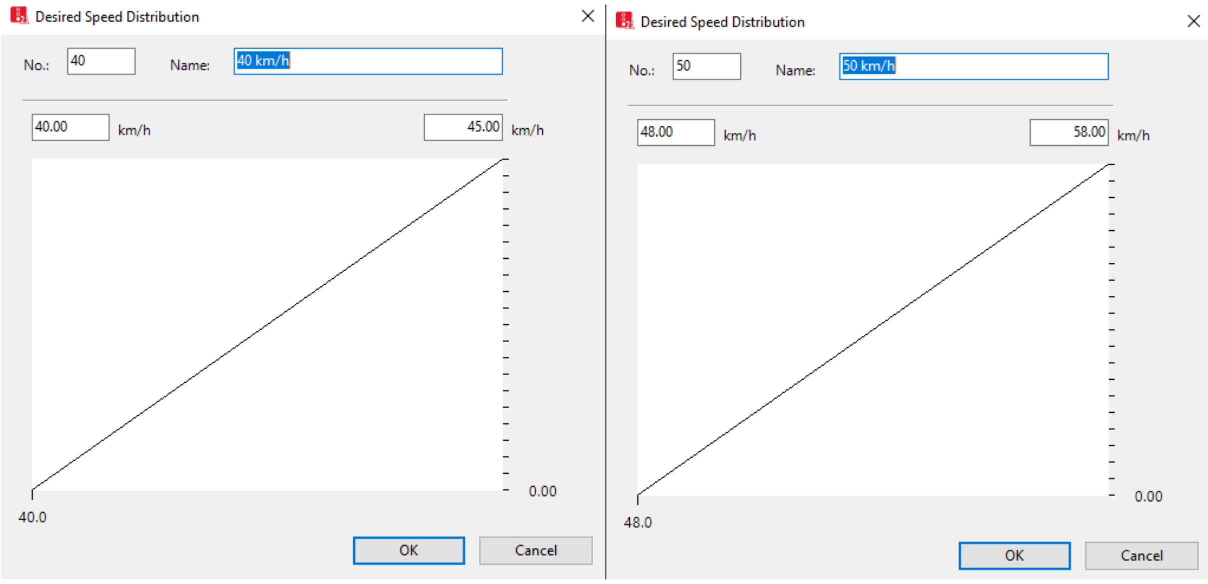


Figure 4-52 Speed Distribution for All Vehicle Types

The figure above shows a linear distribution of speed between the lower limit and upper limit. For example, the speed distribution of 40 km/h shows a uniformly distributed speed between 40 km/h and 45 km/h. While the speed distribution of 50 km/h shows a uniformly distributed speed between 48 km/h and 58 km/h.

Speed distribution allows for more realistic representation of vehicle in the network.

4.8.4 Driving Behavior

Driving behavior forms the foundation of how Vissim simulate each move of vehicles. Vissim traffic flow model is a stochastic, time-step based, microscopic model that treats driver-vehicle units as basic entities, which means:

- Vehicles are not running at fixed assignment with uniformed speed – this is not just a video
- Vehicles are reacting to other vehicles in the model consistently
- When put in origin and destination of traffic, route need to be selected by the model for vehicles
- The driving behavior in traffic flow model contains a psycho-physical car following model for vehicle movement, which is based on Wiedemann's extensive research work:
- Wiedemann, R. (1974). Simulation des Straßenverkehrsflusses. Schriftenreihe des Instituts für Verkehrswesen der Universität Karlsruhe (seit 2009 KIT – Karlsruher Institut für Technologie), Heft 8
- Wiedemann, R. (1991). Modeling of RTI-Elements on multi-lane roads. In: Advanced Telematics in Road Transport edited by the Commission of the European Community, DG XIII, Brussels

This makes the simulation model realistic replication of the real-world situation, and thus can be used for testing changes in traffic configurations i the network.

Normally, roads in urban areas are based on Wiedemann, R. (1974) which forms the driving behavior of 1 Urban (motorized). As the Penang model is based on urban settings, the default driving behavior parameters (1 Urban motorized) were selected for intersections and links in the Vissim network.

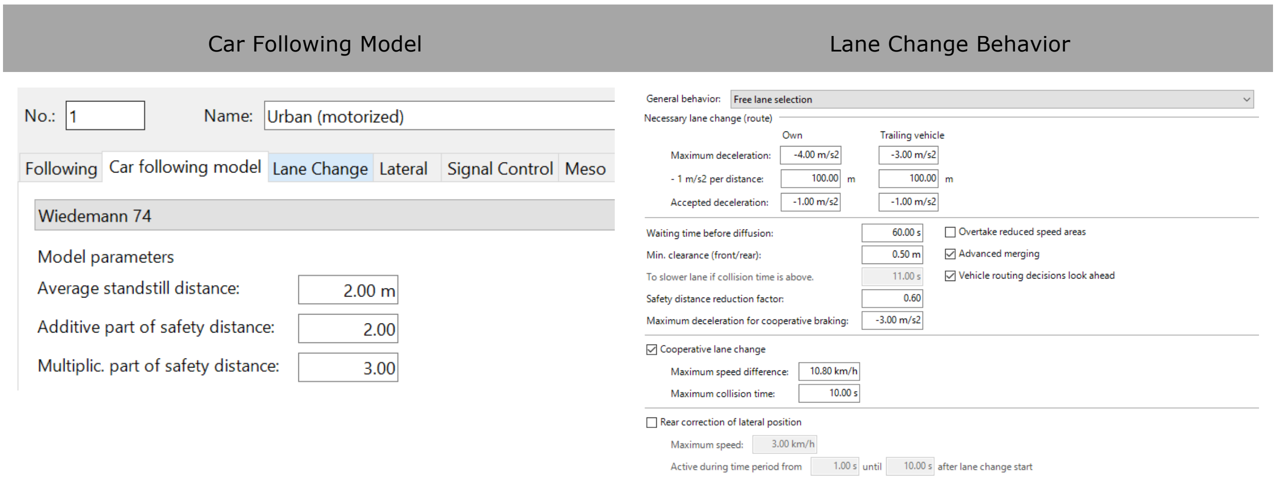


Figure 4-53 Default Car Following and Lane Change Behavior

4.9 Model Calibration

4.9.1 Turn Volume Calibration

The objective of model calibration is to obtain the best match possible between the modelled performance estimates in Vissim and the field measurements of performance. It should be noted that there are no universally accepted procedures for conducting calibration for complex transportation networks.

In this assessment, we adopted the following calibration targets and general parameters for the calibration, based on FHWA Traffic Analysis Toolbox Volume III, and summarized below:

Hourly Flows (Model Versus Observed)

- Turning movement Flows
- GEH<5 for 85% of the movements

The simulation model was run on dynamic assignment technique. The simulation model was run on dynamic assignment technique in this current model. Dynamic assignment allows vehicles to choose best route possible in the network. Flow chart below shows the steps involved in dynamic assignment.

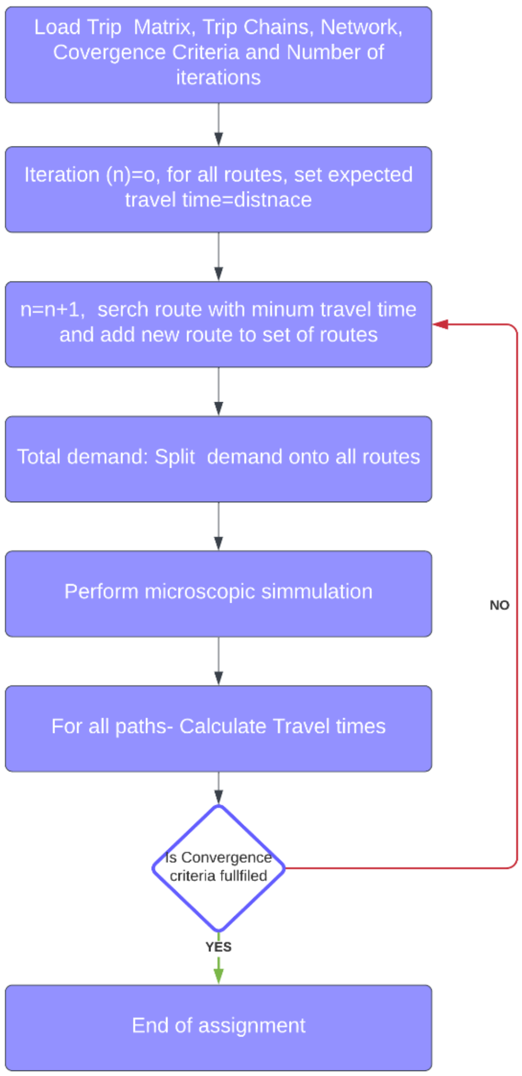


Figure 4-54 Dynamic Assignment Process

To carry out dynamic assignment, initially zones need to be defined. Traffic coming out from zones (origin) to be given relative flow (1) and for the zones where the traffic is coming in (destination) will be given relative flow (0).

Every junction in the model is defined with node to carry out dynamic assignment. The model is run for several iterations with fixed random seed (42) to allow the model to converge.

The stability of the model is measured in terms of convergence. Convergence criterion used is "Travel time on paths" with 15% as percentage change of travel time for all paths compared to the previous simulation run. Also, 90% has utilized for required share of converged paths.

The Cost and Path files are archived for each of the iteration of the model when run on Dynamic assignment in microscopic simulation. Cost file contains weighted sum of travel distance, travel time and link specific costs. Path file contains all the associated paths of the cost file. The final converged path and cost files are then utilized again to run the final iteration on Dynamic assignment in Microsimulation to extract results like GEH, Queue lengths and Delays for both AM and PM peak models.

Observed turning movements from all sites were used to calibrate the traffic volumes for the AM and PM base models. The difference between the modelled and the surveyed turning movements are tabulated in the tables below and converted into GEH statistics, for the purpose of comparison.

Most of the movements have a GEH of below 5 and have satisfied the requirement. The results show that the Vissim model has been well calibrated in turning movements. Observed volumes from the primary survey are compared against the modelled volume and the resulting GEH is estimated. The summary of the same is shown below.

Table 4-13 GEH Estimates-AM Peak-Base

Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
1	J1-W-Left	1452	1455	0.09	YES
	J1-E-Right	304	280	1.42	YES
	J1-E-Through	1022	980	1.34	YES
2	J2-W-Left	172	95	6.64	NO
	J1-W-Through	1447	1512	1.7	YES
	J2-N-Left	68	74	0.68	YES
	J2-E-Through	1016	1082	2.04	YES
3	J3-W-Left	245	245	0.02	YES
	J3-W-Through	1553	1564	0.27	YES
	J3-N-Left	65	59	0.76	YES
	J3-E-Through	1016	1082	2.04	YES
4	J4-W-Left	38	0	8.72	NO
	J4-W-Through	1593	1594	0.01	YES
	J4-N-Left	3	0	2.45	YES
	J4-E-Through	958	860	3.27	YES
5	J5-W-Left	411	576	7.41	NO
	J5-W-Through	1537	1537	0.01	YES
	J5-N-Left	82	83	0.08	YES
	J5-E-Through	800	930	4.41	YES
	J5-S-Left	15	13	0.6	YES

Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
13	J13-N-Left	74	61	1.55	YES
	J13-N-Through	118	116	0.21	YES
	J13-N-Right	168	153	1.17	YES
	J13-S-Left	50	42	1.15	YES
	J13-S-Through	331	371	2.15	YES
	J13-S-Right	208	164	3.21	YES
14	J14-W-Right	4	0	2.83	YES
	J14-W-Through	205	211	0.42	YES
	J14-N-Right	10	0	4.47	YES
15	J15-W-Left	165	190	1.89	YES
	J15-W-Right	29	25	0.77	YES
	J15-N-Through	29	25	0.77	YES
	J15-S-Through	235	193	2.87	YES
16	J16-W	1427	1540	2.93	YES
	J16-N	807	881	2.55	YES
	J16-E	37	34	0.44	YES
17	J17-S-Right	1049	1129	2.42	YES
	J17-S-Left	465	411	2.6	YES
	J17-W-Through	434	404	1.45	YES
18	J18-W-Left	219	238	1.22	YES
	J18-W-Through	465	411	2.6	YES
	J18-E-Right	235	193	2.87	YES
	J18-E-Through	270	247	1.45	YES
19	J19-W-Through	441	452	0.51	YES

Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
	J19-N-Left	317	307	0.59	YES
	J19-E-Through	244	231	0.83	YES
20	J20-W-Left	245	245	0.02	YES
	J20-W-Through	372	426	2.69	YES
	J20-W-Right	41	14	5.15	NO
	J20-S-Left	35	0	8.37	NO
	J20-S-Through	76	69	0.82	YES
	J20-S-Right	45	25	3.33	YES
	J20-E-Left	57	60	0.39	YES
	J20-E-Through	129	119	0.94	YES
	J20-E-Right	53	53	0.03	YES
21	J21-W-Through	288	292	0.23	YES
	J21-W-Right	9	0	4.24	YES
	J21-S-Left	135	139	0.32	YES
	J21-S-Right	188	193	0.38	YES
	J21-E-Left	20	0	6.32	NO
	J21-E-Through	148	119	2.56	YES
	J21-N-Left	209	202	0.49	YES
	J21-N-Right	81	74	0.85	YES
	J21-N-Through	20	0	6.32	NO
22	J22-W-Through	248	248	0.02	YES
	J22-W-Left	185	193	0.55	YES
	J22-E-Through	414	374	2.01	YES
23	J22-W-Left	124	115	0.87	YES

Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
	J22-W-Through	195	188	0.49	YES
	J22-W-Right	41	14	5.15	NO
	J22-S-Through	257	313	3.34	YES
	J22-S-Right	65	59	0.76	YES
	J22-E-Left	164	161	0.22	YES
	J22-E-Right	62	55	0.88	YES
	J22-N-Left	128	140	1.05	YES
	J22-N-Through	153	131	1.86	YES
Proportion of Turns with GEH<5					**92%**

Table 4-14 GEH Estimates-PM Peak-Base

Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
1	J1-W-Left	779	800	1	YES
	J1-E-Right	220	226	0	YES
	J1-E-Through	2213	1925	6	NO
2	J2-W-Left	80	70	1	YES
	J1-W-Through	720	816	3	YES
	J2-N-Left	56	56	0	YES
	J2-E-Through	2242	2165	2	YES
3	J3-W-Left	160	143	1	YES
	J3-W-Through	748	840	3	YES
	J3-N-Left	84	46	5	YES
	J3-E-Through	2231	2170	1	YES
4	J4-W-Left	8	0	4	YES
	J4-W-Through	860	909	2	YES
	J4-N-Left	14	1	5	YES
	J4-E-Through	2056	1845	5	YES
5	J5-W-Left	254	370	7	NO
	J5-W-Through	681	716	1	YES
	J5-N-Left	106	141	3	YES
	J5-E-Through	1733	1799	2	YES
	J5-S-Left	14	1	5	YES
13	J13-N-Left	61	3	10	NO
	J13-N-Through	144	176	3	YES
	J13-N-Right	408	382	1	YES
	J13-S-Left	96	68	3	YES

Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
	J13-S-Through	283	246	2	YES
	J13-S-Right	86	55	4	YES
14	J14-W-Right	6	1	3	YES
	J14-W-Through	146	145	0	YES
	J14-S-Right	6	1	3	YES
15	J15-W-Left	142	127	1	YES
	J15-W-Right	34	18	3	YES
	J15-N-Through	158	143	1	YES
	J15-S-Through	25	32	1	YES
16	J16-W	1375	1357	0	YES
	J16-N	1399	1370	1	YES
	J16-E	243	206	2	YES
17	J17-S-Right	776	781	0	YES
	J17-S-Left	223	174	4	YES
	J17-W-Through	597	567	1	YES
18	J18-W-Left	145	152	1	YES
	J18-W-Through	636	577	2	YES
	J18-E-Right	61	3	10	NO
	J18-E-Through	182	171	1	YES
19	J19-W-Through	480	448	1	YES
	J19-N-Left	327	310	1	YES
	J19-E-Through	216	233	1	YES
20	J20-W-Left	180	172	1	YES
	J20-W-Through	425	450	1	YES

Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
	J20-W-Right	22	0	7	NO
	J20-S-Left	25	32	1	YES
	J20-S-Through	47	37	2	YES
	J20-S-Right	23	0	7	NO
	J20-E-Left	31	56	4	YES
	J20-E-Through	163	159	0	YES
	J20-E-Right	26	18	2	YES
21	J21-W-Through	315	313	0	YES
	J21-W-Right	12	1	4	YES
	J21-S-Left	156	140	1	YES
	J21-S-Right	127	136	1	YES
	J21-E-Left	15	0	5	NO
	J21-E-Through	192	190	0	YES
	J21-N-Left	183	176	1	YES
	J21-N-Right	133	124	1	YES
	J21-N-Through	17	29	3	YES
22	J22-W-Through	173	139	3	YES
	J22-W-Left	260	242	1	YES
	J22-E-Through	545	501	2	YES
23	J22-W-Left	114	115	0	YES
	J22-W-Through	156	140	1	YES
	J22-W-Right	69	95	3	YES
	J22-S-Through	229	221	1	YES
	J22-S-Right	55	28	4	YES

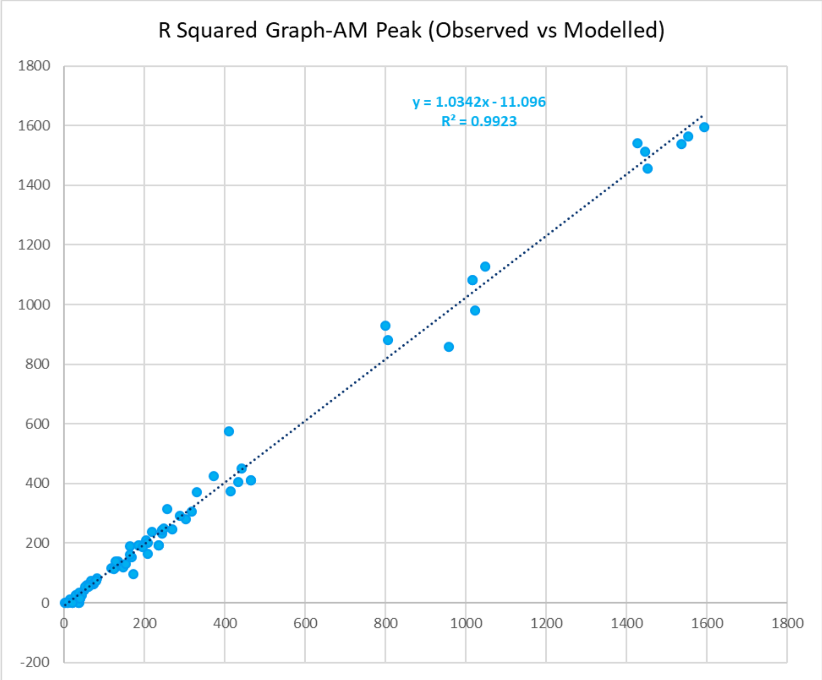
Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
	J22-E-Left	276	256	1	YES
	J22-E-Right	150	138	1	YES
	J22-N-Left	191	188	0	YES
	J22-N-Through	278	242	2	YES
Proportion of Turns with GEH<5					**92%**

It can be inferred from the tables above that the proportion of movements with GEH value less than 5 is at 92% and 92% respectively for the AM peak and PM peak period.

This meets the criteria set at 85% for the model to be considered fit for purpose. This indicates this model well-calibrated.

4.9.2 Observed Vs Modelled Volume Graph

Graph representing the relation between the observed and modelled volume and the corresponding R square value for base condition is presented below. Definition of R-Squared value is explained above.



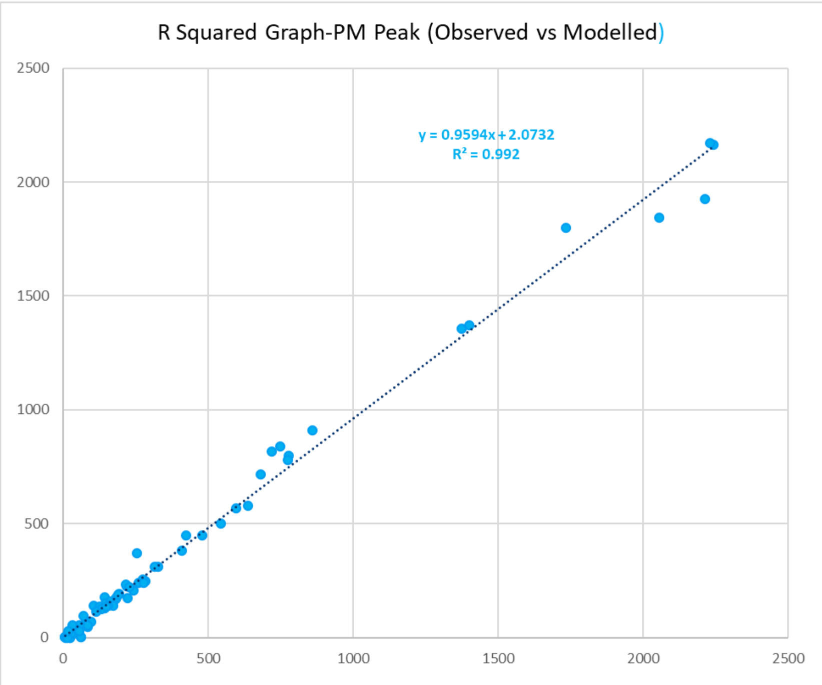


Figure 4-55 Observed Vs Modelled Volume-Graph-Base

It can be told from the figures above that the R-square is at 0.992 and 0.992 respectively for the AM peak and PM peak period.

This means the modeled value closely match the surveyed value. Hence, it indicates this model well-calibrated.

4.9.3 Queue Length Comparison

Comparison of queue length between the observed and modelled is done and is presented in the tables below.

Table 4-15 Queue Length Results-Base AM

Movement	Queue (m)		Junction	Movement	Queue (m)	
	Modelled	Observed			Modelled	Observed
J1-E-Right	0	0	18	J18-E-Right	2	10
J1-E-Through	0	0		J18-E-Through	1	0
J1-W-Left	35	0		J18-W-Left	0	0
J2-N-Left	0	10		J18-W-Through	0	0
J2-W-Left	0	0	19	J19-E-Through	4	15
J2-W-Through	0	0		J19-N-Left	1	30
J3-N-Left	0	15		J19-W-Through	7	5
J3-W-Left	0	0	20	J20-E-Left	0	0
J3-W-Through	0	0		J20-E-Right	0	5
J4-E-Through	4	0		J20-E-Through	0	0
J4-N-Left	0	5		J20-S-Left	0	0
J4-S-Left	0	0		J20-S-Right	0	15
J4-W-Left	7	0		J20-S-Through	0	15
J4-W-Through	7	40		J20-W-Left	0	0
J5-E-Left	0	0		J20-W-Right	0	5
J5-E-Through	0	45		J20-W-Through	0	5
J5-N-Left	0	35	21	J21-E-Left	0	0
J5-S-Left	0	5		J21-E-Through	0	0
J5-W-Left	2	0		J21-N-left	0	10
J5-W-Through	2	45		J21-N-Right	0	5

Movement	Queue (m)		Junction	Movement	Queue (m)	
	Modelled	Observed			Modelled	Observed
J13-N-Left	3	0		J21-N-Through	0	10
J13-N-Right	3	10		J21-S-Left	0	10
J13-N-Through	3	0		J21-S-Right	0	20
J13-S-Left	1	0		J21-S-U-Turn	0	0
J13-S-Right	1	15		J21-W-Right	0	0
J13-S-Through	1	0		J21-W-Through	0	0
J14-S-Right	0	0	22	J22-E-Right	0	0
J14-W-Right	1	0		J22-E-Through	0	0
J15-N-Through	0	0		J22-W-Left	6	0
J15-S-Through	0	0		J22-W-Through	6	0
J15-W-Left	0	15	23	J23-E-Left	16	15
J15-W-Right	0	15		J23-E-Right	16	10
J16-E-Left1	0	0		J23-N-Left	14	15
J16-E-Left2	0	0		J23-N-Through	14	35
J16-E-Right	0	0		J23-S-Right	19	20
J16-N-Through	1	15		J23-S-Through	19	55
J16-N-U-Turn	1	0		J23-W-Left	31	15
J16-W-Left	0	0		J23-W-Right	31	5
J16-W-Right1	0	0		J23-W-Through	31	0
J16-W-Right2	0	5				
J17-S-Left	1	0				
J17-S-Right	1	0				
J17-W-Through	0	0				

Table 4-16 **Queue Length Results-Base PM**

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
1	J1-E-Right	1	0	18	J18-E-Right	0	10
	J1-E-Through	1	0		J18-E-Through	0	0
	J1-W-Left	4	0		J18-W-Left	0	0
2	J2-N-Left	0	10		J18-W-Through	0	0
	J2-W-Left	0	0	19	J19-E-Through	7	5
	J2-W-Through	0	0		J19-N-Left	2	20
3	J3-N-Left	0	15		J19-W-Through	5	5
	J3-W-Left	0	0	20	J20-E-Left	0	0
	J3-W-Through	0	0		J20-E-Right	0	5
4	J4-E-Through	5	0		J20-E-Through	0	0
	J4-N-Left	0	5		J20-S-Left	0	0
	J4-S-Left	0	0		J20-S-Right	0	10
	J4-W-Left	3	0		J20-S-Through	0	5
	J4-W-Through	3	25		J20-W-Left	0	0
5	J5-E-Left	0	0		J20-W-Right	0	5
	J5-E-Through	0	30		J20-W-Through	0	10
	J5-N-Left	0	20	21	J21-E-Left	0	0
	J5-S-Left	0	25		J21-E-Through	0	0
	J5-W-Left	0	0		J21-N-left	0	10
	J5-W-Through	0	30		J21-N-Right	0	10
13	J13-N-Left	11	0		J21-N-Through	0	5
	J13-N-Right	11	20		J21-S-Left	0	10
	J13-N-Through	11	0		J21-S-Right	0	15

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	J13-S-Left	0	0		J21-S-U-Turn	0	0
	J13-S-Right	0	5		J21-W-Right	0	0
	J13-S-Through	0	0		J21-W-Through	0	0
14	J14-S-Right	0	0	22	J22-E-Right	1	0
	J14-W-Right	0	0		J22-E-Through	1	0
15	J15-N-Through	0	0		J22-W-Left	4	0
	J15-S-Through	0	0		J22-W-Through	4	0
	J15-W-Left	0	10	23	J23-E-Left	33	15
	J15-W-Right	0	5		J23-E-Right	33	15
16	J16-E-Left1	3	0		J23-N-Left	25	30
	J16-E-Left2	4	0		J23-N-Through	25	65
	J16-E-Right	4	0		J23-S-Right	13	20
	J16-N-Through	7	15		J23-S-Through	13	105
	J16-N-U-Turn	7	0		J23-W-Left	22	20
	J16-W-Left	1	0		J23-W-Right	22	20
	J16-W-Right1	1	15		J23-W-Through	22	0
	J16-W-Right2	1	15				
17	J17-S-Left	0	0				
	J17-S-Right	0	15				
	J17-W-Through	0	0				

From above tables it can inferred that most of modeled queue lengths are matching with observed queue lengths.

4.10 Model Assessment

4.10.1 Assessment Criteria

With the base model fully calibrated through the steps mentioned above, the model is ready to be used as a base for testing the impacts of various traffic measures and proposals.

To show the implications of such impact, there are key measurements that can be taken from the model as assessment criteria. The criterion considered in this study are as follows:

- Delays (Level of Service)
- Queue Lengths
- Vehicle Travel Time

Out of all the assessment criterion, delays / Level of Service is the most commonly used indicator of junction performance.

4.10.2 Delays (Level of Service)

Level of Service (LOS) criteria for delay as per HCM 2010 is shown in table below.

The Highway Capacity Manual (HCM) uses the concept of level of service (LOS) as a qualitative measure to describe operational conditions of vehicular traffic. The criterion for determining LOS at signalized and unsignalized intersections is delay per vehicle, in seconds per vehicle.

Vehicular LOS analysis is based on a scale from A through F, with A representing the best and F representing the worst traveling conditions.

LOS	Controlled Intersections	Uncontrolled Intersections
A	0-10	0-10
B	11-25	11-15
C	21-35	16-25
D	36-55	26-35
E	56-80	36-50
F	>80	>50

Figure 4-56 LOS Criteria

4.10.3 Assessment Result

All the junctions in trail study area are unsignalized intersections expect Junction 23. Delay results obtained from the model for the junctions in study area are shown in tables below.

Table 4-17 Delay Results Base AM Peak

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
1	J1-E-Right	299	0	A	17	J17-S-Left	470	1	A
	J1-E-Through	1070	0	A		J17-S-Right	1104	1	A
	J1-W-Left	1448	11	B		J17-W-Through	439	0	A
	Total	2817	6	A		**Total**	**2013**	**1**	**A**
2	J2-N-Left	78	3	A	18	J18-E-Right	206	4	A
	J2-W-Left	103	1	A		J18-E-Through	263	2	A
	J2-W-Through	1514	0	A		J18-W-Left	251	2	A
	Total	**1695**	**0**	**A**		J18-W-Through	438	2	A
3	J3-N-Left	45	5	A		**Total**	**1158**	**2**	**A**
	J3-W-Left	233	9	A	19	J19-E-Through	246	10	B
	J3-W-Through	1571	7	A		J19-N-Left	324	4	A

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	Total	**1849**	**7**	A		J19-W-Through	481	12	B
4	J4-E-Through	912	11	B		**Total**	**1051**	**9**	**A**
	J4-N-Left	0	0	A	20	J20-E-Left	64	1	A
	J4-S-Left	40	0	A		J20-E-Right	56	5	A
	J4-W-Left	0	0	A		J20-E-Through	126	2	A
	J4-W-Through	1604	5	A		J20-S-Left	0	0	A
	Total	**2556**	**7**	**A**		J20-S-Right	28	7	A
5	J5-E-Left	53	0	A		J20-S-Through	74	4	A
	J5-E-Through	899	0	A		J20-W-Left	253	2	A
	J5-N-Left	88	4	A		J20-W-Right	14	2	A
	J5-S-Left	14	1	A		J20-W-Through	452	2	A
	J5-W-Left	525	2	A		**Total**	**1067**	**2**	**A**
	J5-W-Through	1543	2	A	21	J21-E-Left	0	0	A
	Total	**3122**	**1**	**A**		J21-E-Through	126	0	A
13	J13-N-Left	65	8	A		J21-N-left	213	1	A
	J13-N-Right	164	12	B		J21-N-Right	79	5	A
	J13-N-Through	124	9	A		J21-N-Through	18	3	A
	J13-S-Left	42	0	A		J21-S-Left	149	1	A
	J13-S-Right	175	2	A		J21-S-Right	205	3	A
	J13-S-Through	309	0	A		J21-S-U-Turn	0	0	A
	Total	**879**	**4**	**A**		J21-W-Right	10	2	A
14	J14-S-Right	0	0	A		J21-W-Through	311	2	A

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	J14-W-Right	0	0	A		**Total**	**1111**	**2**	**A**
	Total	**224**	**2**	**A**	22	J22-E-Right	2	10	B
15	J15-N-Through	27	0	A		J22-E-Through	417	8	A
	J15-S-Through	233	1	A		J22-W-Left	204	6	A
	J15-W-Left	203	1	A		J22-W-Through	264	6	A
	J15-W-Right	19	1	A		**Total**	**887**	**7**	**A**
	Total	**482**	**1**	**A**	23	J23-E-Left	174	58	E
16	J16-E-Left1	36	1	A		J23-E-Right	61	61	E
	J16-E-Left2	12	5	A		J23-N-Left	148	57	E
	J16-E-Right	121	5	A		J23-N-Through	139	56	E
	J16-N-Through	457	4	A		J23-S-Right	63	49	D
	J16-N-U-Turn	0	0	A		J23-S-Through	246	58	E
	J16-W-Left	965	1	A		J23-W-Left	122	80	E
	J16-W-Right1	227	2	A		J23-W-Right	44	105	F
	J16-W-Right2	352	2	A		J23-W-Through	200	84	F
	Total	**2559**	**2**	**A**		**Total**	**1197**	**66**	**E**

Table 4-18 Delay Results Base PM Peak

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
1	J1-E-Right	240	0	A	17	J17-S-Left	186	1	A
	J1-E-Through	2234	0	A		J17-S-Right	782	1	A
	J1-W-Left	804	4	A		J17-W-Through	612	0	A
	Total	3278	1	A		**Total**	**1580**	**0**	**A**
2	J2-N-Left	61	1	A	18	J18-E-Right	3	1	A
	J2-W-Left	72	0	A		J18-E-Through	183	0	A
	J2-W-Through	822	0	A		J18-W-Left	160	2	A
	Total	**955**	**0**	**A**		J18-W-Through	613	2	A
3	J3-N-Left	49	4	A		**Total**	**959**	**2**	**A**
	J3-W-Left	152	1	A	19	J19-E-Through	248	10	B
	J3-W-Through	845	5	A		J19-N-Left	329	4	A
	Total	**1046**	**4**	A		J19-W-Through	474	10	B
4	J4-E-Through	1956	6	A		**Total**	**1051**	**8**	**A**
	J4-N-Left	1	0	A	20	J20-E-Left	61	1	A
	J4-S-Left	20	0	A		J20-E-Right	20	4	A
	J4-W-Left	0	0	A		J20-E-Through	167	1	A
	J4-W-Through	920	5	A		J20-S-Left	32	1	A
	Total	**2897**	**6**	**A**		J20-S-Right	0	0	A
5	J5-E-Left	112	1	A		J20-S-Through	39	4	A
	J5-E-Through	1864	1	A		J20-W-Left	181	2	A
	J5-N-Left	149	1	A		J20-W-Right	0	0	A

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	J5-S-Left	14	3	A		J20-W-Through	470	2	A
	J5-W-Left	345	1	A		**Total**	**970**	**2**	**A**
	J5-W-Through	714	0	A	21	J21-E-Left	0	0	A
	Total	**3198**	**1**	**A**		J21-E-Through	199	0	A
13	J13-N-Left	43	12	B		J21-N-left	186	1	A
	J13-N-Right	404	12	B		J21-N-Right	130	5	A
	J13-N-Through	187	19	C		J21-N-Through	32	3	A
	J13-S-Left	69	-1	A		J21-S-Left	148	1	A
	J13-S-Right	57	2	A		J21-S-Right	144	4	A
	J13-S-Through	219	0	A		J21-S-U-Turn	0	0	A
	Total	**979**	**9**	**A**		J21-W-Right	1	4	A
14	J14-S-Right	0	0	A		J21-W-Through	330	1	A
	J14-W-Right	1	0	A		**Total**	**1170**	**2**	**A**
	Total	**153**	**1**	**A**	22	J22-E-Right	12	3	A
15	J15-N-Through	32	0	A		J22-E-Through	547	9	A
	J15-S-Through	152	1	A		J22-W-Left	256	5	A
	J15-W-Left	134	2	A		J22-W-Through	144	6	A
	J15-W-Right	18	0	A		**Total**	**959**	**7**	**A**
	Total	**336**	**1**	**A**	23	J23-E-Left	270	60	E
16	J16-E-Left1	215	3	A		J23-E-Right	144	60	E
	J16-E-Left2	85	13	B		J23-N-Left	199	61	E
	J16-E-Right	122	15	C		J23-N-Through	257	61	E

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	J16-N-Through	645	9	A		J23-S-Right	29	70	E
	J16-N-U-Turn	109	9	A		J23-S-Through	193	57	E
	J16-W-Left	675	2	A		J23-W-Left	122	71	E
	J16-W-Right1	260	2	A		J23-W-Right	101	72	E
	J16-W-Right2	456	2	A		J23-W-Through	127	71	E
	Total	**3227**	**6**	**A**		**Total**	**1442**	**63**	**E**

Based on summary of delay performance as presented above, all the junctions besides Junction 23 are performing with an overall LOS A. Junction 23 are assessed to perform under LOS E for both AM and PM peaks. This would form the base model performance for future testing in the next stage of the study.

4.10.4 Vehicular Measurement: Density

Traffic density is defined as the number of vehicles occupying a unit length of roadway. The easiest way to visualize traffic density is to consider an aerial photograph of a highway section and count of number of vehicles in 1 mile of a single lane. This will be the density per lane-mile. Traffic densities vary from 0 (no flow) to values representing stopped, bumper to bumper traffic. This upper limit, called jam density, depends on the traffic composition and the clear gaps between vehicles.

4.10.5 Vehicular Measurement: Speed

Speed id defined as distance covered by a vehicle in a specific time period. Average speed is defined as speed maintained by a vehicle over a given stretch of road while the vehicle is in motion.

4.10.6 Vehicular Measurement: Vehicle Travel Time

Average time taken for a vehicle to travel from one section to other section of the road is defined as vehicle travel time.

4.10.7 Vehicular Measurement: Queue Lengths

Queue length is defined as a length of vehicles waiting to move in the road network in which the flow rate is depreciated either by bottle necks or by priority/signalized junctions. Queue lengths for all the scenarios and network performance are presented in Appendix 2 and Appendix 3 of the report respectively.

4.10.8 Pedestrian Measurement: Pedestrian Travel Time

Average time taken for a pedestrian to travel from one section to other section of the road is defined as pedestrian travel time.

4.11 Base Scenario

Results obtained for Base Scenario in study area are presented in below sections.

4.11.1 Vehicular Measurement: Delay/Level of Service

The criterion for determining LOS at signalized and unsignalized intersections is delay per vehicle as explained in section 4.10.2. Below image shows the LOS for junctions in trial study area.

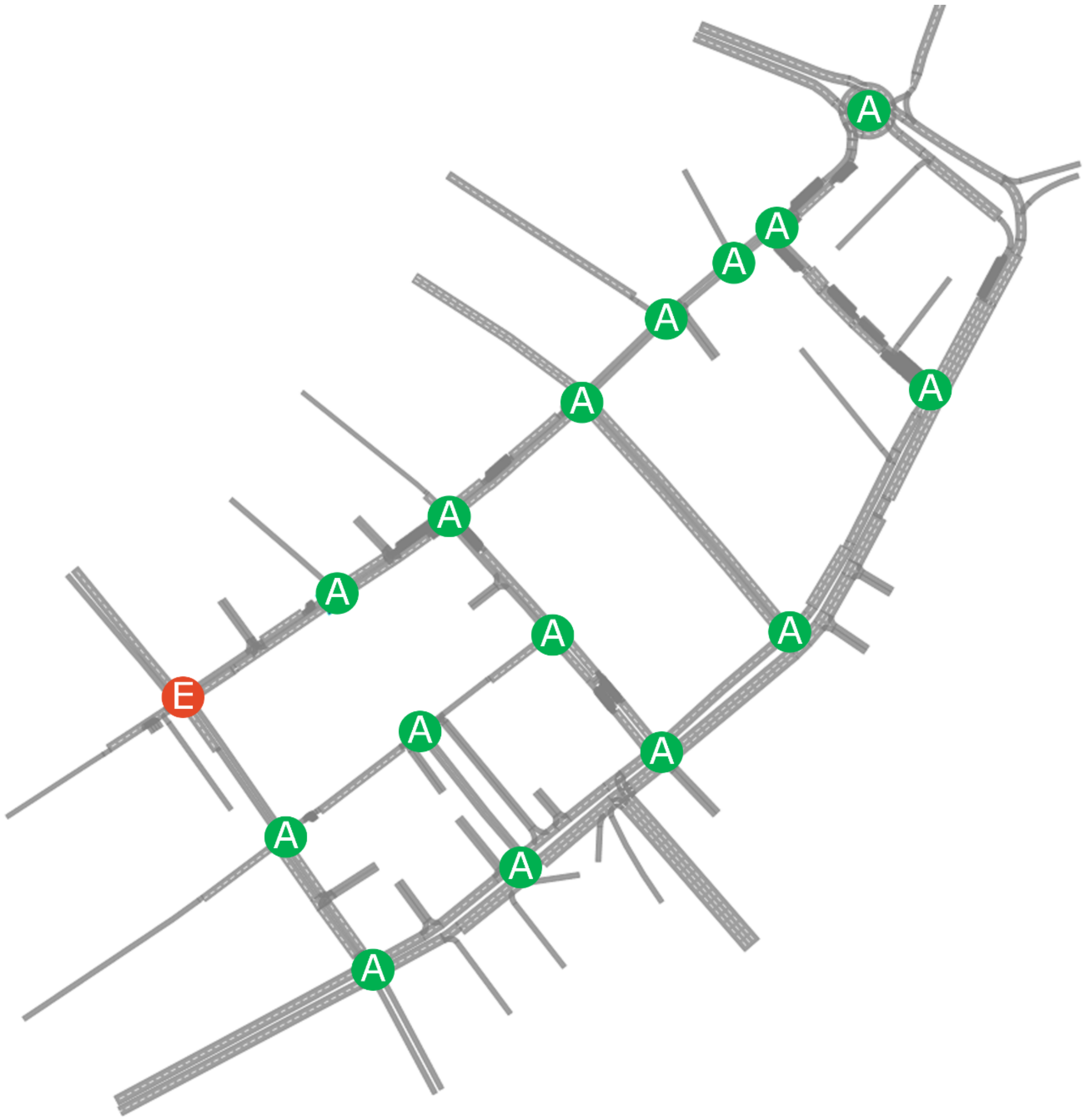


Figure 4-57 Level of Service-Scenario1 - AM and PM peak

All the junctions in Base scenario are performing with LOS A expect J23 which is performing at LOS E.

The diagram below presents the delay (in unit of seconds) experienced by vehicular traffic at each section of the road. In below image, sections with green indicates that delay is less and driving conditions are ideal and sections with yellow and lite orange indicates that congestions is noticeable and sections with red indicates that higher delay is experienced, and vehicles are moving slowly or stopping for reasonable amount of time. Irrespective of color in below image, higher the width of bar higher is the delay experienced by the vehicle.

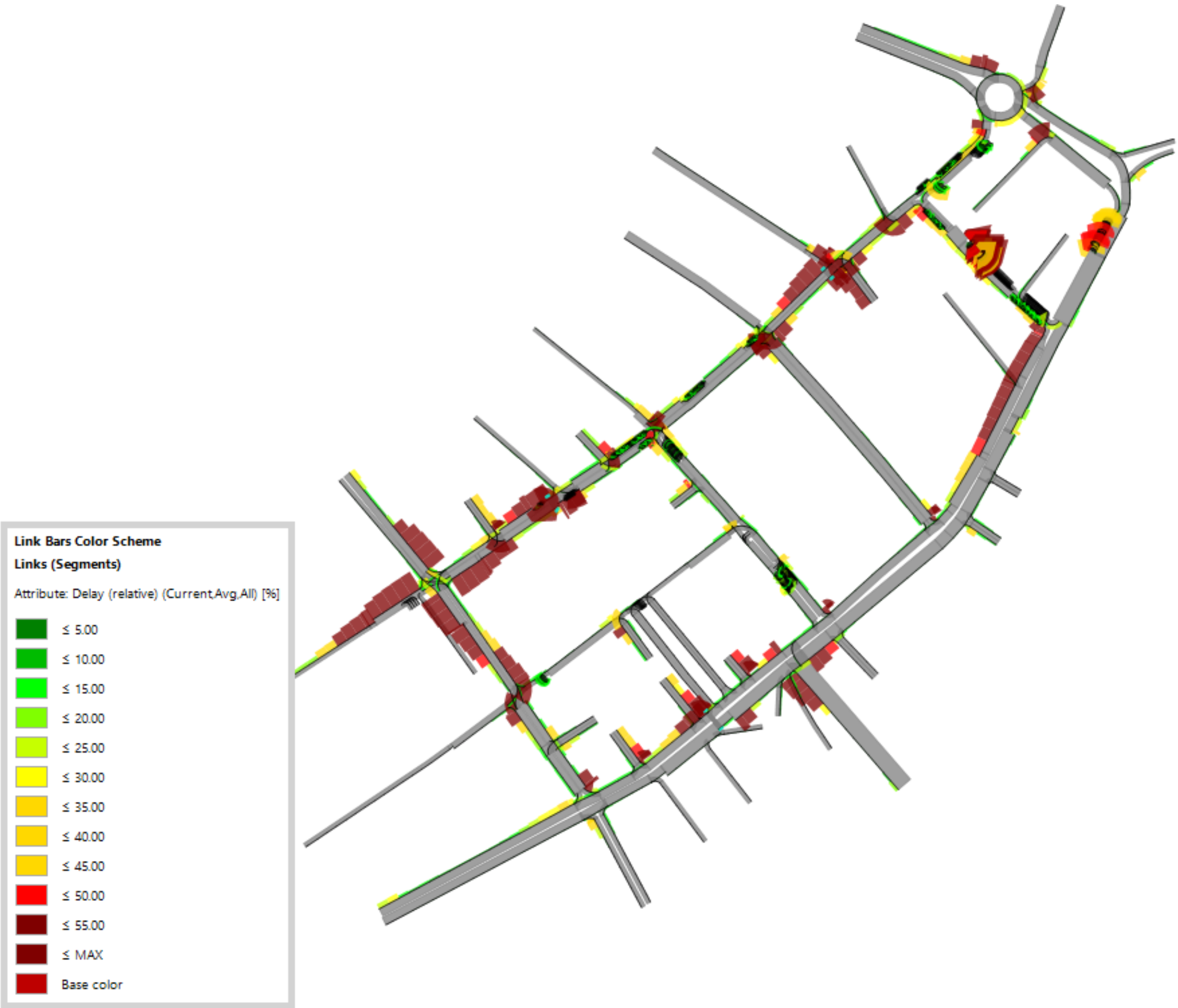


Figure 4-58 Delay-Base Scenario – AM peak

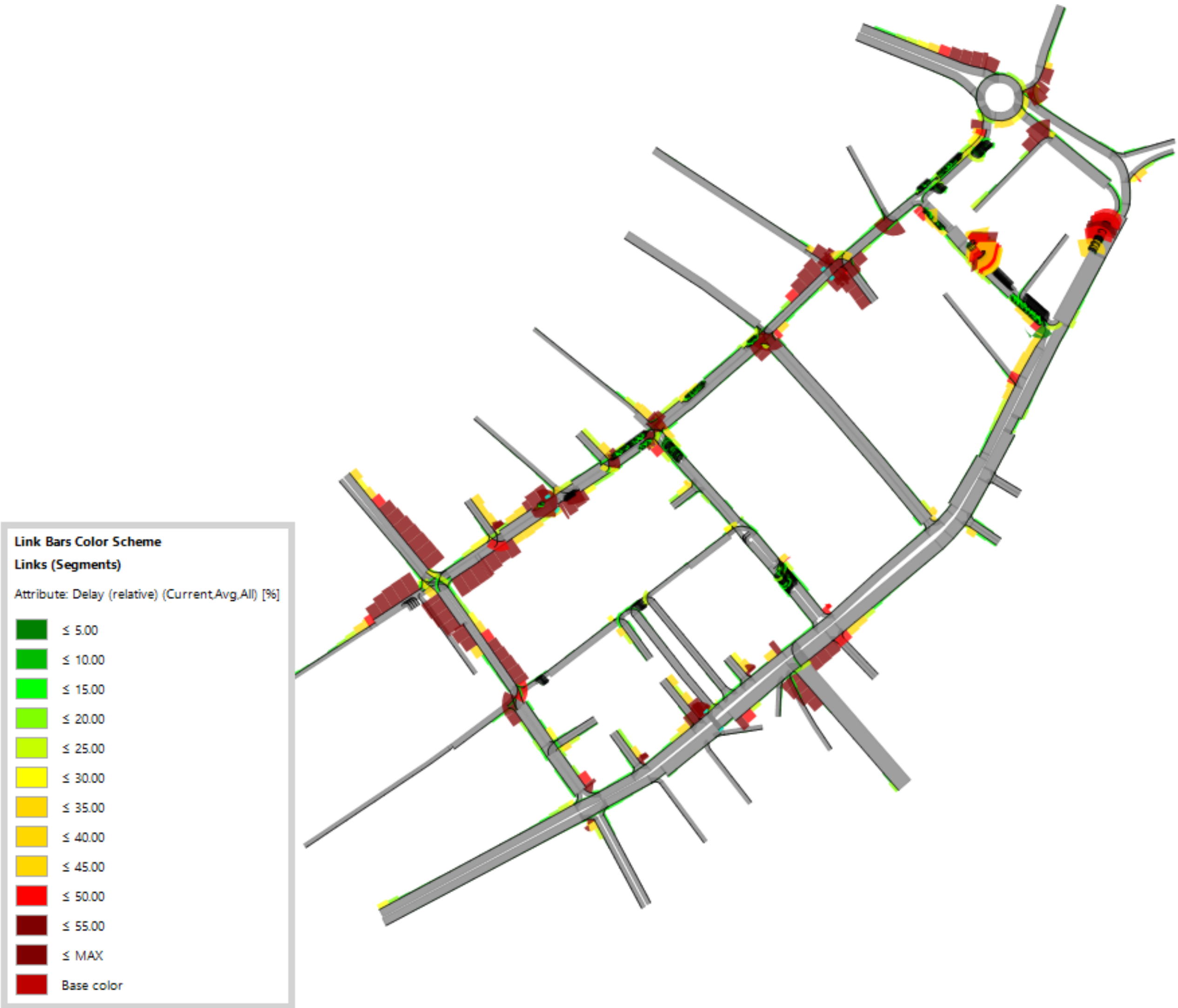


Figure 4-59 Delay-Base Scenario – PM peak

From above graphs it can be observed, dark red plots which indicates higher delay are majorly present on section near J23 in both the peaks.

4.11.2 Vehicular Measurement: Density

Density as explained in earlier sections is the number of vehicles occupying unit length of roadway. Green color bar in below image indicates sections with low density and sections with yellow and orange indicates reasonable density and sections with red and pink indicates higher density, and it is generally experienced near to signalized sections. Width of the bar is proportional to the density experienced at those sections.

Figure 4-60 Density-Base Scenario – AM peak

Figure 4-61 Density-Base Scenario – PM peak

Higher density is usually observed near to priority/signalized junction or when there is a bottle necks in the road network. From above graphs it can be observed that higher densities are observed at sections near J3, J16 and J23.

4.11.3 Vehicular Measurement: Speed

Average speed on road network in scenario-1 is demonstrated in below images. Red color bar indicates sections on the road network with speed around 50 kmph and yellow bars indicates speed around 40 kmph.

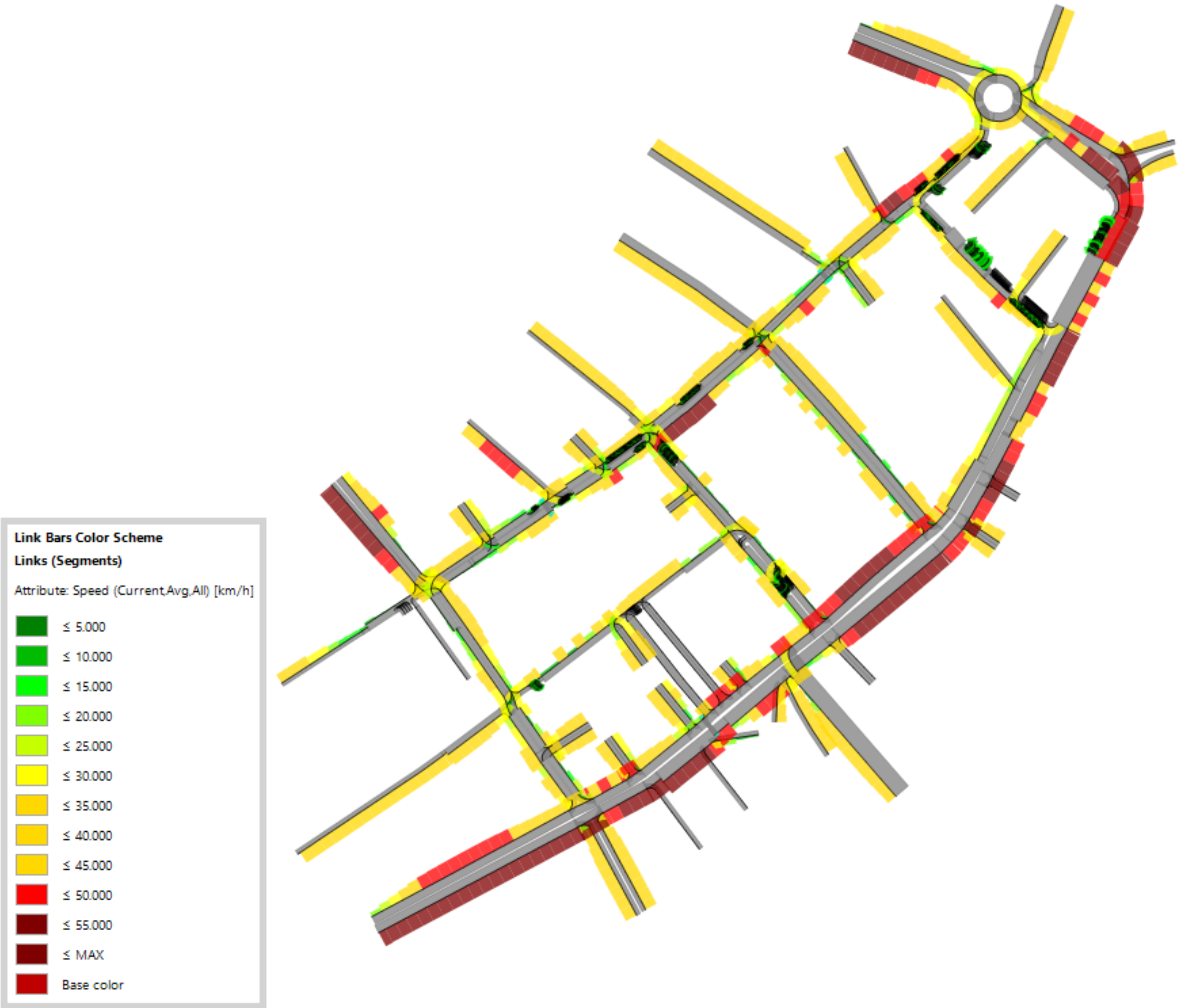


Figure 4-62 Speed- Base Scenario-AM Peak

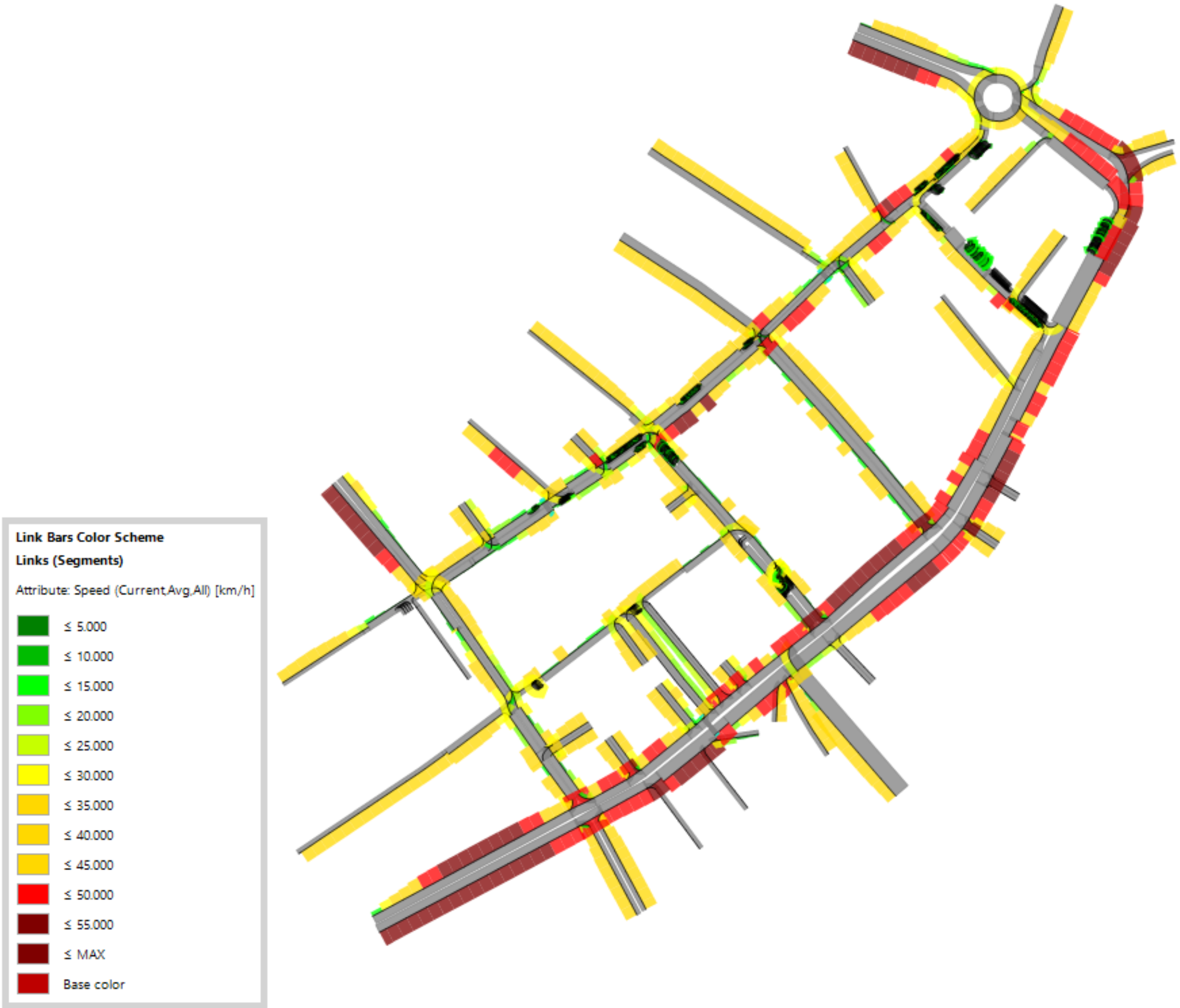


Figure 4-63 Speed- Base Scenario-PM Peak

From above graphs it can be observed that average speed on Pengkalan weld road is around 50kmph and on other roads it is 40 kmph in AM peak.

4.12 Scenario 1

All the junctions in trail study area are unsignalized intersections expect Junction 23. Results obtained for scenario-1 in study area are shown in below sections of the report.

4.12.1 Vehicular Measurement: Delay/Level of Service

The criterion for determining LOS at signalized and unsignalized intersections is delay per vehicle as explained in section 4.10.2. Below image shows the LOS for junctions in trial study area for Scenario 1.

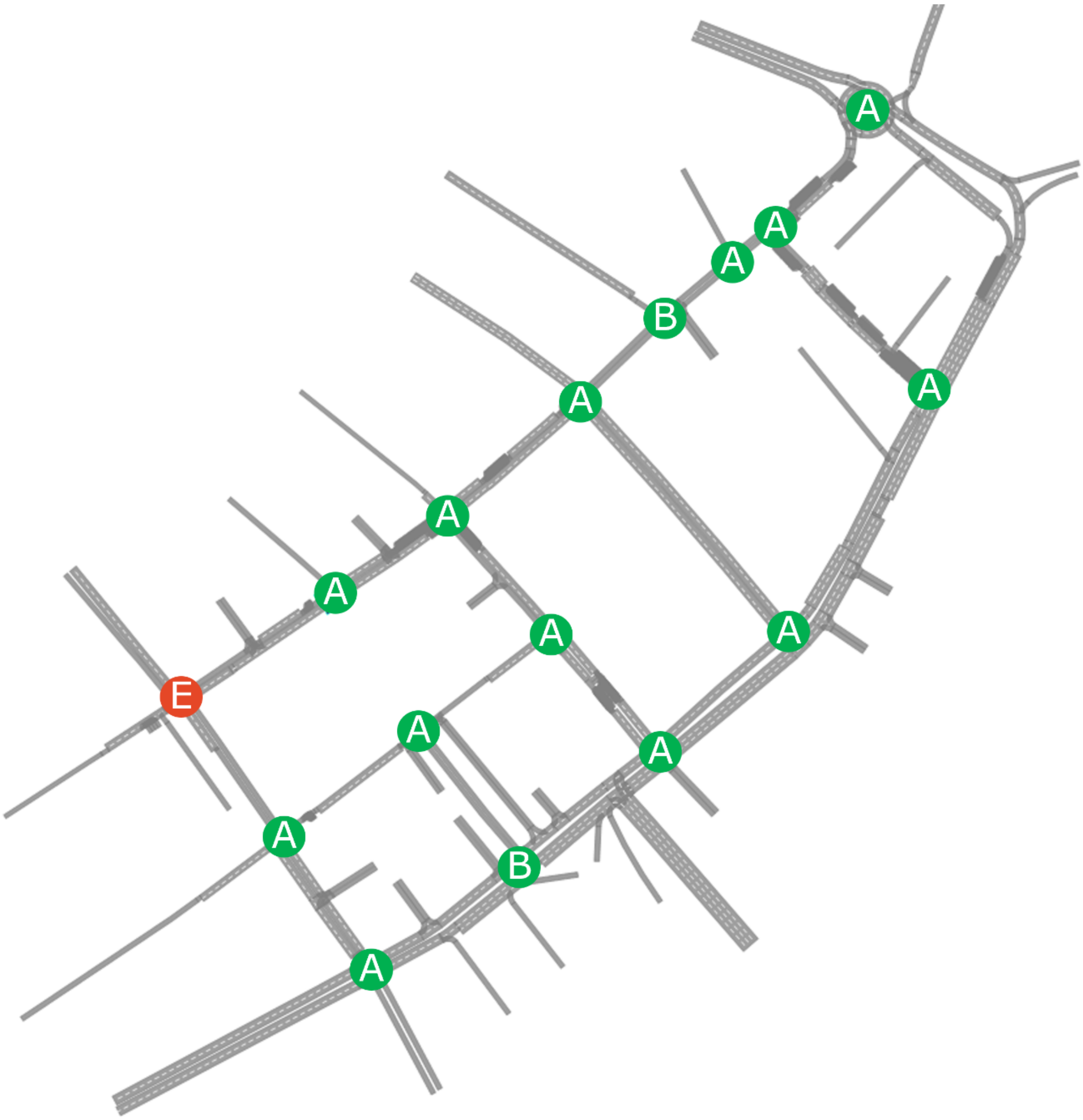


Figure 4-64 Level Of Service-Scenario1 - AM &PM peak

All the junctions in scenario-1 are performing with LOS A expect J4 and J23 which are performing at LOS B and LOS E respectively.

The diagram below presents the delay (in unit of seconds) experienced by vehicular traffic at each section of the road. In below image, sections with green indicates that delay is less and driving conditions are ideal and sections with yellow and lite orange indicates that congestions is noticeable and sections with red indicates that higher delay is experienced, and vehicles are moving slowly or stopping for reasonable amount of time. Irrespective of color in below image, higher the width of bar higher is the delay experienced by the vehicle.

Figure 4-65 Delay-Scenario1 – AM Peak

Figure 4-66 Delay-Scenario1 – PM peak

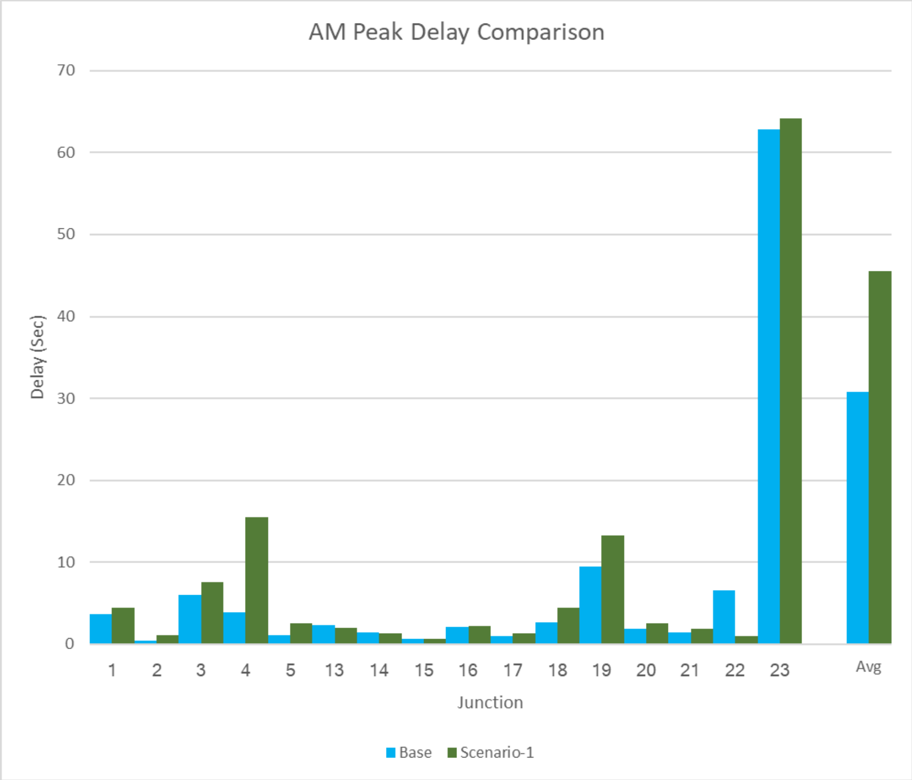


Figure 4-67 Scenario 1 - Delay Comparison -AM peak

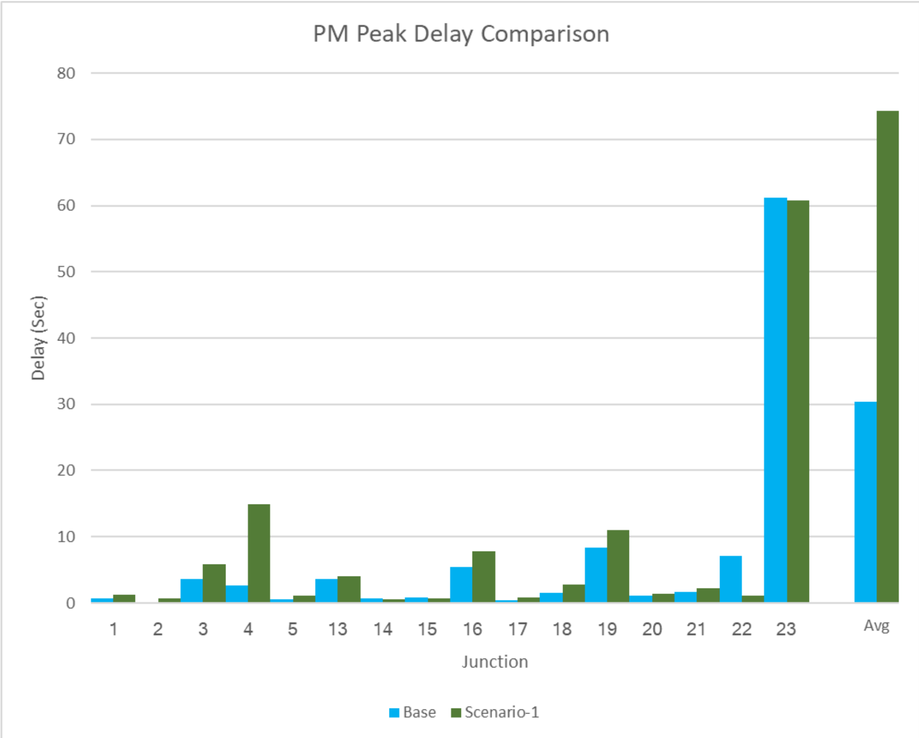


Figure 4-68 Scenario 1 - Delay Comparison -PM peak

From above graphs it can be inferred that all junctions are experiencing more or less same delay as in base scenario expect J4.

Delay is increased at J4 due to implementation of actuated pedestrian signal which gives priority for pedestrian movement and therefore results in increase of vehicular delay.

There is almost 48% and 145% increase in average delay on the road network in scenario-2 when compared with base scenario in AM and PM peak respectively.

4.12.2 Vehicular Measurement: Density

Density as explained in earlier sections is the number of vehicles occupying unit length of roadway. Green color bar in below image indicates sections with low density and sections with yellow and orange indicates reasonable density and sections with red and pink indicates higher density, and it is generally experienced near to signalized sections. Width of the bar is proportional to the density experienced at those sections.

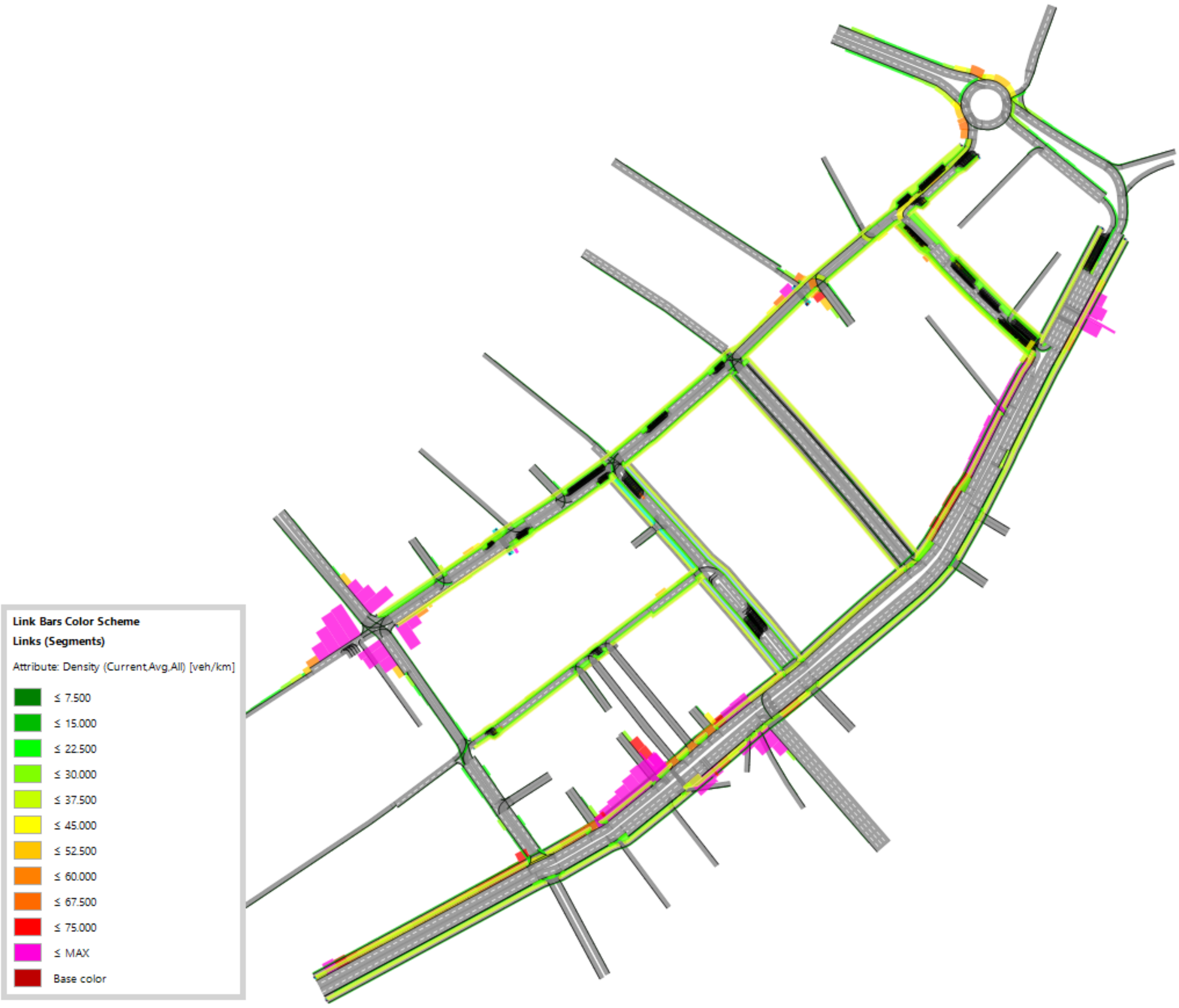


Figure 4-69 Density- Scenario 1-AM Peak

Figure 4-70 Density- Scenario 1-PM Peak

Due to implementation of actuated pedestrian signal along with vertical speed control elements at J1 and J4, density is relative higher at sections near J1 and J4 in both the peaks in scenario1.

4.12.3 Vehicular Measurement: Speed

Average speed on road network in scenario-1 is demonstrated in below images. Red color bar indicates sections on the road network with speed around 50 kmph and yellow bars indicates speed around 40 kmph.

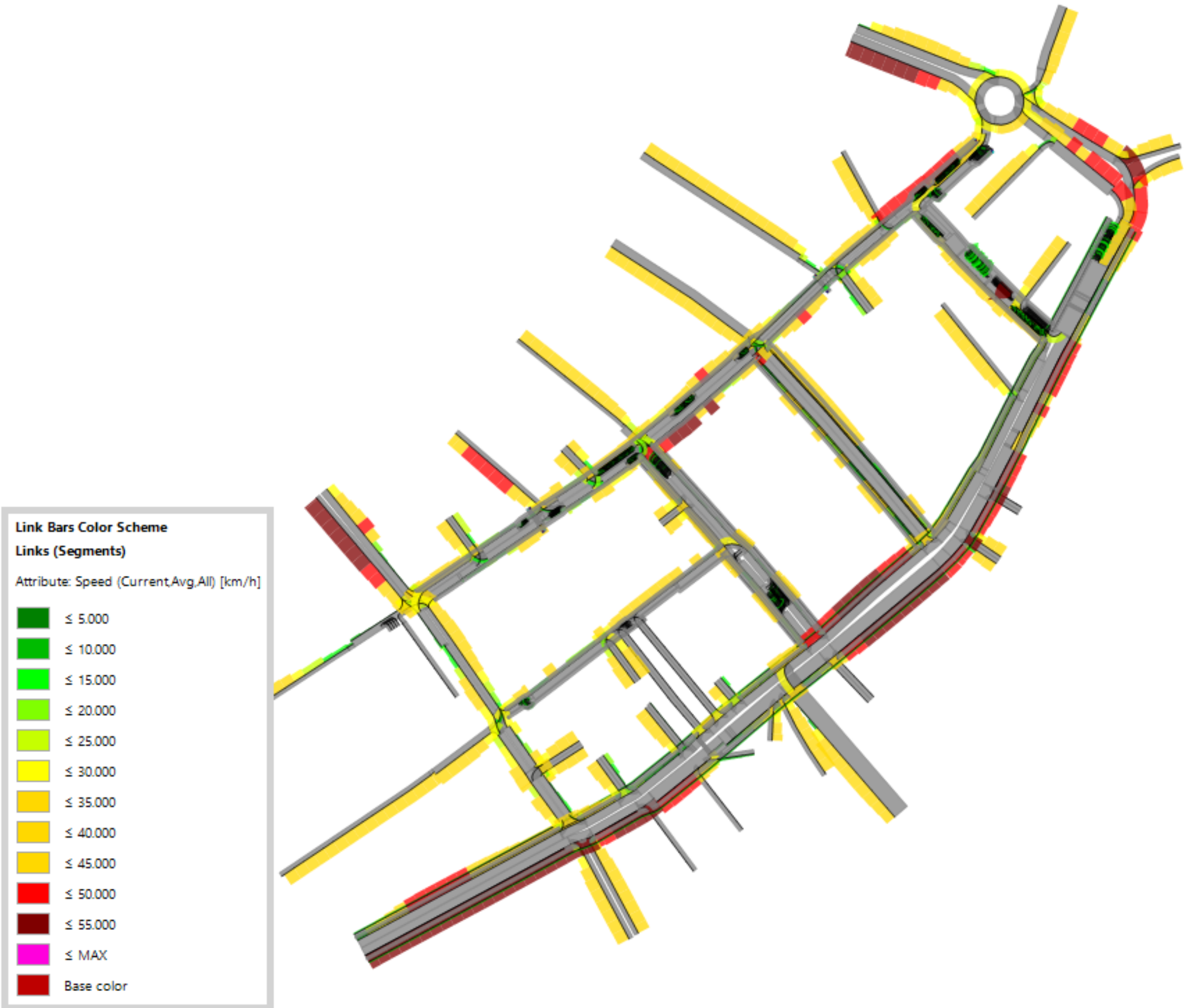


Figure 4-71 Speed- Scenario 1-AM Peak

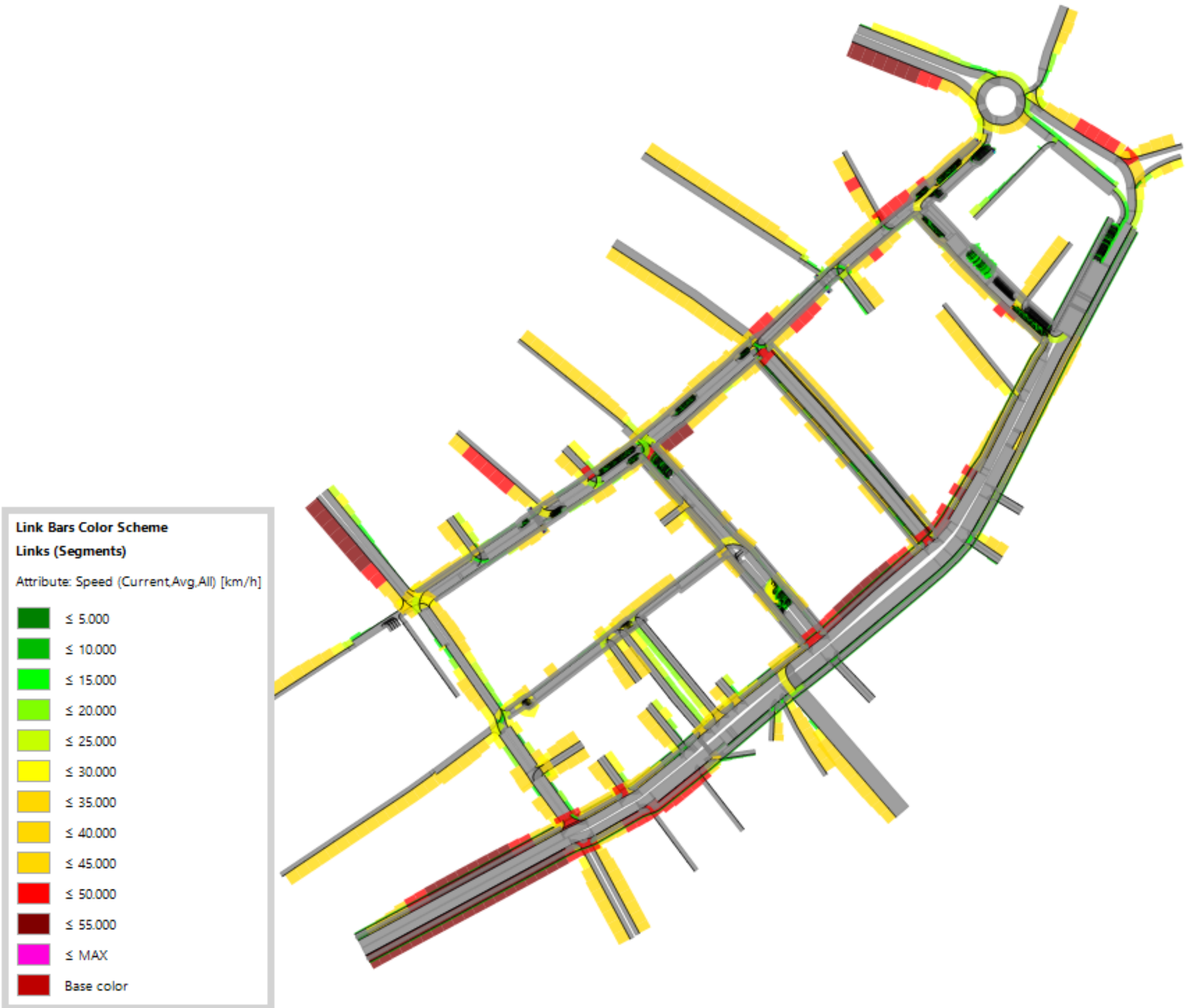


Figure 4-72 Speed- Scenario 1-PM Peak

From above graphs it can be observed that average speed on Pengkalan road is around 50kmph and on other roads it is 40 kmph in AM peak.

In PM peak, sections near to J1 and J4 of Pengkalan road, average road speed dropped to around 20 kmph. Observed reduction of speeds at those sections is due to introduction of vertical speed control and actuated pedestrian signals near J1 and J4.

4.12.4 Pedestrian Measurement: Travel Time

Time taken for pedestrian to travel from one end of Pengkalan weld road to other end in trail study area is measured as shown in figure below.

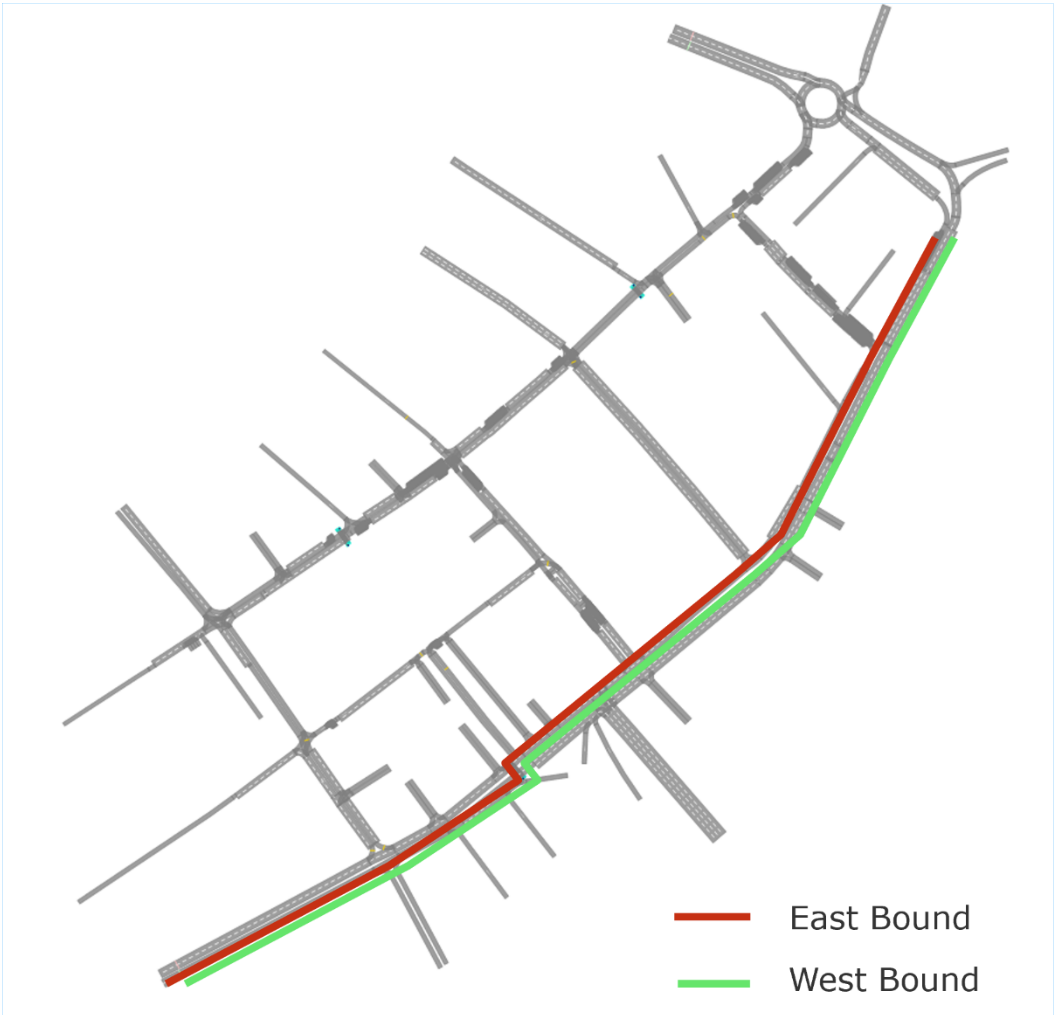


Figure 4-73 Pedestrian travel time sections

For better understanding the pedestrian performance in scenario-1 a comparison between base scenario and scenario-1 is done and is presented below.

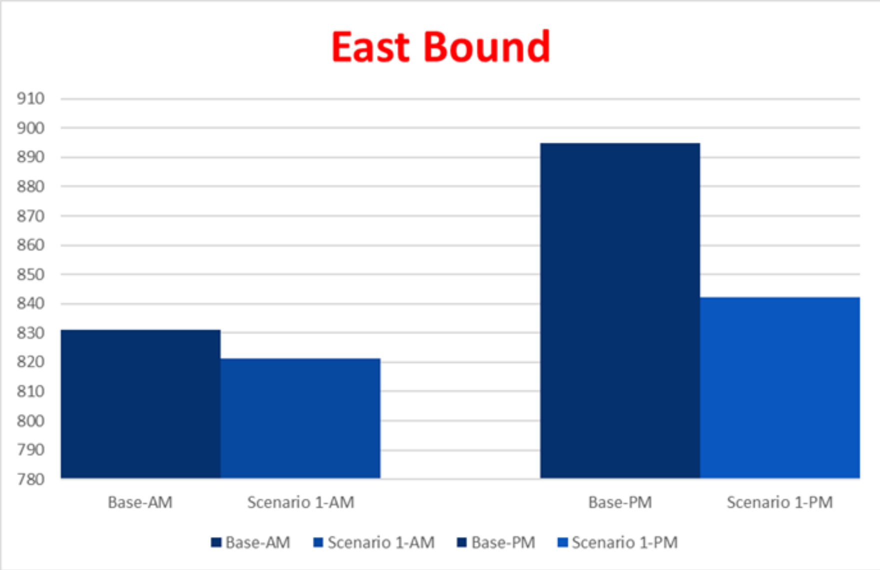


Figure 4-74 Pedestrian travel time-East Bound

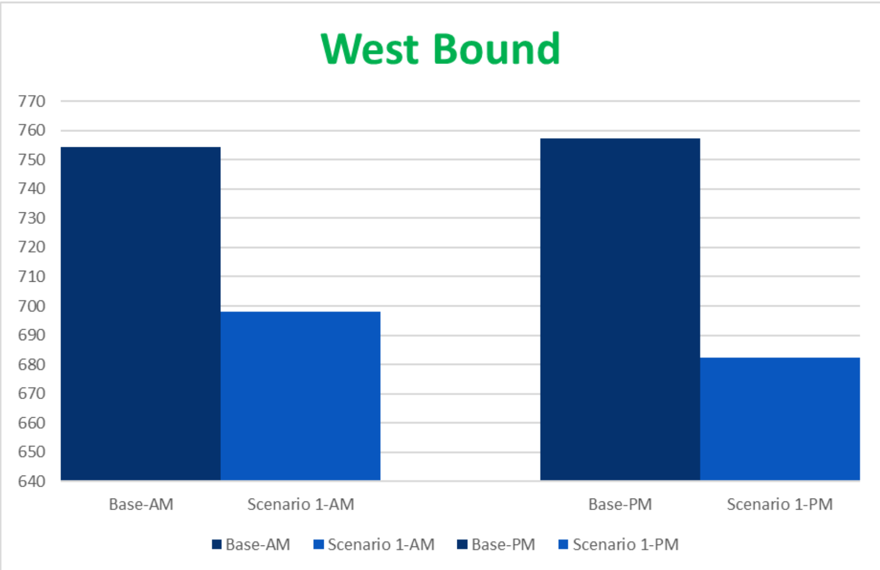


Figure 4-75 Pedestrian travel time-West Bound

There is certainly as decrease of pedestrian travel time in scenario-1 and following points can be inferred from above graphs:

- In east bound direction, pedestrian travel time in Scenario 1 is decreased by 1% and 6% respectively in AM and PM peak when compared with base scenario.
- Travel time is decreased by 8% and 11% in west bound direction when compared with bae scenario.

4.13 Scenario 2

In this scenario, emphasis is given to understand the network performance after adopting road network improvements. Below sections provide the results of the assessment for Scenario 2.

4.13.1 Vehicular Measurement: Delay/Level of service

Based on LOS criteria for signalized and unsignalized intersections as explained in section 5.9.4, LOS for junctions is determined and presented in below images.

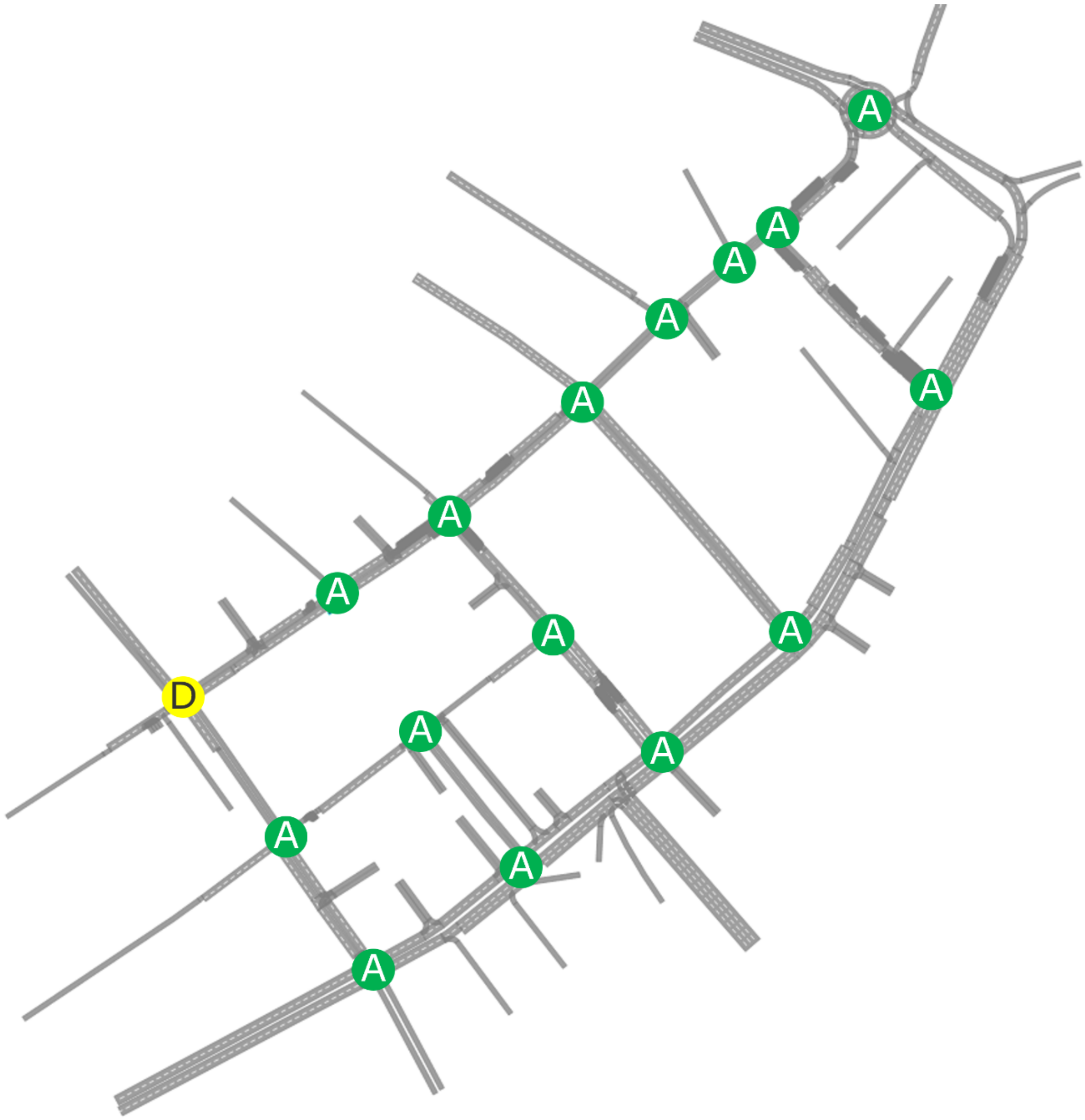


Figure 4-76 Level of Service-Scenario2 - AM peak

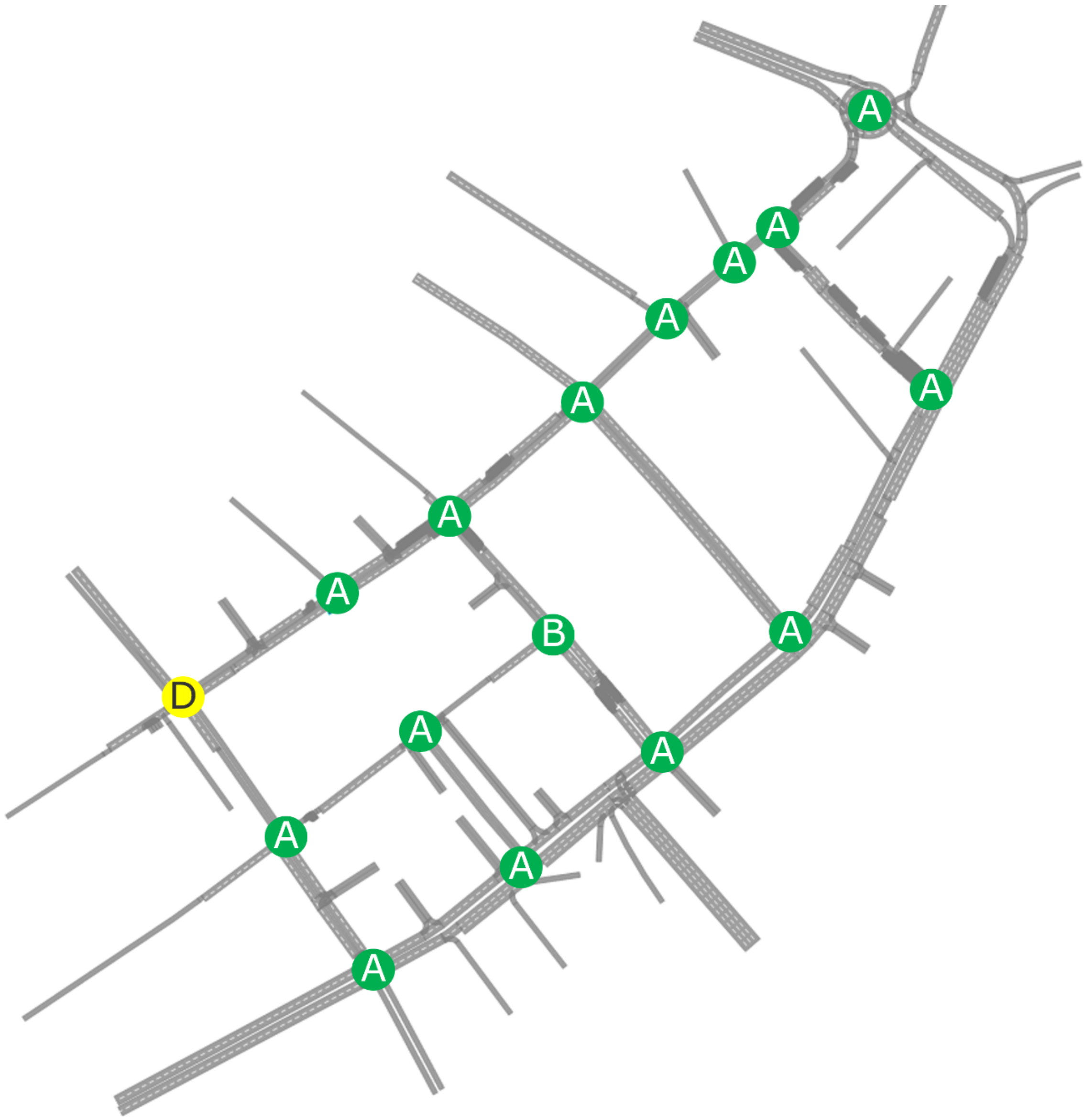


Figure 4-77 Level of Service-Scenario2 - PM peak

From the above images following observation can be done:

- All the junctions in scenario-2 are performing with LOS A expect J23 which is performing at LOS D in AM peak and
- In PM peak, J16 is operating at LOS B and J23 is operating at LOS D. Remaining junctions are operating with LOS A

In below image, sections with green indicates that delay is less and driving conditions are ideal and sections with yellow and lite orange indicates that congestions is noticeable and sections with red indicates that higher delay is experienced, and vehicles are moving slowly or stopping for reasonable amount of time. Irrespective of color in below image, higher the width of bar higher is the delay experienced by the vehicle.

Delay experienced on trial area road network in scenario-2 is displayed in below graphs.

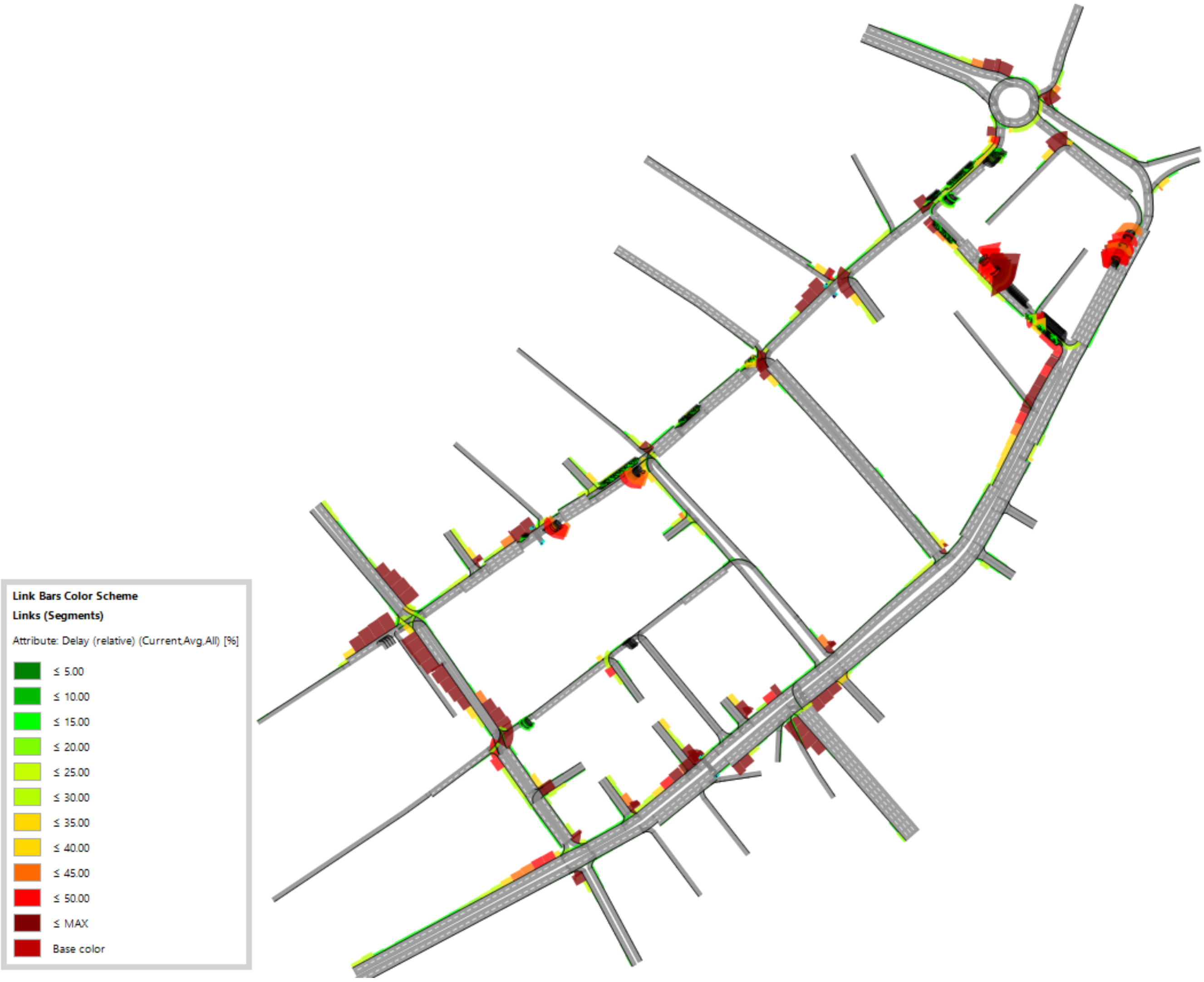


Figure 4-78 Delay-Scenario2 – AM peak

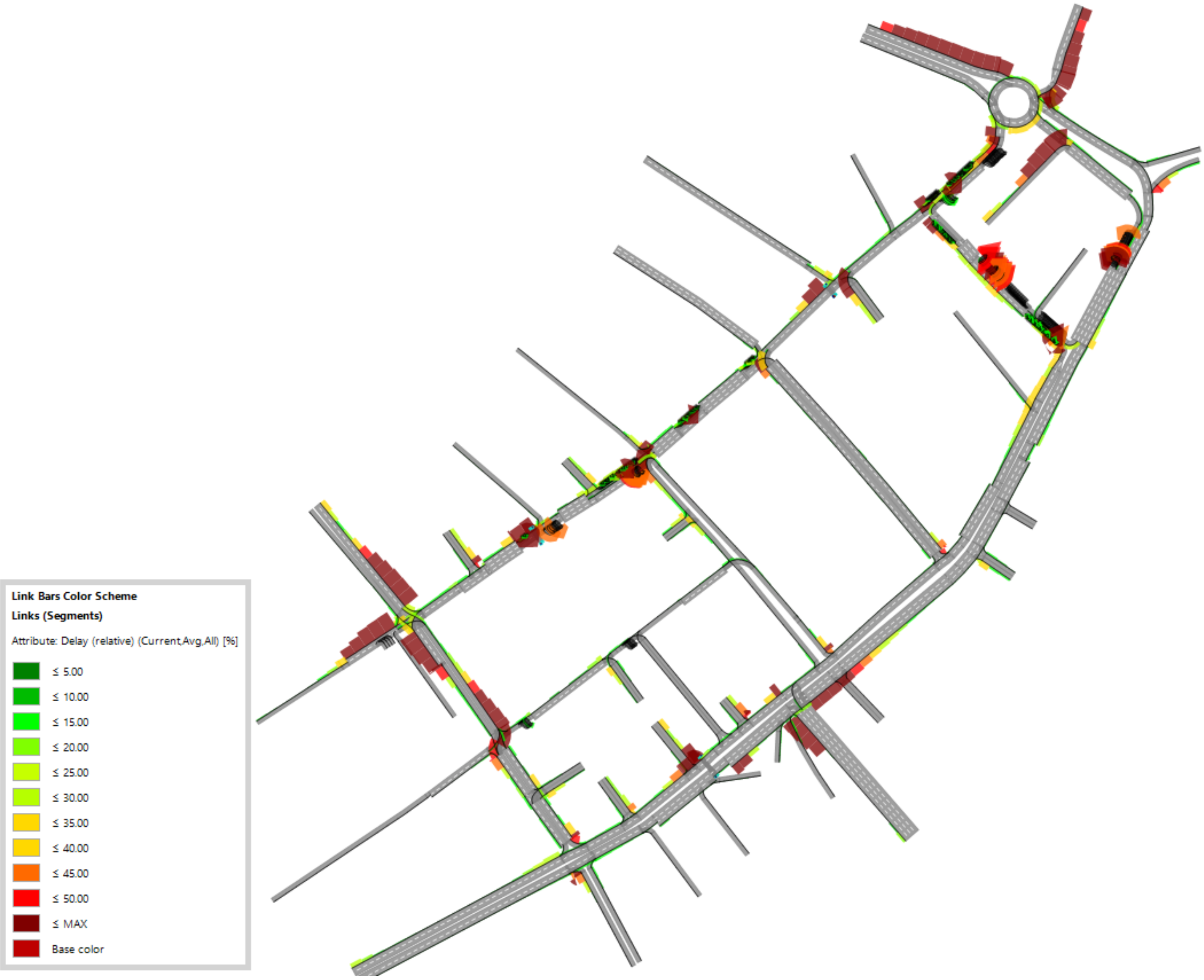


Figure 4-79 Delay-Scenario2 – PM peak

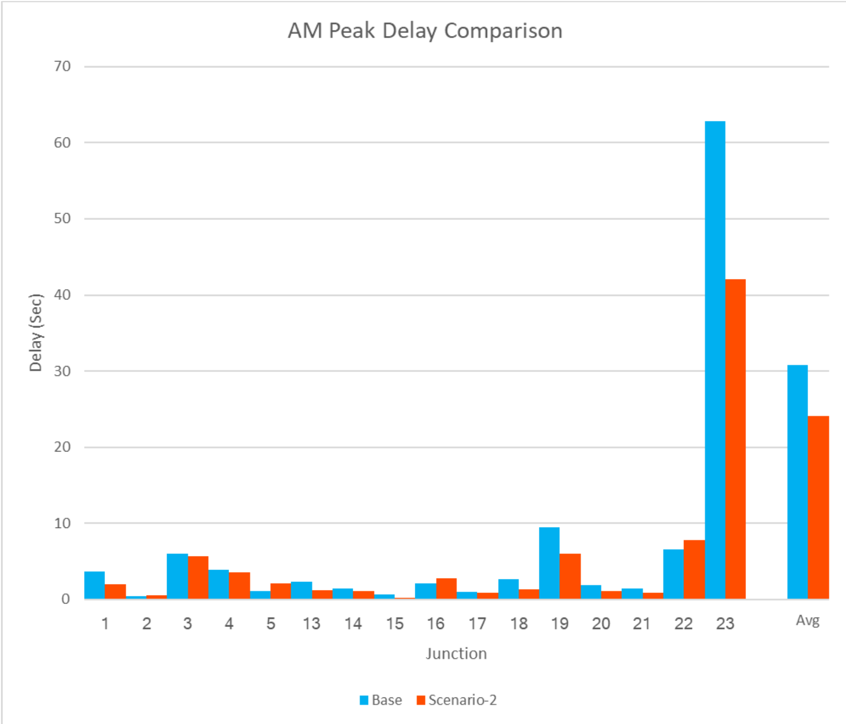


Figure 4-80 Scenario 2 - Delay Comparison -AM peak

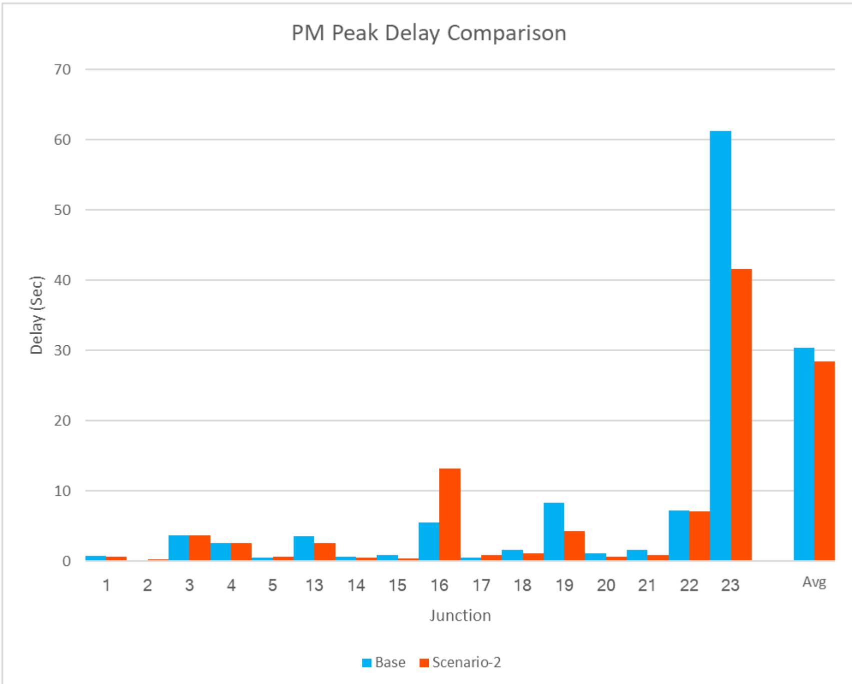


Figure 4-81 Scenario 2 - Delay Comparison -PM peak

Following observation can be made from above delay graphs and plots:

- For all the junctions expect J23, average delay is more or less same as of base scenario;

- Average Delay for J23 is reduced in scenario-2 due to provision of one-way arrangement on beach street which increases effective green time for all the movements and decreases the delay;
- Overall average delay is reduced in scenario2 by 22% and 6% in AM and PM peak respectively

4.13.2 Vehicular Measurement: Density

Density of the road network in scenario-2 is shown in below images. Green color bar in below image indicates sections with low density and sections with yellow and orange indicates reasonable density and sections with red and pink indicates higher density, and it is generally experienced near to signalized sections. Width of the bar is proportional to the density experienced at those sections.

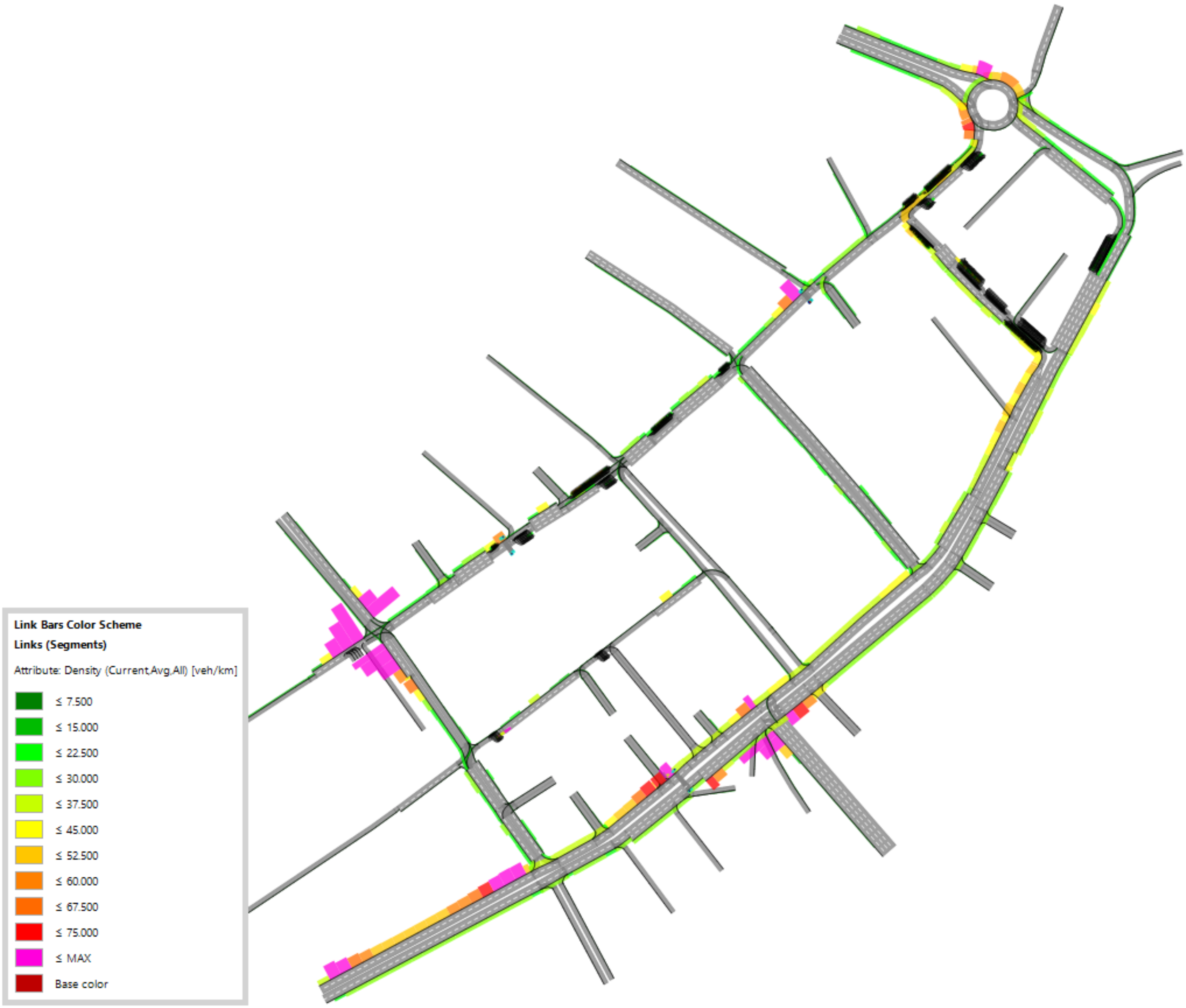


Figure 4-82 Density- Scenario 2-AM Peak

Figure 4-83 Density- Scenario 2-PM Peak

Density on Pengkalan Road west bound is increased due to introduction of one-way arrangement on beach street. Redistribution of trips is expected due to introduction of one-way arrangement, and it resulted in increase of traffic and therefore increase of density on Pengkalan Road.

4.13.3 Vehicular Measurement: Speed

Average speed on road network in scenario-2 is demonstrated in below images. Red color bar indicates sections on the road network with speed around 50 kmph and yellow bars indicates speed around 40 kmph.

Figure 4-84 Speed- Scenario 2-AM Peak

Figure 4-85 Speed- Scenario 2-PM Peak

From above graphs it can be observed that average speed on most sections of Pengkalan road in both AM and PM peak is around 50kmph and on other roads it is around 40 kmph.

4.14 Scenario 3

In this scenario, PT lanes are added on some selected sections of the road and the impact is analyzed in below section of the report.

4.14.1 Vehicular Measurement: Delay/Level of service

LOS for all the junctions in trial study area for scenario3 are shown in below images.

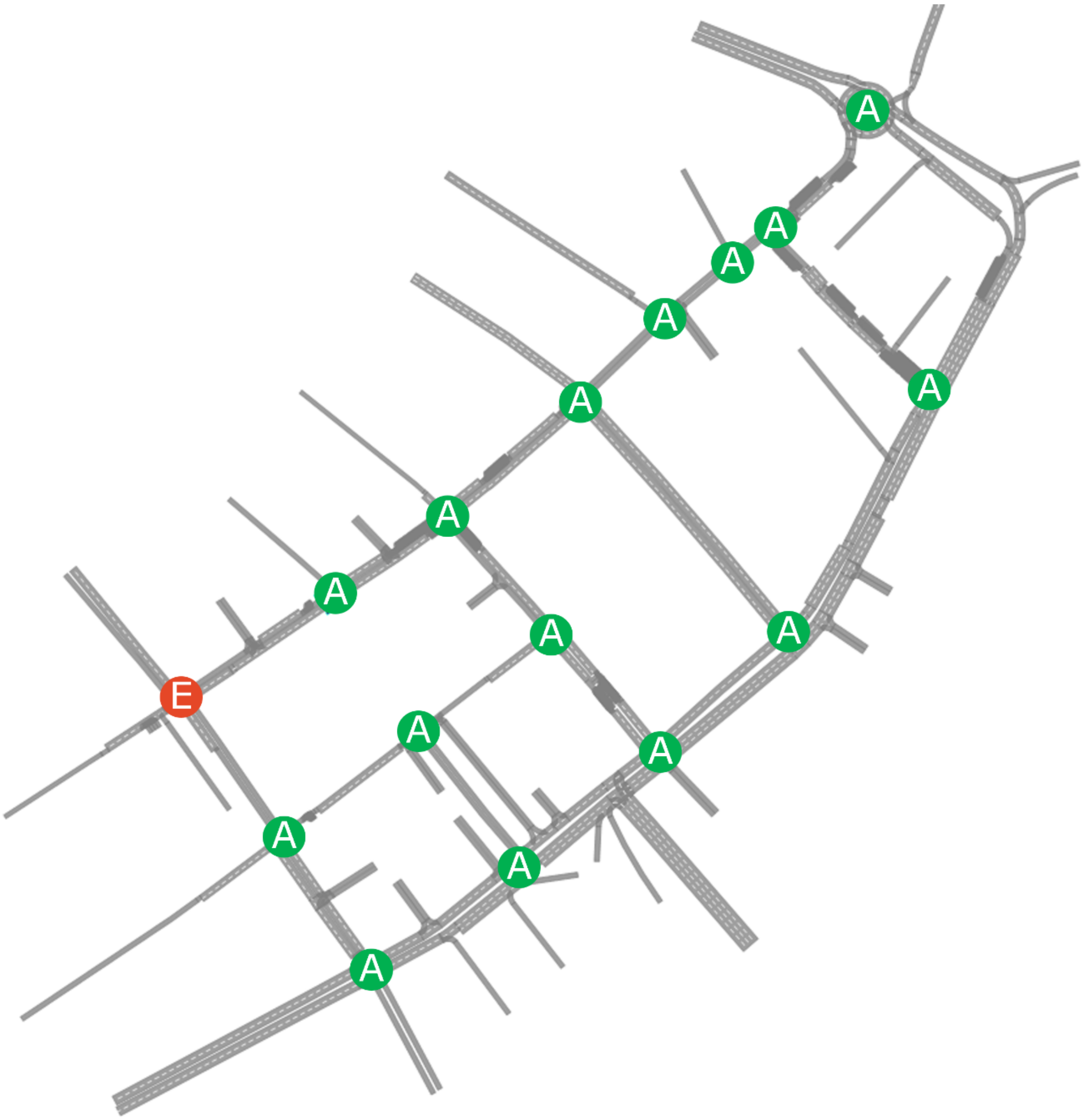


Figure 4-86 Level of Service-Scenario3 – AM & PM peak

All the junctions in scenario-3 in both the peaks are operating at LOS A expect J23 which is operating at LOS E.

Delay experienced on trial area road network in scenario-3 is displayed in below graphs.

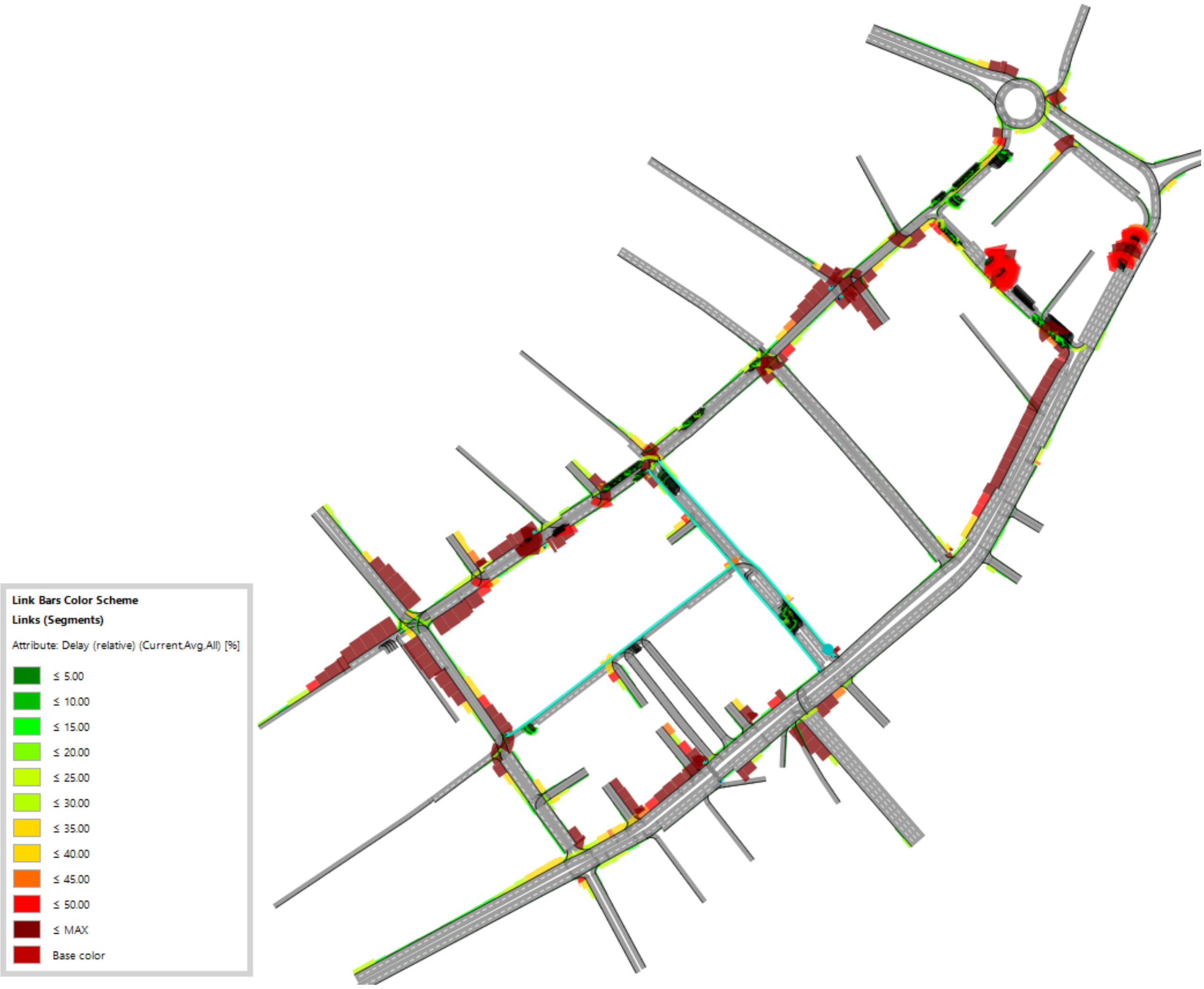


Figure 4-87 Delay-Scenario3 – AM peak

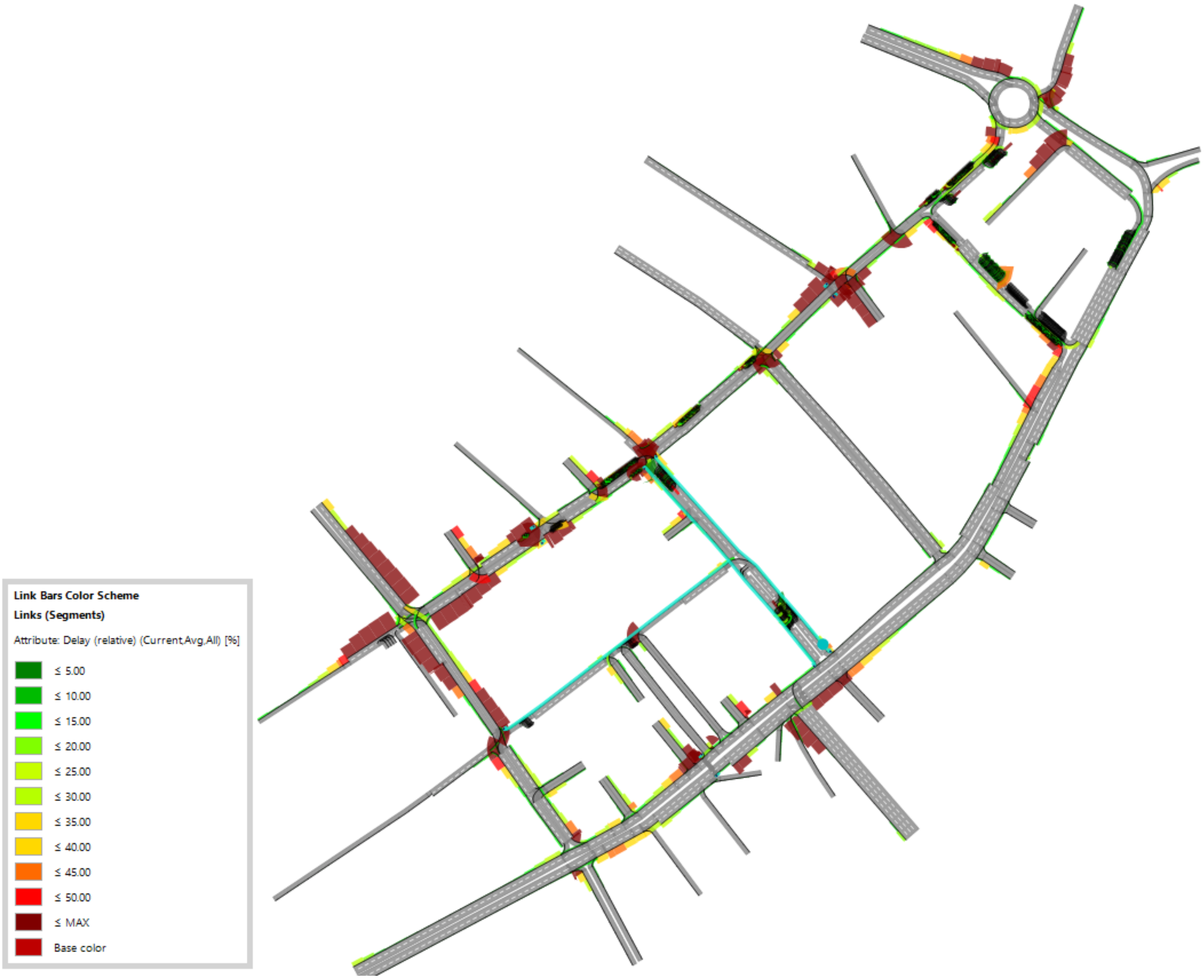


Figure 4-88 Delay-Scenario3 – PM peak

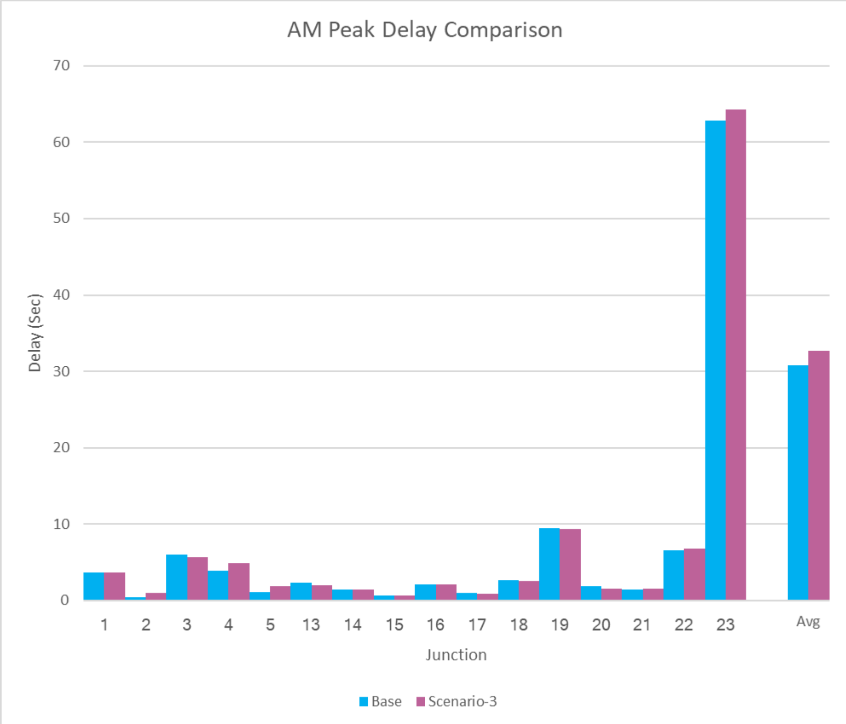


Figure 4-89 Scenario 3 - Delay Comparison -AM peak

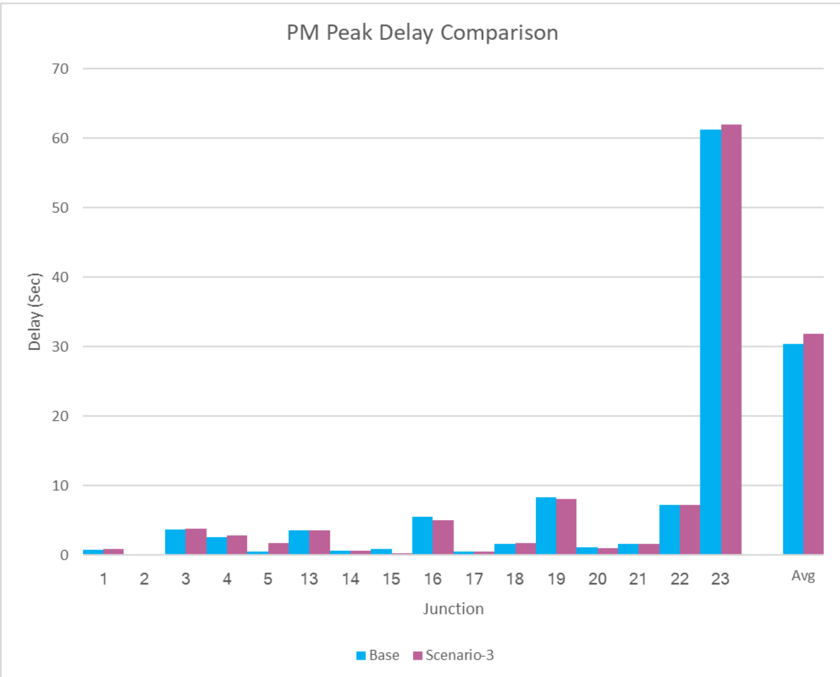


Figure 4-90 Scenario 3 - Delay Comparison -PM peak

Following observation can be made from above delay graphs and plots:

- For all the junctions in study area, average delay is more or less same as of base scenario and
- Overall average delay increase is minor in scenario3 which is 6% and 5% in AM and PM peak respectively

4.14.2 Vehicular-Density

Density of the road network in scenario-3 is shown in below images

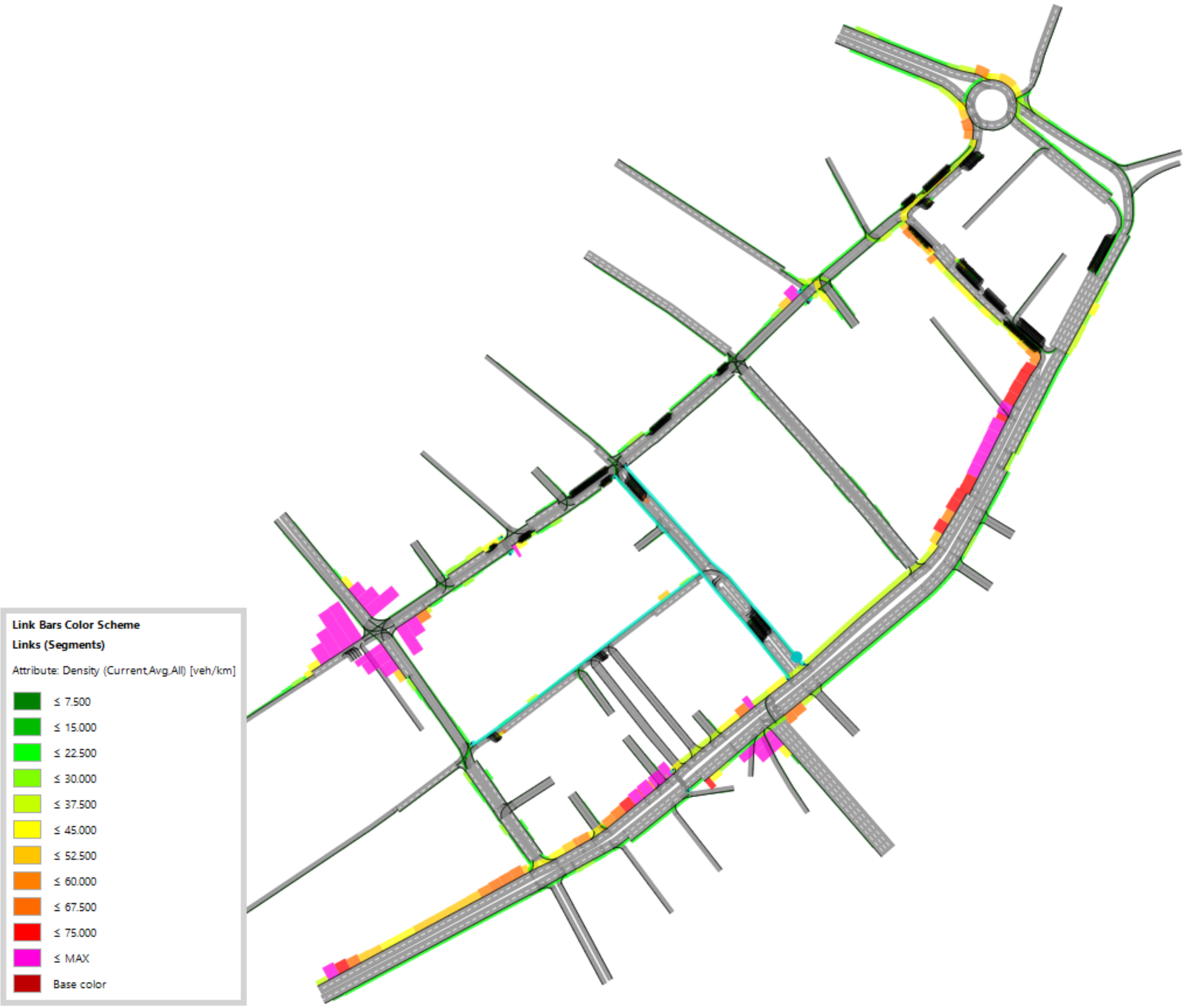


Figure 4-91 Density- Scenario 3-AM Peak

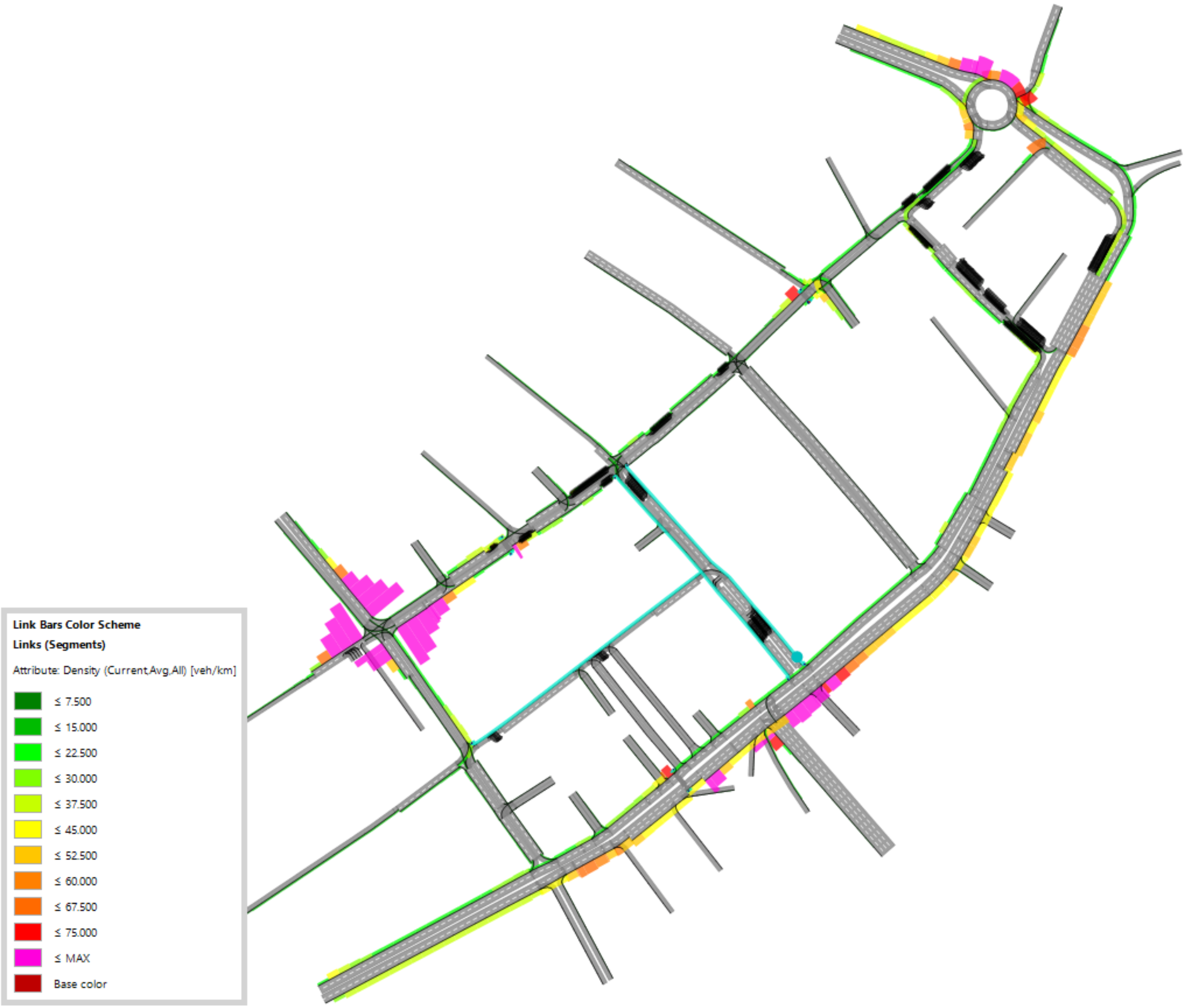


Figure 4-92 Density- Scenario 3-PM Peak

Minor increase in density is observed at sections where PT lane is introduced in both AM and PM peak. Due to introduction of PT lane, all the vehicles will be forced to travel on remaining lanes of the road, and it will decrease the capacity of the road and therefore increase the density.

4.14.3 Vehicular Measurement: Speed

Average speed on road network in scenario-3 is demonstrated in below images

Figure 4-93 Speed- Scenario 3-AM Peak

Figure 4-94 Speed- Scenario 3-PM Peak

From above graphs it can be observed that average speed on most sections of Pengkalan Road in both AM and PM peak is around 50kmph and on other roads it is 40 kmph.

4.15 Scenario 4

Results obtained for scenario-4 in study area are shown in below sections of the report

4.15.1 Vehicular Measurement: Delay/Level of service

LOS for all the junctions in trial study are for scenario4 are shown in below images.

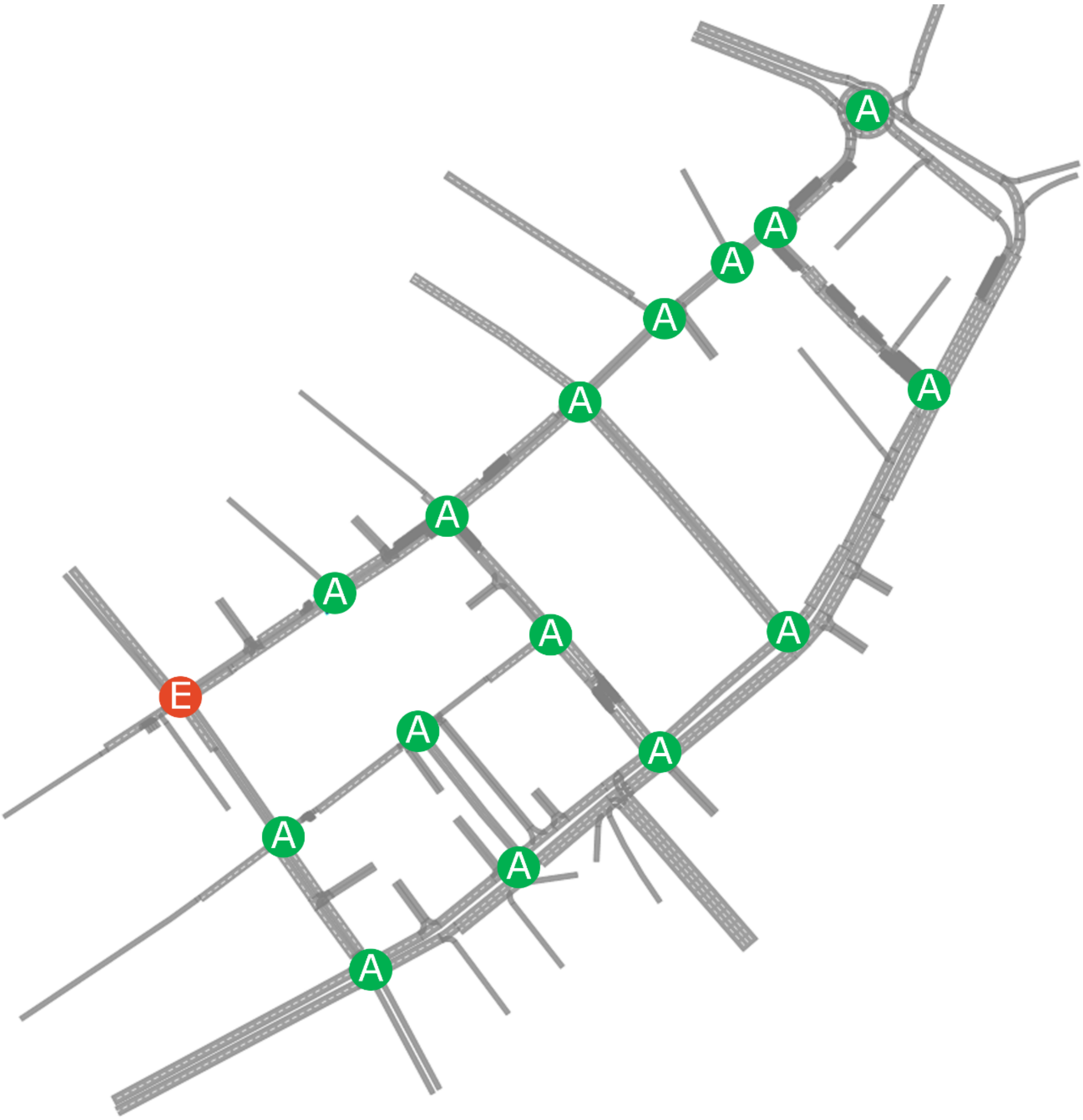


Figure 4-95 Level of Service-Scenario4 – AM Peak

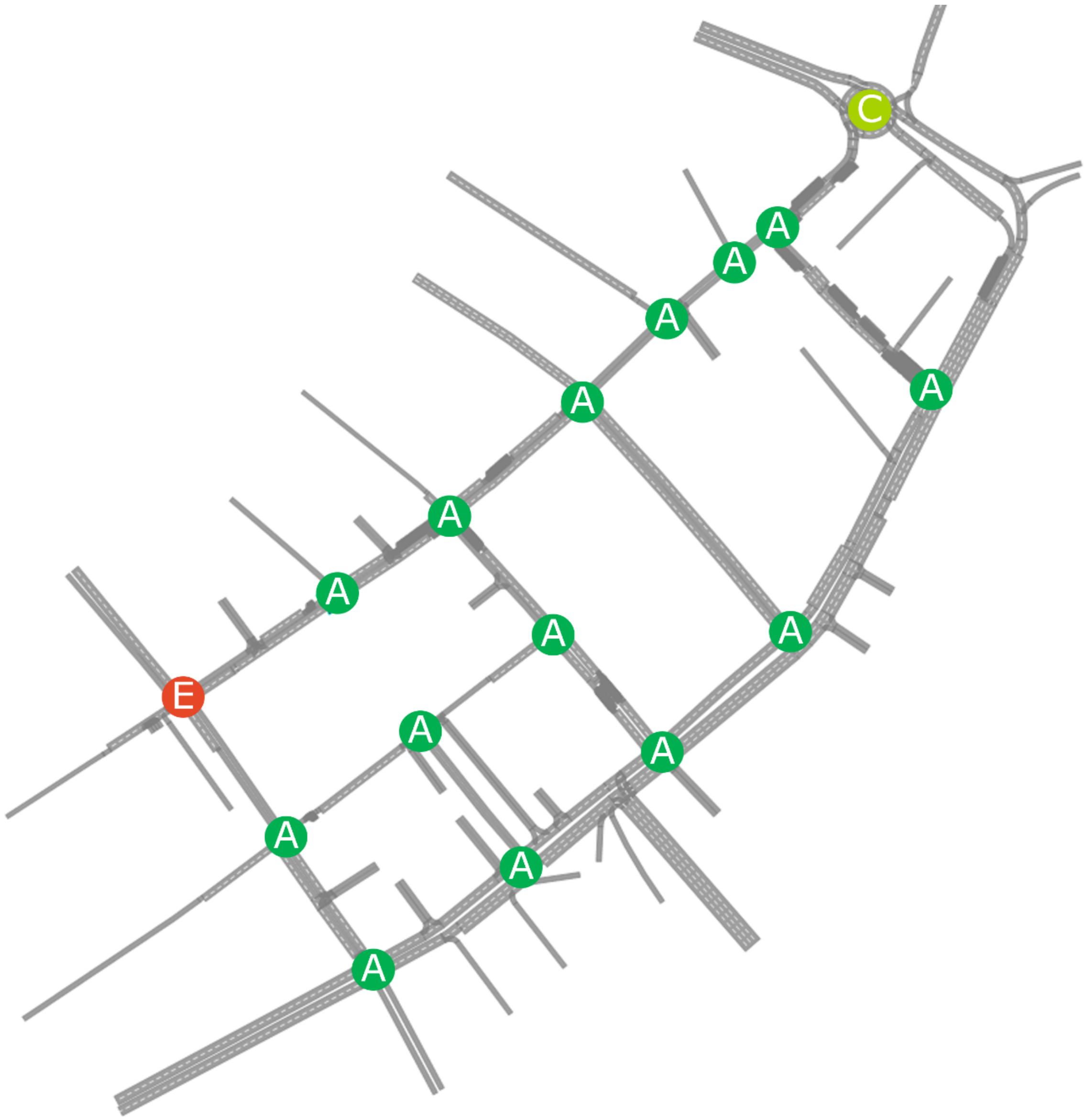


Figure 4-96 Level of Service-Scenario4 – PM Peak

Following observations can be done based on above images:

- In AM peak, all the junctions are operating with LOS A expect J23 which is operating at LOS E and
- J23 and J17 are operating at LOS E and LOS C respectively in PM peak and remaining junctions are performing with LOS A.

Delay experienced on trial area road network in scenario-4 is displayed in below figures.

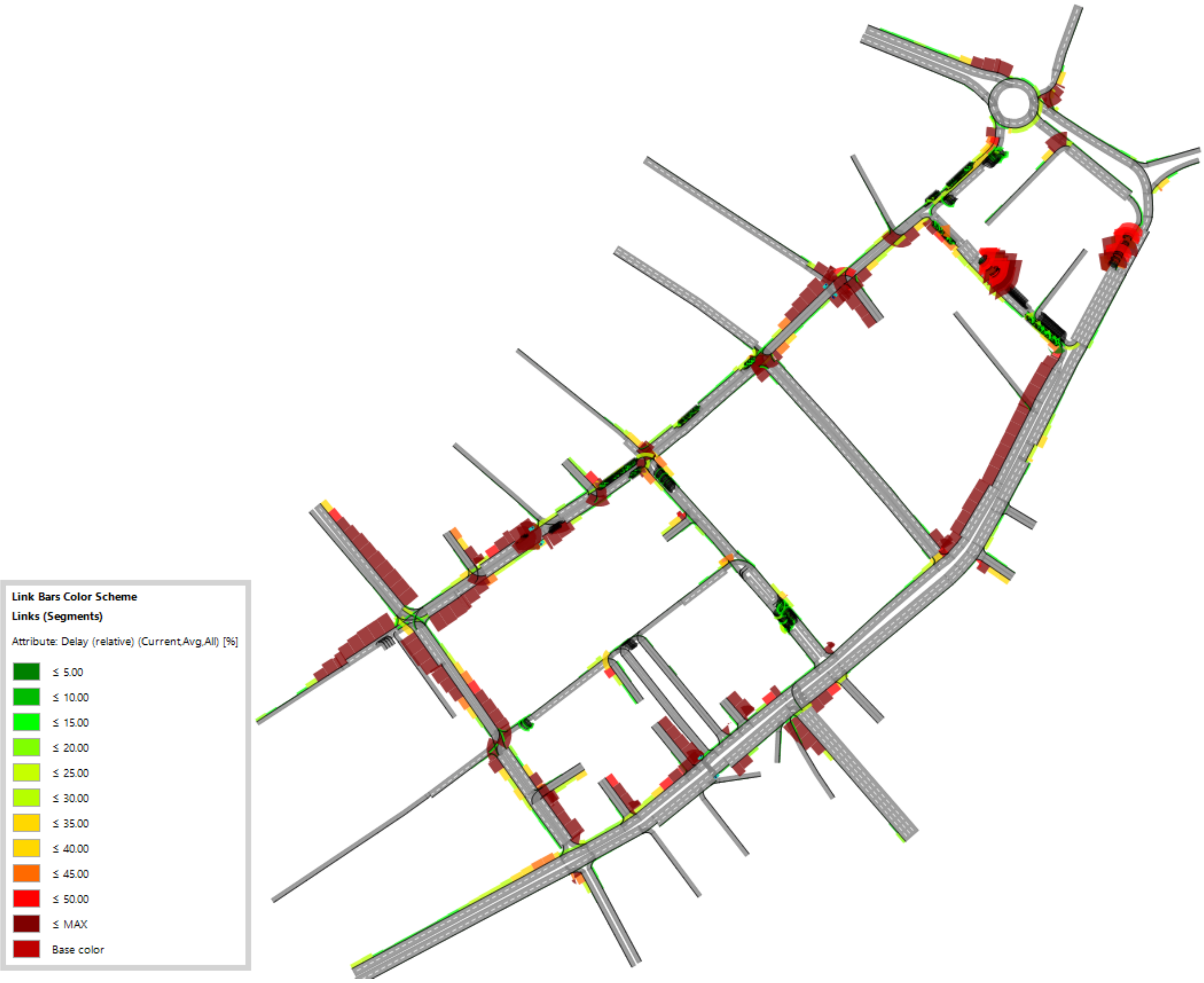


Figure 4-97 Delay-Scenario4 – AM peak

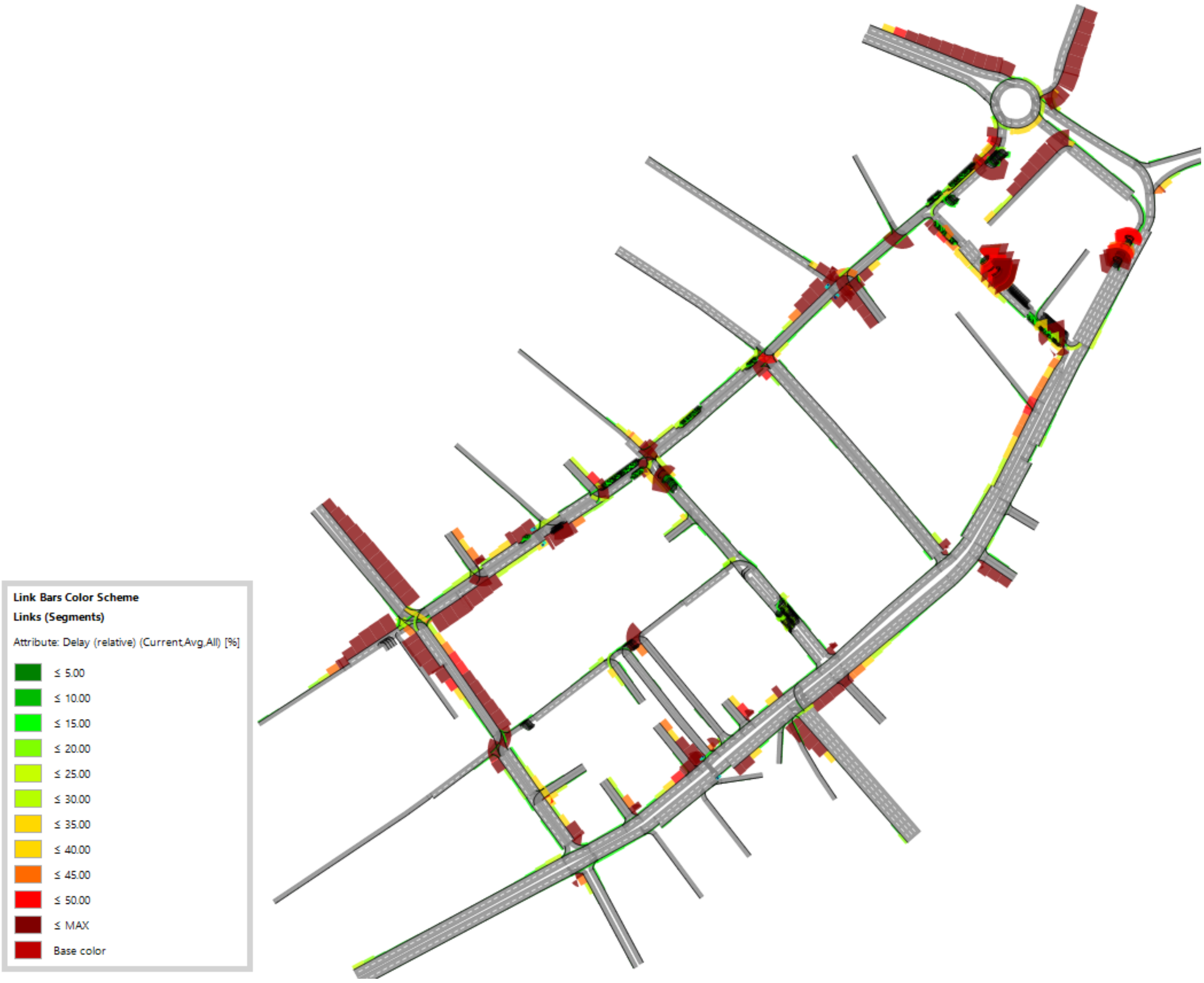


Figure 4-98 Delay-Scenario4 – PM peak

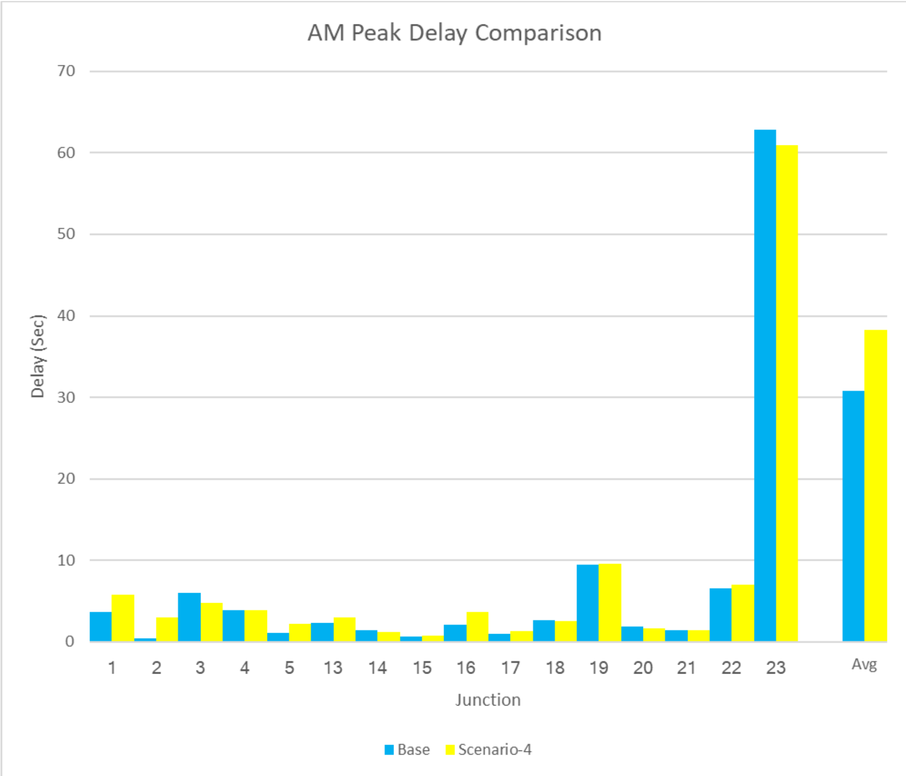


Figure 4-99 Scenario 4 - Delay Comparison -AM peak

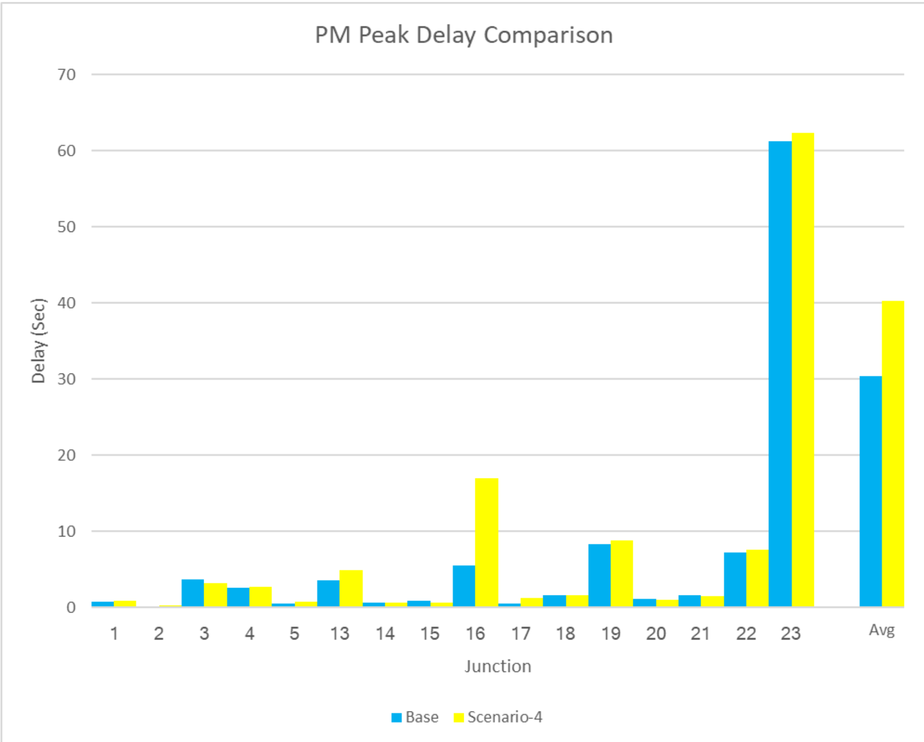


Figure 4-100 Scenario 4 - Delay Comparison -PM peak

Following observation can be made from above delay graphs and plots:

- For all the junctions in study area, average delay is more or less same as of base scenario expect J17 which is experiencing higher delay in PM peak and
- Overall average delay is increased in scenario4 by 24% and 33% in AM and PM peak respectively

4.15.2 Vehicular Measurement: Density

Density of the road network in scenario-4 is shown in below images

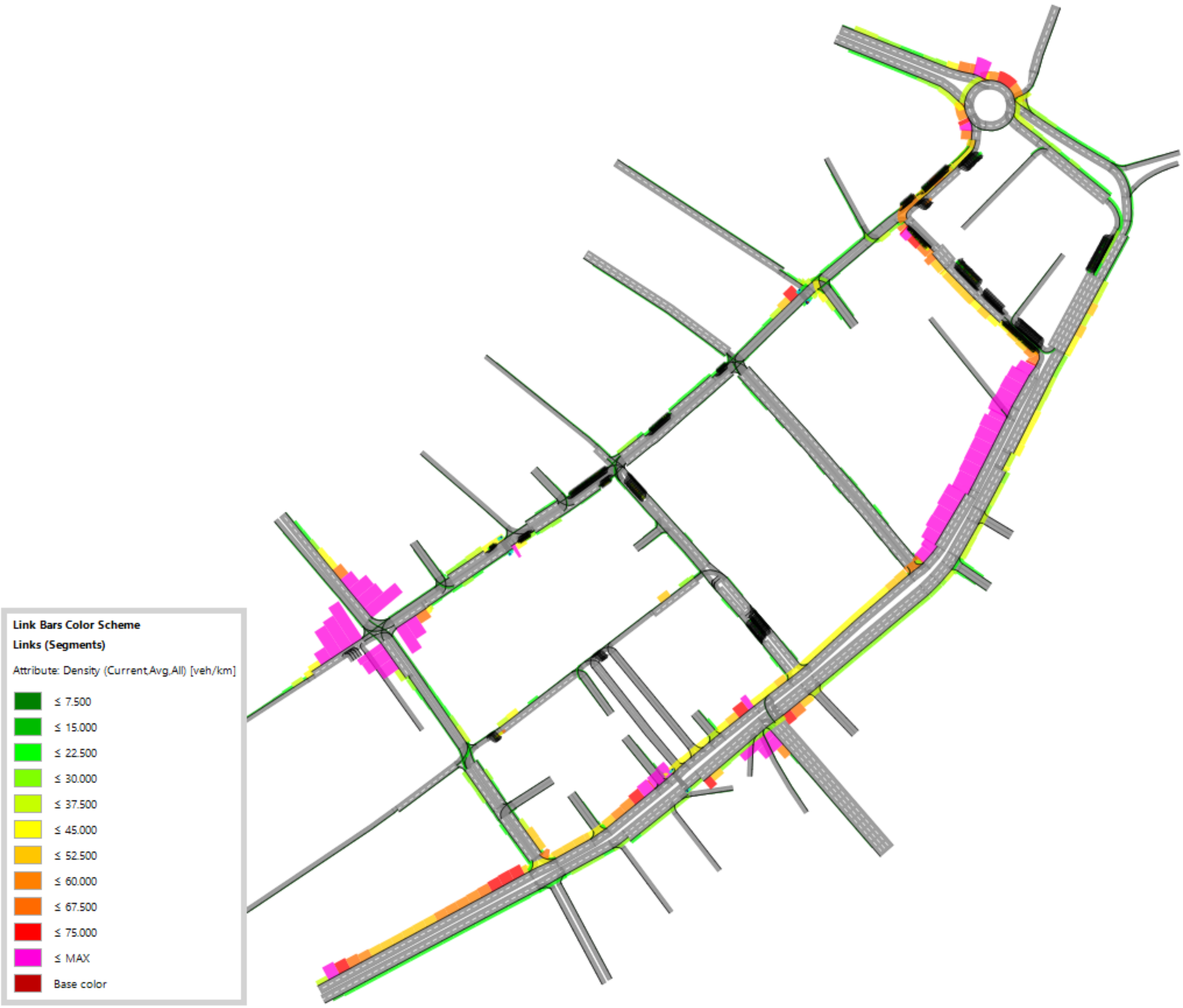


Figure 4-101 Density- Scenario 4-AM Peak

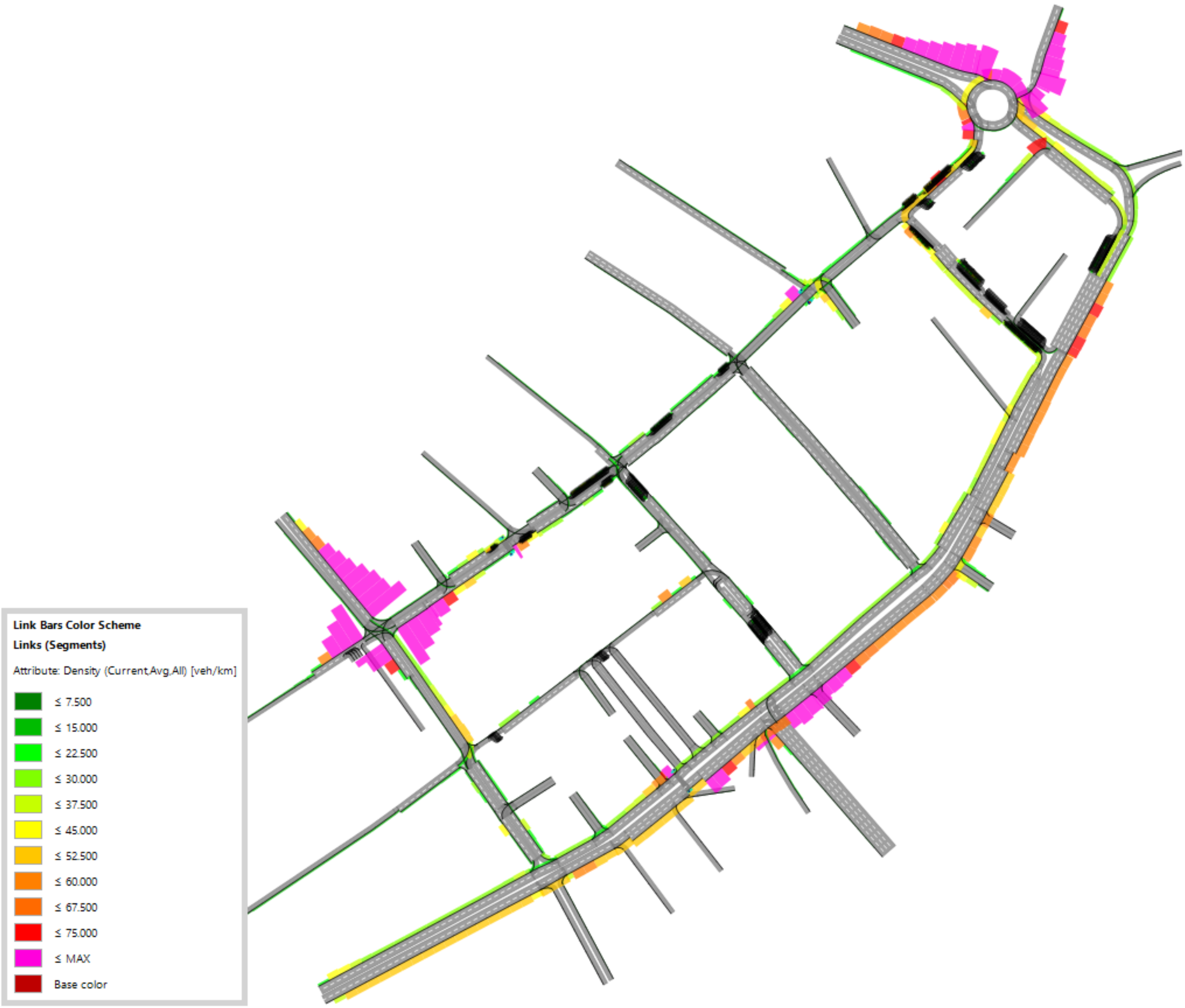


Figure 4-102 Density- Scenario 4-PM Peak

Minor increase in density is observed on Pengkalan Road due to trips generated by proposed new development which is adjacent to Pengkalan Road in both AM and PM peak.

4.15.3 Vehicular Measurement: Speed

Average speed on road network in scenario-4 is demonstrated in the following figures.

Figure 4-103 Speed- Scenario 4-AM Peak

Figure 4-104 Speed- Scenario 4-PM Peak

From above graphs it can be observed that average speed on most sections of Pengkalan Road in both AM and PM peak is around 50kmph and on other roads it is 40 kmph.

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4.16 Comparison and findings

4.16.1 Vehicular Measurement: Delay

Comparison of overall road network performance of the trial study area for all the scenarios considered in terms of delay is presented in figures below.

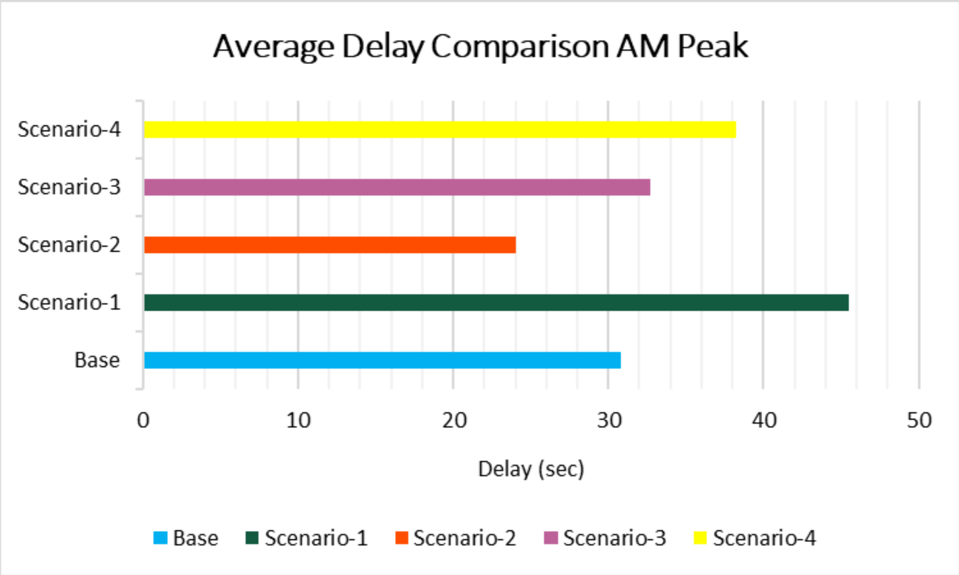

Figure 4-105 Average delay comparison – AM Peak

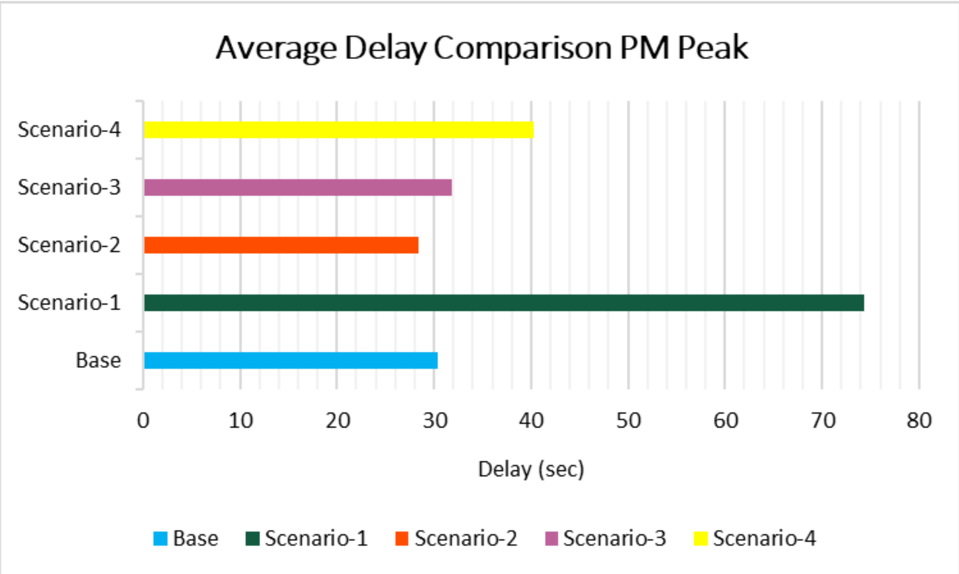

Figure 4-106 Average delay comparison – PM Peak

From above table, following points can be incurred when scenarios are compared with base scenario:

- Scenario 1: Due to introduction of pedestrian, cyclist priority facilities and traffic calming measures such as vertical speed humps in Scenario 1, overall average delay is increased from 31 sec to 46 sec which is around 48% increase in AM Peak. In PM peak overall average delay is increased from 30 sec to 74 sec in PM peak which is 143% increase
- Scenario 2: Road network improvements such as removal of parking, introduction one-way traffic at certain locations of trial study area is done in Scenario 2. Due to these

improvements, interaction between vehicles is decreased and network is expected to perform better. Overall average delay is decreased from 31 sec to 24 which is around 22% decrease and in PM peak minor decrease of 6% is observed.

- Scenario 3: In Scenario 3, PT lane introduction is done at certain locations of Pengkalan Weld Road. Due to this improvement, capacity reduction of road is expected as there will be lane reduction. Overall average delay increase is minor, and it is around 6% and 5% increase in both AM and PM peak respectively
- Scenario 4: New development is proposed adjacent to Pengkalan Weld Road, which is expected to generate around 850 ,1100 trips in total in AM and PM peaks respectively. Estimated trip generation from the proposed development is relatively higher and is expected to deteriorate the overall network performance. Overall average delay is increased from 31 sec to 38 sec in AM peak which is around 24 % increase. In PM peak as well, average delay is increased by 32%.

4.16.3 Vehicular Measurement: Speed

Comparison of overall road network performance for all the scenarios in terms of speed is done and presented in below images.

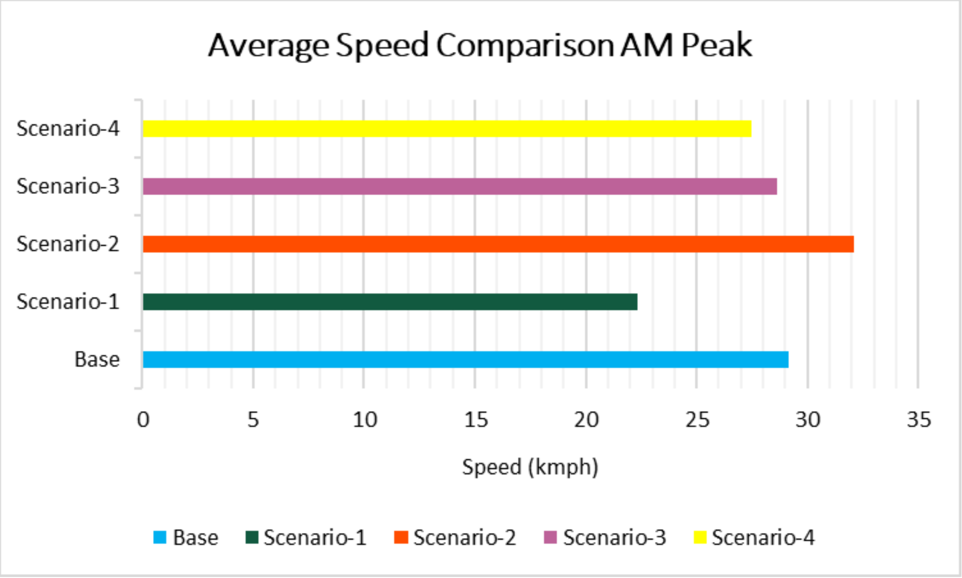

Figure 4-107 Average speed comparison – AM Peak

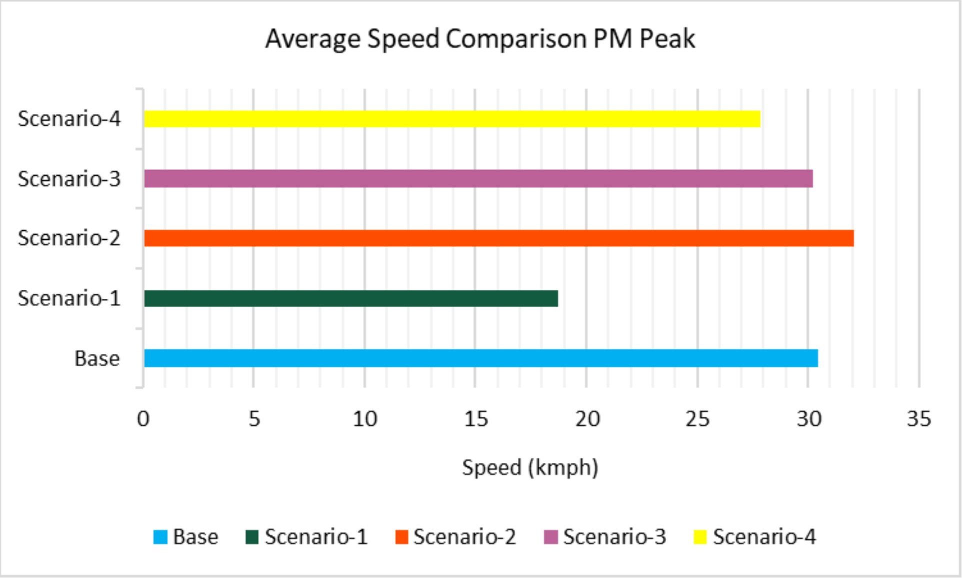

Figure 4-108 Average speed comparison – PM Peak

Following observation can be done from above speed images.

- Average speed of the network is around 30 kmph for all the scenarios expect Scenario 1
- In scenario-1, due to introduction of pedestrian, cyclist priority facilities and traffic calming measures, average speed is reduced to around 22% and 38% in AM and PM peak respectively when compared with Base scenario.

4.16.4 Travel time

Certain sections of road are randomly selected, and travel time measurements are done to understand the impact of improvements carried out in all the scenarios

Below image shows the section considered for travel time measurements.

Figures below show the travel times on sections considered for all the scenarios:

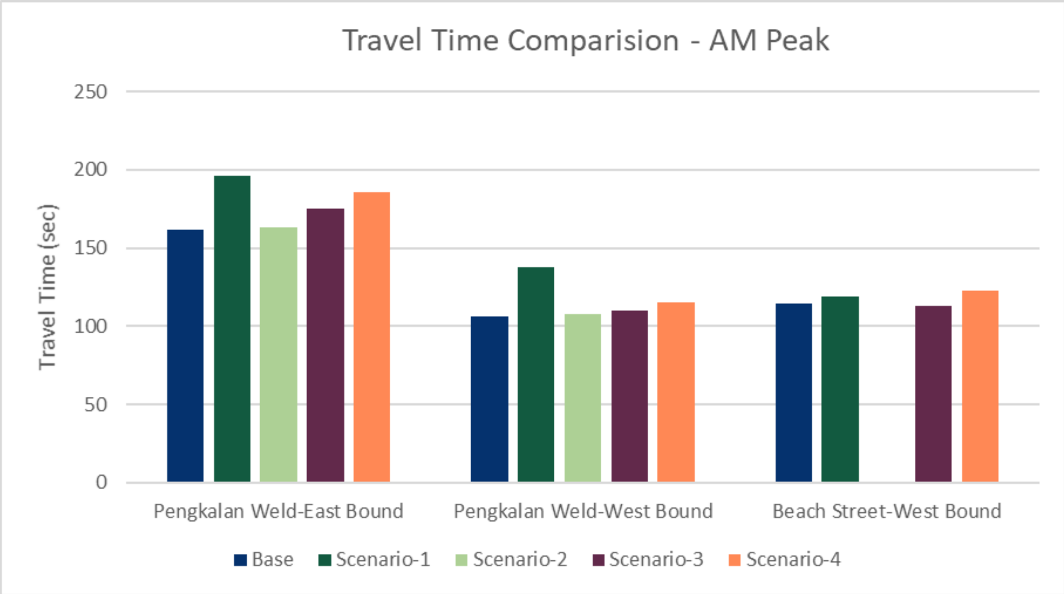

Figure 4-109 Travel Time – AM Peak

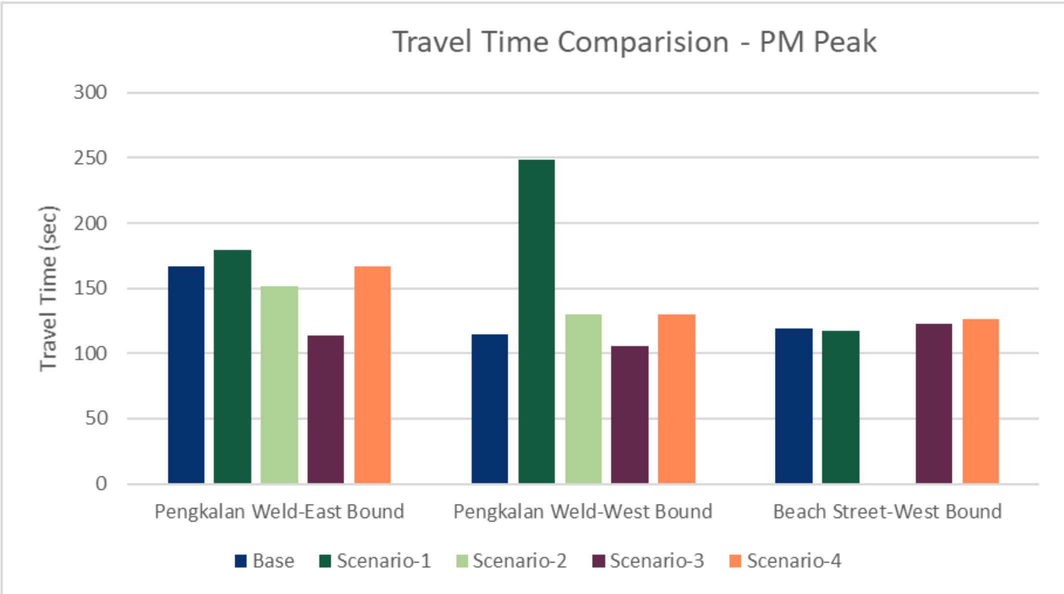

Figure 4-110 Travel Time – PM Peak

From above table, following points can be incurred:

- Pengkalan Weld East Bound: Travel time on Pengkalan Weld Road in east bound direction is higher in scenario-1 compared to all other scenarios. Travel time is 21% and 7% higher in AM and PM peak respectively when compared with base scenario.
- Pengkalan Weld West Bound: Travel time is 29% and 117% higher in AM and PM peak respectively in scenario-1 respectively when compared with base scenario for Pengkalan Weld Road in west bound direction.
- Beach street West Bound: Beach Street west bound is having more or less same travel times in all scenarios.

5. STAGE 2 MODEL AND SCENARIOS

The following section outlines the development of intervention scenarios to be tested in the Stage 2 extended Area micro-simulation model development.

The working group (Ramboll, JA Consult, Digital Penang and MBPP) have held a number of meetings to discuss the intervention scenarios that will be tested in the Stage 2 Extended Area Micro-Simulation model. The basis for developing intervention options was the outcomes derived from the Penang Transport Masterplan 2030 (PTMP) and the Penang Green Transport Plan (PGTP), the latter gave a few specific proposals for the Georgetown area which have broadly been adopted in the scenarios outlined below.

Four scenarios have been developed each with a different focus. The scenarios are tested in the calibrated pilot area micro-simulation model. Following completion of the Task Order/Pilot Project intervention, the models will be given to Digital Penang and MBPP who can then test further interventions in the future.

The intervention scenarios include:

- Scenario 1: Public Transport Priority
- Scenario proposed for this study focuses on providing priority lane to bus operations in the core area of Georgetown
- Scenario 2: Pedestrian and Cyclist Priority
- In this scenario, emphasis is given to Non-Motorized inclusion and conversion of few streets to pedestrian only area.
- Scenario 3: Parking Reduction
- Main objective of this scenario is to understand the impact of reduction of on street parking on some sections of the study area and evaluate the road network performance.
- Scenario 4: Traffic Management Improvements
- Impact of additional measures on traffic management like introduction of new traffic signals.

Full study area for Stage 2 of this study contains 75 junctions in total and the details of the junctions are listed as below:

- Junction 1: Pengkalan Road/Lebuh Downing
- Junction 2: Pengkalan Road/Gat Lebuh Gereja
- Junction 3: Pengkalan Road/Gat Lebuh China
- Junction 4: Pengkalan Road/Gat Lebuh Pasar
- Junction 5: Pengkalan Road/Gat Lebuh Chulia
- Junction 6: Pengkalan Road/Gat Lebuh Armenian
- Junction 7: Pengkalan Road/Gat Lebuh Acheh
- Junction 8: Pengkalan Road/Lintasan Pengkalan 1
- Junction 9: Pengkalan Road/Gat Lebuh Melayu
- Junction 10: Lebuh Victoria/ Gat Lebuh Melayu
- Junction 11: Lebuh Victoria/ Gat Lebuh Acheh
- Junction 12: Lebuh Victoria/ Gat Lebuh Armenian
- Junction 13: Lebuh Victoria/ Gat Lebuh Chulia
- Junction 14: Lebuh Victoria/ Gat Lebuh Pasar
- Junction 15: Lebuh Victoria/ Gat Lebuh China
- Junction 16: Lebuh Pantai/ Pesara King Edward
- Junction 17: Lebuh Pantai/ Lebuh Downing
- Junction 18: Beach Street/ Lebuh Union
- Junction 19: Beach Street/ Bishop Street
- Junction 20: Beach Street/ Gat Lebuh Gereja

- Junction 21: Beach Street/ Gat Lebuh China
- Junction 22: Beach Street/ Gat Lebuh Pasar
- Junction 23: Beach Street/ Gat Lebuh Chulia
- Junction 24: Beach Street/ Lebuh Al Quee
- Junction 25: Beach Street/ Gat Lebuh Armenian
- Junction 26: Beach Street/ Gat Lebuh Acheh
- Junction27: Beach Street/ Gat Lebuh Melayu
- Junction 28: Lorong Ikan/ Lebuh Melayu
- Junction 29: Lorong Toh Aka/ Lorong Carnavon
- Junction 30: Lebuh Acheh/Lebuh Cannon
- Junction 31: Lebuh Acheh/Lebuh Armenian
- Junction 32: Jalan Masjid Kapitan Keling/Jalan Kampung Kolam
- Junction 33: Jalan Masjid Kapitan Keling/Jalan Buckingham
- Junction 34: Jalan Masjid Kapitan Keling/Chulia Street
- Junction 35: Chulia Street/Lebuh King
- Junction 36: Chulia Street/Lebuh Penang
- Junction 37: Lebuh Pasar/Penang Street
- Junction 38: Lebuh Pasar/ Lebuh King
- Junction 39: Lebuh Pasar/ Queen Street
- Junction 40: Jalan Masjid Kapitan Keling/ Lebuh Pasar
- Junction 41: Jalan Masjid Kapitan Keling/ Lorong Stewart
- Junction 42: Jalan Masjid Kapitan Keling/ Lebuh China
- Junction 43: Lebuh China/Queen Street
- Junction 44: Lebuh China/Lebuh King
- Junction 45: Lebuh China/Lebuh Penang
- Junction 46: Lebuh Gereja /Lebuh Penang
- Junction 47: Lebuh King /Church Street
- Junction 48: Church Street/Queen Street
- Junction 49: Jalan Masjid Kapitan Keling/ Church Street
- Junction 50: Jalan Masjid Kapitan Keling/ Lorong Argus
- Junction 51: Jalan Masjid Kapitan Keling/ Bishop Street
- Junction 52: Bishop Street/Lebuh King
- Junction 53: Bishop Street/Lebuh Penang
- Junction 54: Lebuh Penang/Lebuh Union
- Junction 55: Lebuh Penang/Light Street
- Junction 56: Lebuh King/Light Street
- Junction 57: Lebuh Light/Jalan Padang Kota Lana
- Junction 58: Lebuh Light/Jalan Masjid Kapitan Keling
- Junction 59: Jalan Masjid Kapitan Keling/Lebuh Farquhar
- Junction 60: Lebuh Light/Jalan Tun Syed Sheh Barakbah
- Junction 61: Lebuh Farquhar/Local road
- Junction 62: Lebuh Light/Jalan Green Hall
- Junction 63: Lebuh Light/ Lebuh Farquhar
- Junction 64: Lebuh Light/ Love Ln
- Junction 65: Love Ln/Lorong Argus
- Junction 66: Love Ln/Mountri Street
- Junction 67: Lorong Stewart/Lorong Chulia
- Junction 68: Love Ln/Chulia Street
- Junction 69: Chulia Street/lebuh Carnavon
- Junction 70: Chulia Street/lebuh Chulia
- Junction 71: Lebuh Campbell/Lebuh Carnarvo
- Junction 72: Pesara Claimant/Lebuh Carnarvon
- Junction 73: Jalan Kampung Kolam/Lebuh Carnarvon

- Junction 74: Lebuh Carnarvon/Lebuh Acheh
- Junction 75: Lebuh Carnarvon/Lebuh Kimberley

The junctions are shown in the figure below, with the Stage 2 Full Model boundary in red.

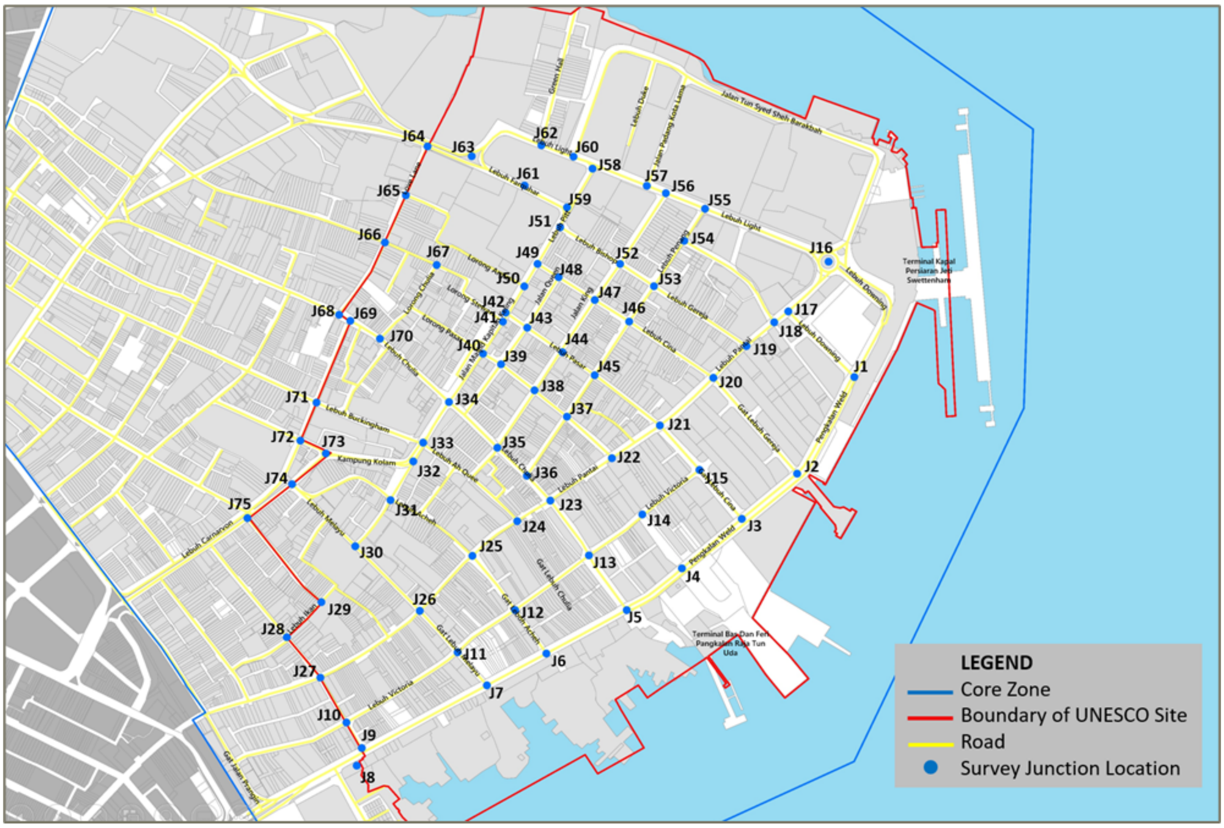

Figure 5-1 Model Area

Full study area model has been coded using information obtained from on-site surveys. Junction configurations and geometry was also validated during on-site traffic surveys and the model was updated to reflect any on-site changes observed.

5.1 Stage 2 Model Zoning System

The zoning system that is adopted for the trail study area is as shown in the figure given below.

Zones represent the entry and exit points of traffic models, where vehicular traffic arrives and departs the network. Other zones represent parking areas where vehicles will dwell for a period of time after entering the network, prior to departing from the network.

Figure 5-2 Zoning System

The figure above shows the location of zones bringing traffic into and out of the model, as well as parking areas. The following table gives a description of zone purpose.

Table 5-1 Zone Description

Zone Number	Description	Road Name	Zone Number	Description	Road Name
1	Origin/Destination Zone	Local Road	83	Parking Zone	Parking between J17 and J16
2	Origin/Destination Zone	Local Road	84	Parking Zone	Parking between J3 and J15
3	Origin/Destination Zone	Access to Ferry Terminal	85	Parking Zone	Parking north of J57
4	Origin/Destination Zone	Jalan Gereja	86	Parking Zone	Parking north of J57
5	Origin/Destination Zone	Access to Terminal	87	Parking Zone	Parking north of J57
6	Origin/Destination Zone	Access to Bus stop	88	Parking Zone	Parking between J49 and J51
7	Origin/Destination Zone	Local Road	89	Parking Zone	Parking between J49 and J50
8	Origin/Destination Zone	Local Road	90	Parking Zone	Parking between J49 and J50
9	Origin/Destination Zone	Pengkalan weld	91	Parking Zone	Parking between J42 and J50
10	Origin/Destination Zone	Local Road	92	Parking Zone	Parking between J42 and J50
11	Origin/Destination Zone	Victoria Street	93	Parking Zone	Parking between J34 and J70
12	Origin/Destination Zone	Local Road	94	Parking Zone	Parking between J34 and J70
13	Origin/Destination Zone	Beach Street	95	Parking Zone	Parking between J66 and J68

Zone Number	Description	Road Name	Zone Number	Description	Road Name
14	Origin/Destination Zone	Lorong Chee Em	96	Parking Zone	Parking between J66 and J68
15	Origin/Destination Zone	Lorong Ikan	97	Parking Zone	Parking between J65 and J66
16	Origin/Destination Zone	Lebuh Melayu	98	Parking Zone	Parking between J64 and J65
17	Origin/Destination Zone	Lebuh Carnarvon	99	Parking Zone	Parking between J51 and J52
18	Origin/Destination Zone	Lebuh Union	100	Parking Zone	Parking between J51 and J52
19	Origin/Destination Zone	Access to parking	101	Parking Zone	Parking between J52 and J53
20	Origin/Destination Zone	Access to parking	102	Parking Zone	Parking between J52 and J53
21	Origin/Destination Zone	Local Road	103	Parking Zone	Parking between J19 and J53
22	Origin/Destination Zone	Access to parking	104	Parking Zone	Parking between J19 and J53
23	Origin/Destination Zone	Local Road	105	Parking Zone	Parking between J54 and J55
24	Origin/Destination Zone	Access to parking	106	Parking Zone	Parking between J54 and J55
25	Origin/Destination Zone	Access to parking	107	Parking Zone	Parking between J53 and J54

Zone Number	Description	Road Name	Zone Number	Description	Road Name
26	Origin/Destination Zone	Access to parking	108	Parking Zone	Parking between J53 and J54
27	Origin/Destination Zone	Local Road	109	Parking Zone	Parking between J46 and J53
28	Origin/Destination Zone	Local Road	110	Parking Zone	Parking between J46 and J53
29	Origin/Destination Zone	Access to parking	111	Parking Zone	Parking between J45 and J46
30	Origin/Destination Zone	Local Road	112	Parking Zone	Parking between J45 and J46
31	Origin/Destination Zone	Lebuh Klang	113	Parking Zone	Parking between J37 and J45
32	Origin/Destination Zone	Lebuh Union	114	Parking Zone	Parking between J37 and J45
33	Origin/Destination Zone	Local Road	115	Parking Zone	Parking between J36 and J37
34	Origin/Destination Zone	Lebuh Kimberley	116	Parking Zone	Parking between J36 and J37
35	Origin/Destination Zone	Lorong Soo Hong	117	Parking Zone	Parking between J20 and J46
36	Origin/Destination Zone	Halaman Sei Tan	118	Parking Zone	Parking between J46 and J47
37	Origin/Destination Zone	SK & SMK Hutchings	119	Parking Zone	Parking between J46 and J47

Zone Number	Description	Road Name	Zone Number	Description	Road Name
38	Origin/Destination Zone	Lorong Ngah Aboo	120	Parking Zone	Parking between J47 and J48
39	Origin/Destination Zone	Pesara Clainmant	121	Parking Zone	Parking between J47 and J48
40	Origin/Destination Zone	Lebuh Campbell	122	Parking Zone	Parking between J48 and J49
41	Origin/Destination Zone	Chulia Street	123	Parking Zone	Parking between J48 and J49
42	Origin/Destination Zone	Muntri Street	124	Parking Zone	Parking between J42 and J43
43	Origin/Destination Zone	Lebuh Farquhar	125	Parking Zone	Parking between J42 and J43
44	Origin/Destination Zone	Jalan Green Hall	126	Parking Zone	Parking between J43 and J44
45	Origin/Destination Zone	Lebuh Duke	127	Parking Zone	Parking between J43 and J44
46	Origin/Destination Zone	Local Road	128	Parking Zone	Parking between J44 and J45
47	Origin/Destination Zone	Local Road	129	Parking Zone	Parking between J44 and J45
48	Origin/Destination Zone	Local Road	130	Parking Zone	Parking between J21 and J45
49	Origin/Destination Zone	Local Road	131	Parking Zone	Parking between J21 and J45

Zone Number	Description	Road Name	Zone Number	Description	Road Name
50	Origin/Destination Zone	Local Road	132	Parking Zone	Parking between J22 and J37
51	Origin/Destination Zone	Lorong Cheapside	133	Parking Zone	Parking between J22 and J37
52	Parking Zone	Parking between J17 and J16	134	Parking Zone	Parking between J35 and J38
53	Parking Zone	Parking between J1 and J17	135	Parking Zone	Parking between J35 and J38
54	Parking Zone	Parking between J1 and J17	136	Parking Zone	Parking between J38 and J44
55	Parking Zone	Parking between J17 and J16	137	Parking Zone	Parking between J38 and J44
56	Parking Zone	Parking between J1 and J16	138	Parking Zone	Parking between J44 and J47
57	Parking Zone	Parking between J13 and J14	139	Parking Zone	Parking between J44 and J47
58	Parking Zone	Parking between J14 and J15	140	Parking Zone	Parking between J47 and J52
59	Parking Zone	Parking between J1 and J16	141	Parking Zone	Parking between J47 and J52
60	Parking Zone	Parking between J13 and J14	142	Parking Zone	Parking between J43 and J48
61	Parking Zone	Parking between J1 and J2	143	Parking Zone	Parking between J39 and J43

Zone Number	Description	Road Name	Zone Number	Description	Road Name
62	Parking Zone	Parking between J2 and J20	144	Parking Zone	Parking between J39 and J43
63	Parking Zone	Parking between J2 and J20	145	Parking Zone	Parking between J34 and J35
64	Parking Zone	Parking between J3 and J15	146	Parking Zone	Parking between J23 and J35
65	Parking Zone	Parking between J3 and J15	147	Parking Zone	Parking between J23 and J35
66	Parking Zone	Parking between J3 and J15	148	Parking Zone	Parking south J39
67	Parking Zone	Parking between J15 and J21	149	Parking Zone	Parking between J74 and J75
68	Parking Zone	Parking between J15 and J21	150	Parking Zone	Parking between J74 and J75
69	Parking Zone	Parking between J20 and J21	151	Parking Zone	Parking between J28 and J29
70	Parking Zone	Parking between J20 and J21	152	Parking Zone	Parking between J27 and J28
71	Parking Zone	Parking between J20 and J21	153	Parking Zone	Parking between J25 and J26
72	Parking Zone	Parking between J5 and J13	154	Parking Zone	Parking between J25 and J26
73	Parking Zone	Parking between J5 and J13	155	Parking Zone	Parking between J23 and J24

Zone Number	Description	Road Name	Zone Number	Description	Road Name
74	Parking Zone	Parking between J12 and J13	156	Parking Zone	Parking between J11 and J12
75	Parking Zone	Parking between J22 and J23	157	Parking Zone	Parking between J11 and J12
76	Parking Zone	Parking between J22 and J23	158	Parking Zone	Parking between J10 and J11
77	Parking Zone	Parking between J22 and J23	159	Parking Zone	Parking between J10 and J11
78	Parking Zone	Parking between J21 and J22	160	Parking Zone	Parking between J12 and J25
79	Parking Zone	Parking between J21 and J22	161	Parking Zone	Parking between J30 and J31
80	Parking Zone	Parking between J21 and J22	162	Parking Zone	Parking between J31 and J32
81	Parking Zone	Parking between J21 and J22	163	Parking Zone	Parking between J26 and J30
82	Parking Zone	Parking between J22 and J23			

5.2 Study Methodology

In developing a transport model, the aim is to accurately reflect on-site traffic behaviors, volumes routing and congestion levels. Traffic volumes at junctions will be collected in both morning (AM) and afternoon (PM) peak hours through video-surveys, and a process of matrix estimation is undertaken to translate traffic volumes to a matrix representing the origins and destinations of all vehicles into and out of the network.

Methodology adopted for Stage 1 will be utilized for Stage 2 as well. However, this will be applied for the extended area for Stage 2 with new survey data as applicable.

Date and processed as contained in this Calibration Report is aimed at developing a base year simulation model which accurately represents the trip characteristics and observed volume on the ground. This base year model, once properly calibrated, would provide the project with a good basis to test traffic schemes and future traffic volume with.

The entire model development and calibration proceed contains the following steps, which are illustrated further with more details in the subsections of this report.

1. **Matrix Estimation:** to translate survey traffic volume to simulation model input. In this step, the volume collected in both AM and PM peak hours through primary surveys is converted to a unified unit called Passenger Car Unit (PCU) volumes and utilized for matrix estimation to derive matrices.
2. **Model Calibration with Turn Volume**: to ensure model value match with observed value, per each turning movements at traffic junctions.
3. **Split Matrices:** to separate the uniformed matrices based on PCU value to each individual vehicle types. It is done based on traffic proportion obtained through surveys to get individual vehicular demand.
4. **Segregate Parking Demand:** parking demand need to be added in the model due to the presence of on-street and off-street parking bays in the study are. Parking demand for cars and motorcycle are extracted from their respective matrices to replicate parking in the model
5. **Model Calibration with Queue:** a final check of modeled value versus observed value. As traffic queues are the final results of the relationship between traffic capacity and demand, it is most suitable to be selected as the final check, once all inputs to the model are completed.

Detailed description is provided in below sections. Methodology adopted for Stage 2 area Vissim model is outlined in the flow chart given below.

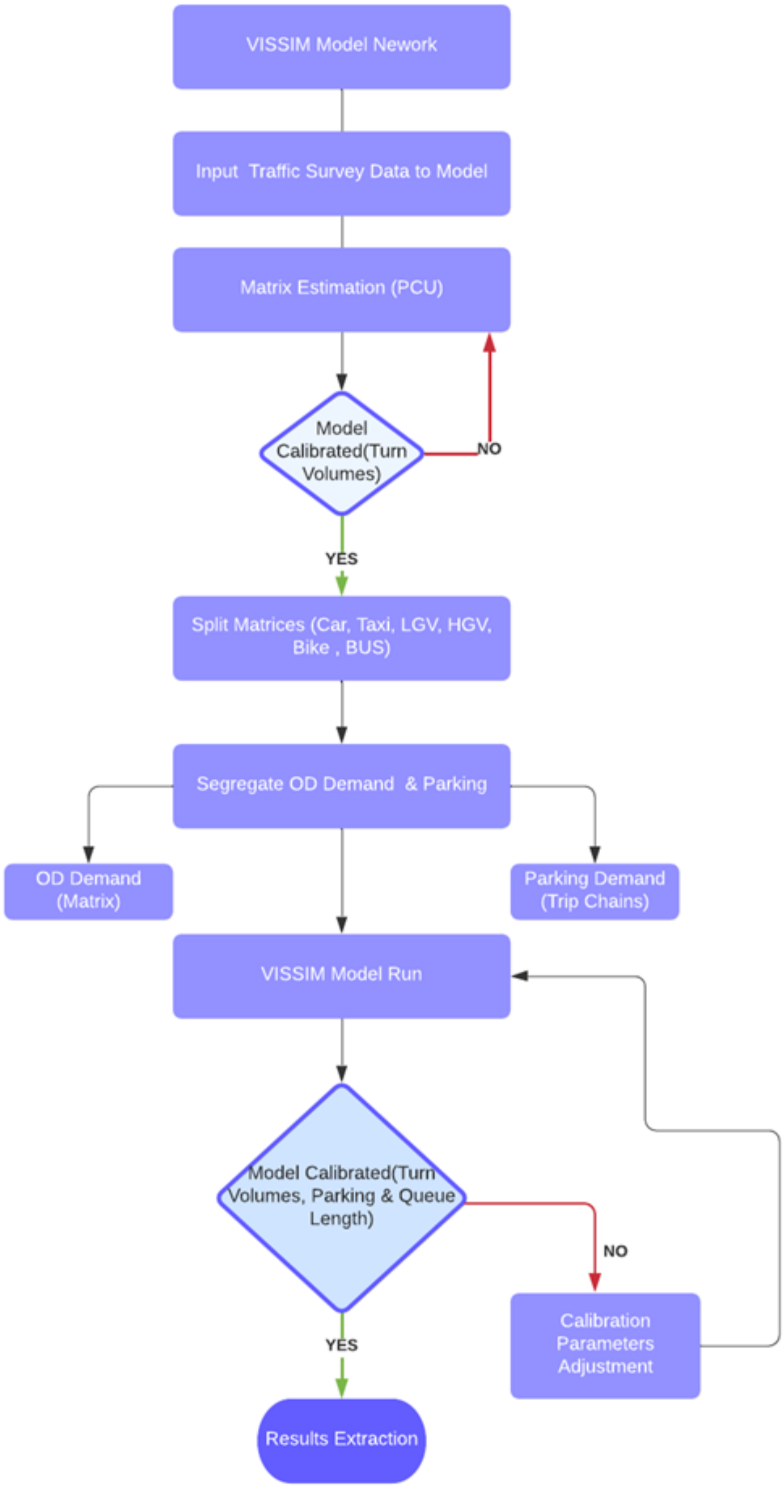

Figure 5-3 Study Methodology

5.2.1 Matrix Estimation

Matrix estimation module in Vissim is used along with the observed volume from surveys to derive matrices in both AM and PM peak. Unit matrix as a start is used to estimate the final matrices based on the observed counts as turn volumes. Several iterations are run in the process to arrive at the final matrix to be adopted for the model.

Vissim uses the least squares method in the matrix estimation procedure. The total of squares of the difference between the count data and volumes, and the total of squares of the differences between the original and corrected matrix values is minimized. Using 'squares' allows negative and positive differences to be treated equally. Origin-Destination pairs with a volume of zero is not adjusted.

As an example, AM PCU Matrix derived from matrix estimation using turn counts from surveys is shown in figure below.

The matrix has "Origins", which means the zone the trip is departing from, in rows. While, "Destinations", which means the zone the trip is arriving at, are in columns.

Taking the cell marked in green in the table below, this value refers to the number of trips traveling from Zone 2 to Zone 3.

Matrix estimation for Stage 2 is similar to Stage 1 but with increased zones and additional demand considering the extended area for Stage 2.

Table 5-2 PCU Matrix AM Peak

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
1	0	0	8	0	1	1	1	0	135	0	0	0	1	2	0	0	0	0	1	0	0	1	1	9	0	6	6	0	0	0	0	1	1	0	0	0	1	1	1	1	0	1	1	1	0	1	0	1	0	1	0
2	1	1	1	1	1	1	1	12	181	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	0	0	0	0	1	0	0	0	40	0	0	1	1	1	0	1	0	0	1	0	7	1	0	0	1	0	0	0	3	0	0	1	1	1	0	0	0	1	1	1	0	1	0	0	0	0	0	1	0	1	1
4	0	0	1	0	1	20	0	0	85	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	0	0	1	0	0	1	0	0	0
5	0	0	1	0	1	1	0	0	62	0	0	1	1	1	0	0	0	0	1	0	0	1	1	0	1	0	0	0	0	0	0	1	23	1	0	0	1	1	1	1	0	1	101	0	0	1	0	1	0	1	0
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	0	0	0	0	1	1	1	0	52	0	0	0	1	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	0	1	1	1	1	0	0	1	0	1	0
8	15	0	1	0	1	4	0	0	14	0	0	0	1	0	0	0	0	0	1	1	0	1	0	24	8	21	21	0	1	0	0	1	45	0	0	0	0	1	1	1	0	1	1	1	1	1	0	1	8	1	0
9	140	0	148	1	1	125	24	2	13	69	30	25	1	43	38	88	36	110	1	48	97	1	1	148	134	146	146	9	75	88	12	1	1	15	33	71	36	1	1	1	104	1	1	33	1	1	67	1	134	1	31
10	0	0	0	1	1	1	0	0	16	0	4	8	1	26	0	19	4	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	2	2	0	1	1	1	3	1	1	0	1	1	0	1	0	0	0
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	0	0	1	1	1	0	0	0	0	0	5	38	1	18	6	0	6	1	1	1	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	28	0	0	0	0	1	0	4	0
13	0	0	1	0	1	0	1	0	48	9	36	40	1	58	24	74	35	1	1	1	0	1	0	0	0	0	0	0	1	16	0	1	2	13	32	35	1	1	1	1	33	1	1	0	1	0	0	1	2	0	0
14	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	40	1	1	0	1	19	1	1	1	15	1	1	1	1	1	3	1	0	0	1	1	1	0	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	0	0	108	0	1	1	1	0	36	2	25	49	1	67	1	15	84	0	1	10	0	1	36	0	0	0	1	0	1	28	21	1	69	244	10	3	45	57	54	1	114	1	48	41	22	0	0	1	0	22	54
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	0	1	0	0	1	0	0	1	40	1	1	76	1	0	0	1	0	0	1	1	7	1	91	1	1	1	0	1	3	1	0	1	0	1	1	1	0	1	1	1	0	1	1	0	0	0	1	1	1	0	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	204	1	1	1	1	1	1	1	0	1	1	1	0	0	1	0	0	1	1	9	1	1	1	1	0	1	1	3	1	18	1	1	10	1	0	1	1	1	1	1	1	1	1	1	168	1	1	1	1	0
23	1	1	1	13	1	1	1	1	29	1	1	1	1	0	1	1	10	1	1	1	1	1	1	1	1	1	1	20	170	1	2	1	3	1	1	1	1	1	1	1	1	1	2	1	0	0	1	1	1	0	1
24	0	0	2	1	1	1	1	0	39	1	1	1	1	1	1	1	1	80	1	0	0	1	1	1	1	1	1	1	0	1	1	1	23	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
25	1	1	1	1	1	1	1	1	9	1	1	1	1	6	1	1	1	48	1	1	0	1	27	13	22	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
26	1	0	1	0	1	0	1	0	42	1	1	1	1	0	1	1	1	82	1	1	0	1	1	3	1	1	1	0	0	1	1	1	1	28	1	1	1	1	1	1	3	1	103	1	1	1	1	1	1	1	1
27	1	1	3	1	1	0	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1	3	1	1	0	1	0	0	0	1	1	0	1	1	0	1	1	1	1	1	103	1	1	0	1	1	1	1	1
28	0	0	0	0	1	1	1	0	22	1	1	1	1	0	1	1	0	63	1	0	0	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
29	1	0	4	1	1	0	1	0	41	1	1	1	1	0	0	0	25	57	1	0	1	1	1	0	1	0	0	1	1	0	13	1	35	2	0	1	11	1	1	1	2	1	12	10	0	0	0	1	0	0	25
30	0	0	59	0	1	0	1	0	0	0	4	0	1	0	0	0	19	1	1	1	0	1	0	0	0	0	0	0	1	0	0	1	0	2	0	20	0	1	1	1	0	1	0	0	0	0	0	1	5	0	0

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
31	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	1	1	152	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	2	1	0	0	0	0	0	1	0	0	0
32	1	1	1	1	1	1	1	1	1	1	1	0	1	0	13	23	27	3	1	0	1	67	25	1	1	1	1	0	1	2	0	1	47	6	1	1	23	1	1	1	13	1	23	21	0	4	1	1	1	0	0
33	0	1	0	1	1	0	1	1	1	1	0	1	1	69	0	0	7	4	1	0	1	67	1	0	11	0	0	36	1	41	0	1	27	0	0	0	0	1	1	1	1	1	105	0	0	0	1	1	0	0	0
34	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35	0	0	1	1	1	0	1	0	4	0	0	0	1	9	0	0	3	1	1	1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	0	19	1	1	0	1	0	1	0
36	0	0	1	1	1	0	0	0	13	0	3	6	1	24	0	0	2	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1	2	1	1	35	1	0	0	1	0	0	0
37	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	1	1	1	0	1	45	0	0	0	1	1	1	0	0
38	0	0	0	0	1	1	1	0	0	0	0	1	1	0	0	0	28	0	1	0	1	1	0	0	0	0	0	0	1	0	0	1	0	7	0	0	0	1	1	1	58	1	1	0	0	0	0	1	0	0	1
39	0	0	1	0	1	0	1	0	0	0	0	3	1	0	0	0	36	14	1	0	0	75	0	0	0	0	0	0	1	0	0	1	21	15	0	0	1	1	1	1	0	1	0	0	0	0	0	1	0	0	0
40	0	0	0	0	1	0	0	0	0	0	0	5	1	0	0	0	17	1	1	1	0	1	3	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	1	1	72	1	8	29	0	0	2	1	40	0	10
41	0	0	0	1	1	1	1	0	15	0	3	0	1	0	0	0	17	36	1	1	1	1	0	0	0	0	0	0	53	3	21	1	0	2	0	42	0	1	1	1	19	1	49	0	0	0	3	1	4	0	29
42	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0	0	1	0	0	0	1	0	36	1	0	0	0	0	0	1	1	1	34	1	34	0	0	0	0	1	0	0	0
43	73	27	168	123	1	1	44	42	1	1	0	1	1	2	0	0	84	11	1	69	1	78	0	0	0	0	0	34	1	9	0	1	103	63	0	0	0	1	1	1	65	1	181	103	41	82	0	1	1	41	1
44	1	0	24	1	1	1	0	1	1	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	1	0	1	1	0	0	1	0	30	0	1	0	1	1	1	0	1	38	0	0	0	0	1	1	0	0
45	0	1	12	0	1	1	0	1	1	0	0	1	1	0	0	0	0	0	1	1	19	0	0	1	0	0	1	0	3	0	0	1	0	0	0	1	0	1	1	1	0	1	27	0	0	1	1	1	0	1	0
46	1	0	0	0	1	0	0	0	36	1	0	76	1	0	1	0	5	0	1	0	7	1	1	0	1	1	0	0	3	4	0	1	23	0	0	0	0	1	1	1	0	1	101	0	0	0	1	1	0	0	22
47	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	48	0	0	0	0	1	0	0	0
48	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
49	6	0	14	1	1	1	1	0	0	0	0	0	1	7	0	0	0	1	1	0	0	1	1	15	2	12	12	0	0	0	0	1	1	0	0	0	0	1	1	1	0	1	115	1	1	0	0	1	0	1	0
50	0	0	0	1	1	0	1	0	1	1	1	1	1	1	17	0	2	0	1	0	7	1	1	0	1	0	1	0	1	0	0	1	23	0	0	1	0	1	1	1	0	1	101	0	0	1	1	1	1	0	0
51	0	0	0	1	1	0	0	0	0	0	13	0	1	0	0	0	0	7	1	1	1	1	0	0	0	0	0	0	1	0	0	1	13	0	0	10	0	1	1	1	73	1	7	0	0	0	0	1	1	0	0

Table 5-3 **PCU Matrix PM Peak**

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
1	0	0	0	0	0	0	0	0	339	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0
2	0	0	0	0	0	0	0	9	410	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	71	0	0	0	0	175	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	115	0	0	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	6	0	0	0	0	44	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
9	81	0	0	0	0	122	0	5	0	35	8	9	0	23	22	87	58	100	0	0	0	0	0	85	44	24	75	0	7	81	11	0	0	14	28	4	0	0	0	0	152	0	0	0	0	0	0	0	80	0	9
10	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	61	79	0	9	25	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0	0	0	0	58	0
13	0	0	0	0	0	0	0	0	0	20	57	47	0	64	6	74	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	25	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66	0	0	0	0	7	0	0	0	100	0	0	0	0	0	0	12	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	239	0	0	0	0	0	18	0	16	30	0	47	0	0	62	0	0	55	0	0	13	0	0	0	0	0	0	8	0	0	2	248	31	0	0	37	63	0	123	0	14	50	0	0	0	0	0	0	19
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	175	0	0	98	0	0	0	0	0	0	0	0	0	0	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	226	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	1	0	0	29	0	0	0	0	0	0	0	0	454	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	35	0	0	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	125	0	26	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	79	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	71	0	0	0	0	0	0	0	0	0	0	0	0	0	40	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	88	0	0	0	0	0	0	0	0	20	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	16	0	60	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
29	0	0	0	0	0	0	0	0	41	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	28	0	49	56	0	0	11	0	0	0	10	0	0	0	0	0	0	0	0	0	90
30	0	0	59	0	0	0	0	0	0	0	44	0	0	0	0	0	176	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	181	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	58	1	4	0	0	0	94	45	0	0	0	0	0	0	0	0	0	45	0	0	0	7	0	0	0	61	0	6	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	53	0	0	27	0	0	0	0	96	0	0	1	0	0	47	0	65	0	0	2	0	0	0	0	0	0	0	3	0	146	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	39	0	0	0	0	30	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	69	0	5	2	0	11	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	0	0	9	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	179	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	46	0	0	0	0	78	2	0	0	0	35	0	0	0	0	0	0	0	0	0	0	7	32	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	88	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	43	0	0	0	0	0	0	116	0	8	25	0	0	0	0	99	0	5
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	42	0	0	0	0	0	0	0	0	0	0	71	2	23	0	0	0	0	110	0	0	0	0	17	0	61	0	0	0	0	0	0	0	30
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69	0	0	0	0	0	0	0	0	0	15	0	51	0	0	0	0	0	0	0	0
43	29	108	0	212	0	0	123	0	367	0	0	0	0	0	0	0	100	0	0	10	0	58	0	0	0	0	0	38	0	0	0	0	70	54	0	0	0	0	0	0	63	0	216	0	170	0	0	0	0	170	0
44	0	0	154	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122	0	0	0	0	0	0	0	0	185	0	0	0	0	0	0	0	0
45	0	0	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	252	0	0	98	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	147	0	0	0	0	0	0	0	14
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	5	0	0	0	0	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	147	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	147	0	35	0	0	0	0	0	0	0	0

5.2.2 Model Calibration with Turn Volumes

During the matrix estimation process, inputs from traffic survey data was used to correct the matrix and calibrate the model to be in line with on-site conditions.

In this process, there is a transport engineering measurement called GEH statics to be used as an important parameter is estimated for every iteration to make the matrices fit for purpose.

The GEH Statistic is designed to compare two sets of traffic volumes. Using the GEH Statistic avoids some pitfalls that occur when using simple percentages to compare two sets of volumes. This is because the traffic volumes in real-world transportation systems vary over a wide range. The GEH statistic reduces this problem because the GEH statistic is non-linear, a single acceptance threshold based on GEH can be used over a wide range of traffic volumes. The formula for GEH statistics is:

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}}$$

where M is the hourly traffic volume from the traffic model and C is the real-world hourly traffic count

An iterative procedure will be done in the calibration process until GEH for the observed and modelled data points is less than 5 and the resultant matrix with more than 85% percentage of links with GEH<5 is deemed fit-for-purpose.

The matrix estimation process is then re-run with the inputs from site surveyed traffic volumes to correct the matrix. After this iterative process, the following results can be obtained from the calibrated model.

Both AM and PM Peak hour calibration results are presented in section 5.9 for Stage 2.

5.2.3 Split Matrices

Once PCU matrix is derived, it is further split into Car, Taxi, LGV, HGV and motorcycle matrices based on traffic proportion obtained from survey data as shown in figure below.

After all matrices are derived, model run is carried out and individual modelled turn counts of all the junctions are compared with surveyed turn counts and made sure that GEH requirement is met.

Table 5-4 AM Peak Traffic Composition

Junction	Mode (Total PCU)					
	Car	Taxi	LGV	HGV	Bus	Motorcycle
1	1653	48	117.5	6	180	773
2	1584	28	112.5	9	180	789
3	1630	24	107.5	9	177	931
4	1626	13	107.5	9	165	722
5	1884	15	125	6	153	829
13	1941	10	137.5	3	18	917
14	1988	13	155	3	18	1273
15	2036	30	177.5	3	15	959
16	2110	17	185	3	15	1482
17	268	5	52.5	0	0	234
18	185	1	67.5	0	0	182
19	166	3	45	0	0	149
20	464	9	70	0	132	275
21	99	6	15	0	30	71
22	177	10	12.5	0	30	227
23	1544	26	95	3	132	470
24	1207	60	77.5	0	96	506
25	676	14	45	0	21	433
26	527	23	47.5	0	21	383

Junction	Mode (Total PCU)					
	Car	Taxi	LGV	HGV	Bus	Motorcycle
27	606	10	55	0	18	361
28	598	10	37.5	0	30	429
29	428	1	30	0	3	384
30	615	1	67.5	0	105	397
31	199	1	25	0	0	225
32	228	3	45	0	0	200
33	296	1	67.5	0	0	255
34	364	4	100	0	0	373
35	128	3	60	0	0	118
36	14	0	0	0	0	37
37	114	5	25	0	0	139
38	121	2	25	0	0	143
39	404	14	57.5	0	51	509
40	55	0	7.5	0	0	85
41	665	23	75	0	153	468
42	420	13	42.5	0	105	321
43	378	4	37.5	0	114	383
44	185	2	10	0	3	173
45	160	1	10	3	3	186
46	116	3	0	0	3	164
47	450	14	20	0	18	293
48	583	10	23	3	18	625
49	574	20	20	3	18	452

Junction	Mode (Total PCU)					
	Car	Taxi	LGV	HGV	Bus	Motorcycle
50	253	5	10	0	0	187
51	275	2	12.5	0	3	209
52	324	3	25	0	3	235
53	478	1	27.5	0	0	269
54	318	12	45	0	0	275
55	242	2	10	0	0	133
56	602	12	20	0	18	417
57	498	6	13	0	18	473
58	770	10	30	0	18	407
59	387	1	17.5	0	3	190
60	478	3	25	0	6	291
61	293	10	17.5	0	0	244
62	1365	24	72.5	6	63	435
63	1489	24	77.5	6	60	506
64	1567	12	75	9	60	656
65	1920	26	105	3	57	572
66	1475	13	73	0	45	794
67	1263	8	72.5	3	33	479
68	1028	34	42.5	0	42	458
69	1349	10	55	0	36	509
70	2035	17	87.5	3	63	993
71	1816	32	82.5	3	45	667
72	98	2	10	0	0	79

Junction	Mode (Total PCU)					
	Car	Taxi	LGV	HGV	Bus	Motorcycle
73	213	1	20	0	0	154
74	42	0	2.5	0	0	95
75	352	9	47.5	0	87	562
Total	53509	831	4050	96	3036	32726
Proportion	56.8%	0.9%	4.3%	0.1%	3.2%	34.7%

Table 5-5 PM Peak Traffic Compositions

Junction	Mode (Total PCU)					
	Car	Taxi	LGV	HGV	Bus	Motorcycle
1	2009	28	147.5	6	147	873
2	1938	24	147.5	6	147	834
3	1984	32	155	6	165	880
4	1950	15	147.5	6	132	718
5	1949	18	155	6	102	711
13	2126	10	175	0	12	871
14	2279	15	195	0	12	1399
15	2180	12	235	3	12	1033
16	2385	12	237.5	3	12	1497
17	443	5	57.5	0	0	215
18	562	1	62.5	0	0	315
19	468	0	40	0	0	209
20	627	1	65	0	126	256
21	79	0	15	0	33	29
22	191	0	27.5	0	33	106

Junction	Mode (Total PCU)					
	Car	Taxi	LGV	HGV	Bus	Motorcycle
23	2114	7	152.5	6	108	629
24	1089	28	70	0	84	324
25	657	4	40	0	18	304
26	608	5	50	0	18	341
27	591	7	65	0	18	259
28	710	10	65	0	18	348
29	573	7	37.5	0	0	360
30	948	4	55	0	96	411
31	243	0	15	0	0	147
32	297	3	32.5	0	0	207
33	352	4	60	0	0	278
34	322	4	110	0	0	253
35	151	2	55	0	0	110
36	21	1	7.5	0	0	19
37	263	5	17.5	0	0	221
38	249	5	17.5	0	0	209
39	601	14	65	0	45	583
40	88	2	7.5	0	0	87
41	1110	25	133	0	150	590
42	701	12	60	0	96	350
43	639	12	30	0	99	378
44	387	2	15	0	0	178
45	382	7	37.5	0	0	194

Junction	Mode (Total PCU)					
	Car	Taxi	LGV	HGV	Bus	Motorcycle
46	288	4	12.5	0	0	176
47	686	16	48	0	15	350
48	788	10	73	6	15	611
49	755	18	63	6	15	449
50	255	5	20	0	0	152
51	393	3	12.5	0	0	164
52	434	2	42.5	0	0	214
53	468	5	37.5	0	0	200
54	449	6	32.5	0	0	173
55	303	2	17.5	0	0	133
56	801	18	58	0	15	417
57	659	9	48	0	15	459
58	786	20	55	0	15	398
59	305	3	20	0	0	133
60	513	0	25	0	0	213
61	271	2	25	0	0	131
62	1631	8	115	6	60	485
63	1800	8	142.5	6	60	562
64	1802	3	137.5	6	60	735
65	2139	32	193	3	60	680
66	1601	18	135	3	48	812
67	1581	12	125	3	30	683
68	1318	58	102.5	3	45	447

Junction	Mode (Total PCU)					
	Car	Taxi	LGV	HGV	Bus	Motorcycle
69	1528	12	102.5	0	12	539
70	2479	19	200	6	60	1077
71	2255	36	205	6	45	796
72	92	4	12.5	0	0	81
73	207	3	37.5	0	0	152
74	88	4	27.5	0	0	96
75	628	8	85	0	72	644
Total	66115	749	5815	96	2601	32682
Proportion	61.2%	0.7%	5.4%	0.1%	2.4%	30.2%

5.2.4 Model Calibration with Queues

After all the steps above, the model is further calibrated with queue length data recorded from the on-site traffic survey.

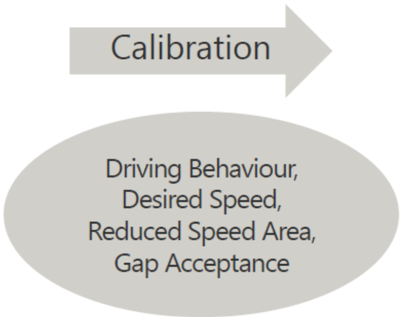
Queues are formed as a results of all the factor impacting vehicles in the network. It could be due to traffic volume, network capacity, signal configuration, vehicle speed, or driving behavior.

With traffic volume and network capacity already calibrated in the previous steps of the model calibration process described in sections above, queue calibration provides a chance for the model to be calibrated against driving behavior changes. These could include:

- Driving behavior
- Signal configuration
- Vehicle speed
- Reduction of speed at turns
- Gap acceptance

An example of the queue length calibration process is show in the figure below.

Queue Length (m)		
Before Change in Driving behaviour Parameters		
Movement	Observed	Modelled
J2-W-Through	110	40
J2-W-Right	110	40
J2-S-Left	50	20
J2-S-Right	50	20
J2-E-Left	120	80
J2-E-Through	120	80



Queue Length (m)		
After Change in Driving behaviour Parameters		
Movement	Observed	Modelled
J2-W-Through	110	105
J2-W-Right	110	105
J2-S-Left	50	50
J2-S-Right	50	50
J2-E-Left	120	125
J2-E-Through	120	125

Figure 5-4 Example of Queue Calibration

After calibration, modeled queue lengths will generate similar value to observed queue length, which indicates the model replicates the traffic situation on-site and is a good representation of the real-work traffic operations and network performance.

5.3 Scenario 1: Public Transport Priority

In scenario 1, emphasis is given to providing provision on dedicated bus lanes for some sections of Jalan Masjid Kapitan Keling which in turn offers fast, comfortable, and cost-effective urban transport system.

Vissim model is being used to test out the effectiveness on the bus priority scheme, as well as the impact on vehicular traffic when these schemes are implemented. The detailed traffic scheme changes are documented as in the figure and table below.

Figure 5-5 Scenario 1 Scheme

Individual traffic schemes proposed within this scenario are outlined, based on the location in the model area, in the table below.

Table 5-6 Scenario 1 Details

Scenario 1		
Theme	**Road**	**Details**
Public Transport Improvements	**Jalan Masjid Kapitan Keling:** Bus Lane	Design using offset transit lane. The standard width for road lane is 3.3m. Benefits: 1) Offset transit lanes reduce delays due to congestion. 2) Offset transit lanes raise the visibility of high-quality services, especially rapid service. Figure 5-6 below shows the proposed public transport lane on Jalan Masjid Kapitan Keling.

The following images shows the comparison of existing and proposed schemes in section view, as per location.

Figure 5-6 Scenario 1 Scheme Comparison Section View – Jalan Masjid Kapitan Keling

Main objective of this scenario is to understand the impact of implementation of dedicated public transport lanes on some sections of the study area on the road network performance. Since there is no change in vehicular demand and distribution, the OD matrix and trip chain used in this scenario is same as that of base calibrated model.

Below images indicated the location of added bus lane in Vissim model and depicts Vissim model after inclusion of all the traffic measures for Scenario 1.

Figure 5-7 Scenario 1 – Base Lane Location

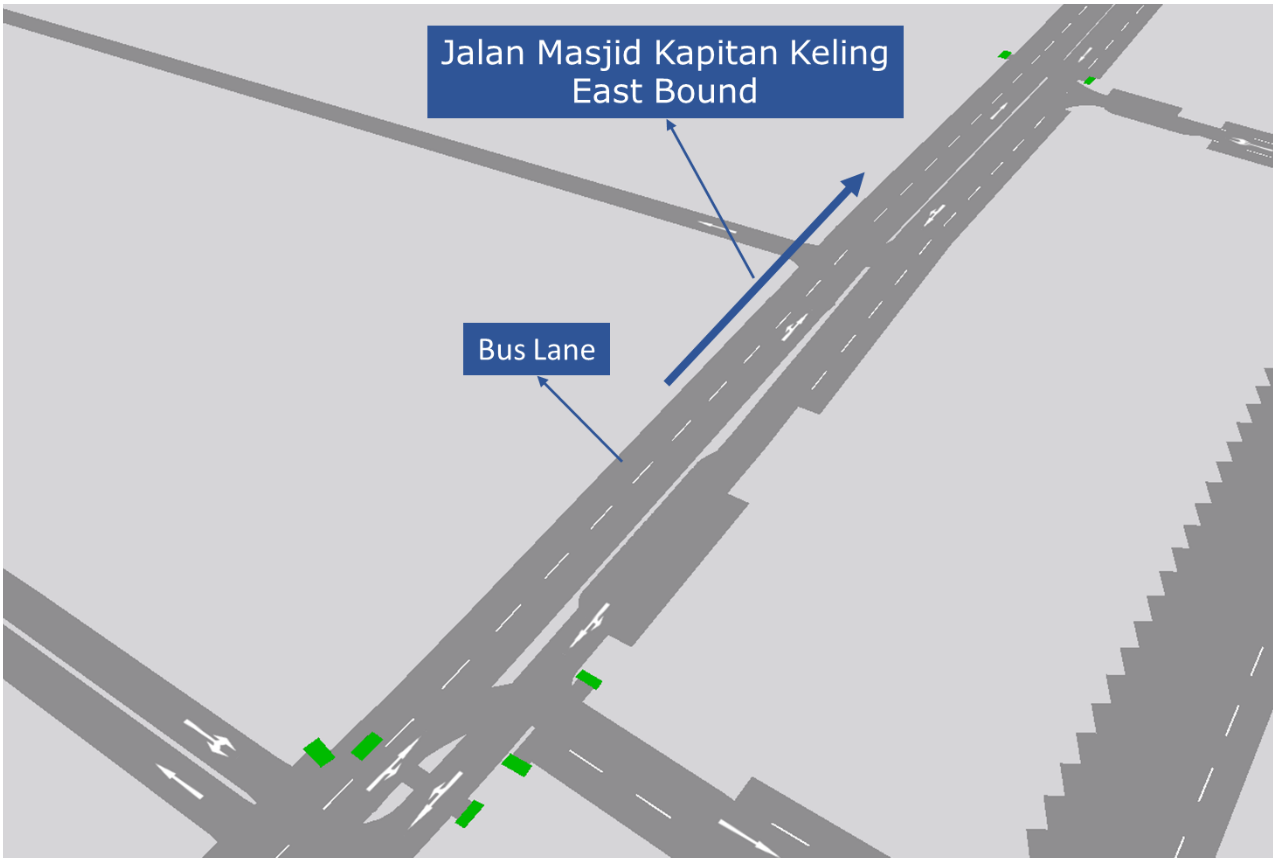


Figure 5-8 **Scenario 1 – Jalan Masjid Kapitan Keling**

5.4 Scenario 2: Pedestrian and Cyclist Priority

Scenario 2 proposed for this study focuses on providing priority pedestrian and cyclist corridors in the core area of Georgetown.

These facilities would mean pedestrians and cyclists will enjoy wider space when commuting through the city and be given priorities at key junctions. Overall, these measures are designed to improve the pedestrian experience and reduce the travel time needed through the city, resulting in a larger shift from traditional private car mode to walking and cycling.

Vissim simulation model is being used to test out the effectiveness on the priority scheme, as well as the impact on vehicular traffic when these schemes are implemented. The detailed traffic scheme changes are documented as in the figure and table below.

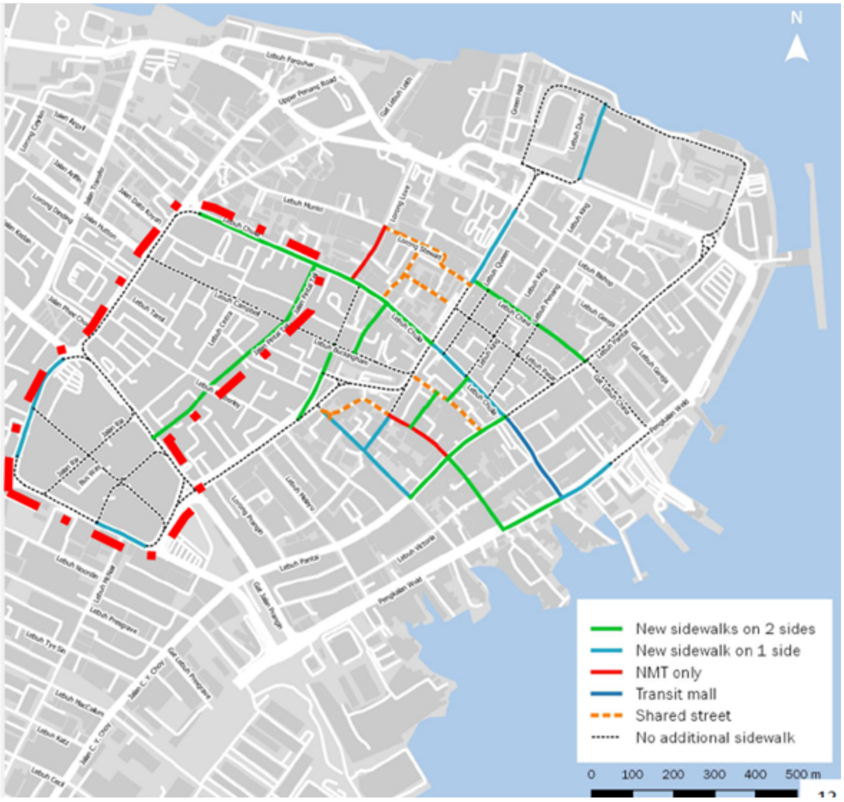


Figure 5-9 Scenario 2 Scheme Footpath Network

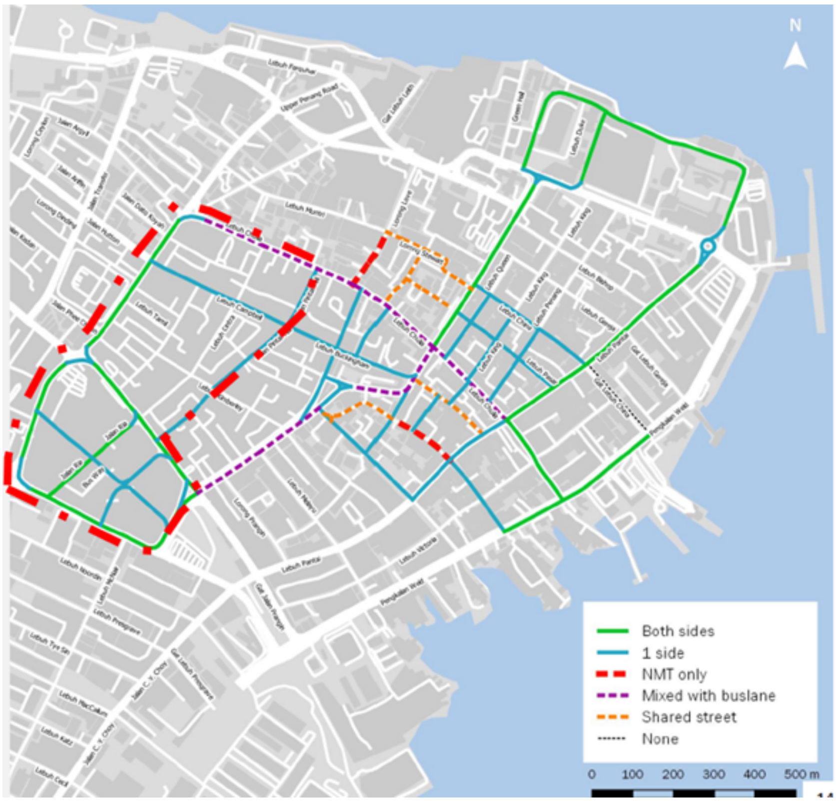


Figure 5-10 Scenario 2 Scheme Bike Lane Network

Individual traffic schemes proposed for non-motorized transport (NMT) intervention within this scenario are outlined, based on the location in the model area, in the table below.

Table 5-7 Scenario 2 Scheme Details

Scenario 2		
Theme	**Road**	**Details**
New Sidewalk on 2 Sides	**Gat Lebuh Armenian, Lebuh Pantai, Lebuh Carnarvon, Lebuh China, Lebuh Chulia, and Lorong Sek Chuan.**	To expand the pedestrian walk on both sides of the street with the following measurement: 1) Pedestrian walk total width: 4m with separation as follows: a) Walking path: 2.4m b) Landscaping: 1.5m
New Sidewalk on 1 Side	**Jalan Masjid Kapitan Keling, Lebuh Acheh, Lebuh Cannon, and Lebuh Chulia.**	To expand the pedestrian walk on 1 side of the street with the following measurement: 1) Pedestrian walk total width: 4m with separation as follows: a) Walking path: 2.4m b) Landscaping: 1.5m
Bike Lane on Both Sides	**Jalan Masjid Kapitan Keling, Lebuh Pantai, and Gat Lebuh Chulia.**	Bike lane to be designed on both sides of the street, with the measurement as follows: 1) Lane width: 1.8m 2) Demarcation width: 1m
Bike Lane on 1 Side	**Lebuh China, Lebuh Pantai, Gat Lebuh Armenian, Lebuh Acheh, Lebuh Cannon, Lebuh Carnarvon, and Lorong Seck Chuan**	Bike lane to be designed on 1 side of the street, with the measurement as follows: 1) Lane width: 1.8m 2) Demarcation width: 1m
Shared Street	**Lebuh Armenian, and Lorong Chulia.**	Design principles: 1) Must prioritize vulnerable users, ensuring that clear paths are maintained.

Scenario 2		
		2) Drainage channels and permeable materials should be provided in accordance with existing curb lines and slope. 3) Provide tactile warning strips at the entrance to all shared spaces. Warning strips should span the entire intersection crossing. 4) Maintain a clear path for delivery vehicles, and mark dedicated areas for vehicular movement with a change in paving pattern or type. 5) Pedestrian walk space to maintain at least 1.8m width. 6) Install signage to educate the public on how to use a shared street in the early stages of conversion.
Non-Motorized Transport (NMT) Intervention	**Lorong Love**	Design Principles: 1) Increase the frontage area available for businesses in the city and create intimate environments by transforming laneways and alleys with active ground floor uses. 2) Maintain an accessible clear path of 3.5 m for emergency vehicle access. 3) Movable furniture can be placed in the emergency access path so long as they do not impede necessary but infrequent movements.

The following images shows the comparison of existing and proposed schemes in section view, as per location.

Figure 5-11 Scenario 2 Scheme Comparison Section View – Shared Street

Figure 5-12 Scenario 2 Scheme Comparison NMT Proposal – Lorong Love

Main objective of this scenario is to test the impact of provision of pedestrian and cyclist priority facilities along with traffic calming measures on overall network performance. Since there is no change in vehicular demand and distribution, the OD matrix and trip chain used in this scenario is same as that of base calibrated model.

As explained, the following major modifications to road network are carried out in Scenario 2:

- Lorong Love conversion to NMT only;
- Bike lanes added to one or both sides of the selected road.

Below images indicate the location of the bike lane and NMT only section added and depicts the Scenario 2 in Vissim after implementation of all the interventions.

Figure 5-13 Location of Bike Lane and NMT Intervention

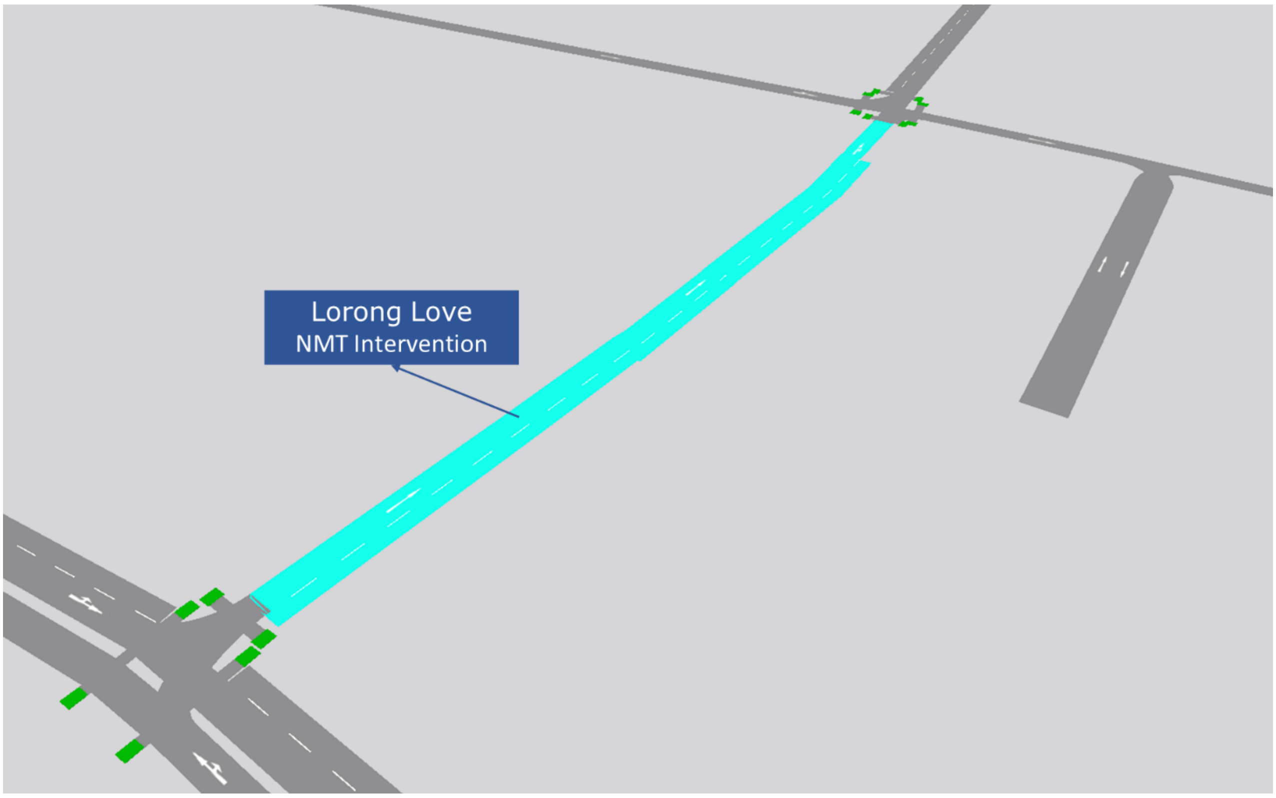


Figure 5-14 Scenario 2- Lorong Love

5.5 Scenario 3: Parking Reduction

Objective of this scenario is to analyses the impact of removal of selected on-street parking that cause capacity constraints to bus and NMT users.

A total of over 300 on-street parking will be removed from the Heritage Area. This number account for only 12% of the total on-street parking available in the area.

Vissim simulation model is being used to test out the effectiveness on the priority scheme, as well as the impact on vehicular traffic when these schemes are implemented. The detailed traffic scheme changes are documented as in the figure and table below.

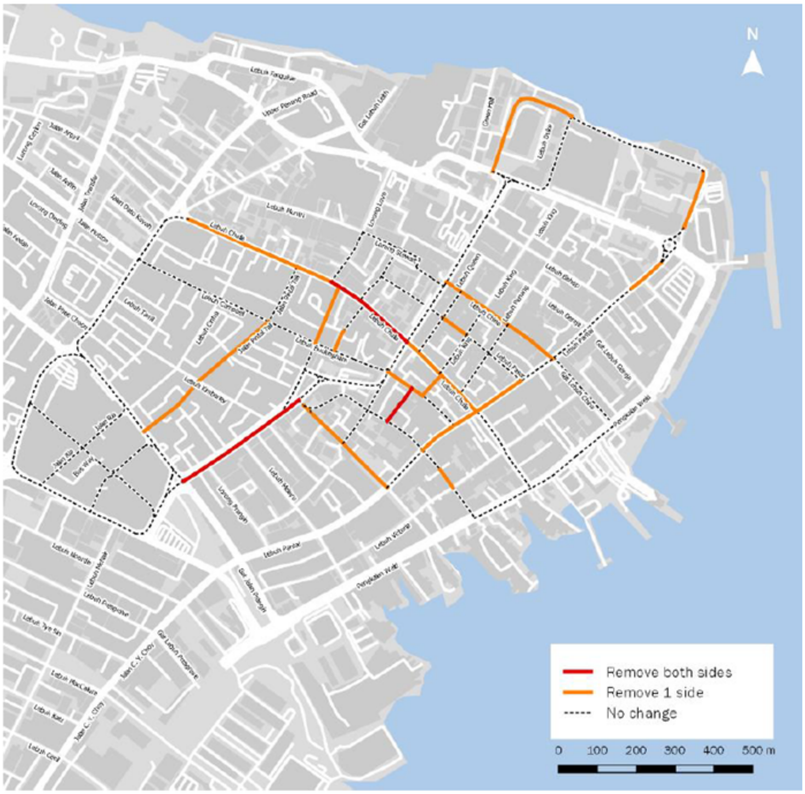


Figure 5-15 Scenario 3 Scheme Location of On-street Parking Spaces Removal

Individual traffic schemes proposed within this scenario are outlined, based on the location in the model area, in the table below.

Table 5-8 Scenario 3 Scheme Details

Scenario 3		
Theme	**Road**	**Details**
Remove Parking Lots on Both Sides	**Lebuh Chulia, and Lebuh Carnavon**	To remove parking lots on both sides of the streets. Vehicles in the network will proceed to their destination without stopping at the parking lot directly.
Remove Parking Lots on 1 Side	**Jalan Tun Syed Sheh Barakbah, Gat Lebuh Acheh, Gat Lebuh Armenian, Lebuh Pantai, Lebuh Chulia, Lebuh Chee Em, Lebuh Victoria, Lebuh Pasar, Lebuh China,**	To remove parking lots on one side of the streets. Vehicles in the network will proceed to their destination without stopping at the parking lot directly.

Scenario 3		
Theme	**Road**	**Details**
	Lorong Seck Chuan, and Lebuh Carnavon.	

Main objective of this scenario is to understand the network performance after adopting road network improvements.

As explained, following major modifications to road network are carried out in Scenario 3

Remove on-street parking on one or both sides of the road.

Below images indicate the location of the on-street parking lots removed the Scenario 3 in Vissim.

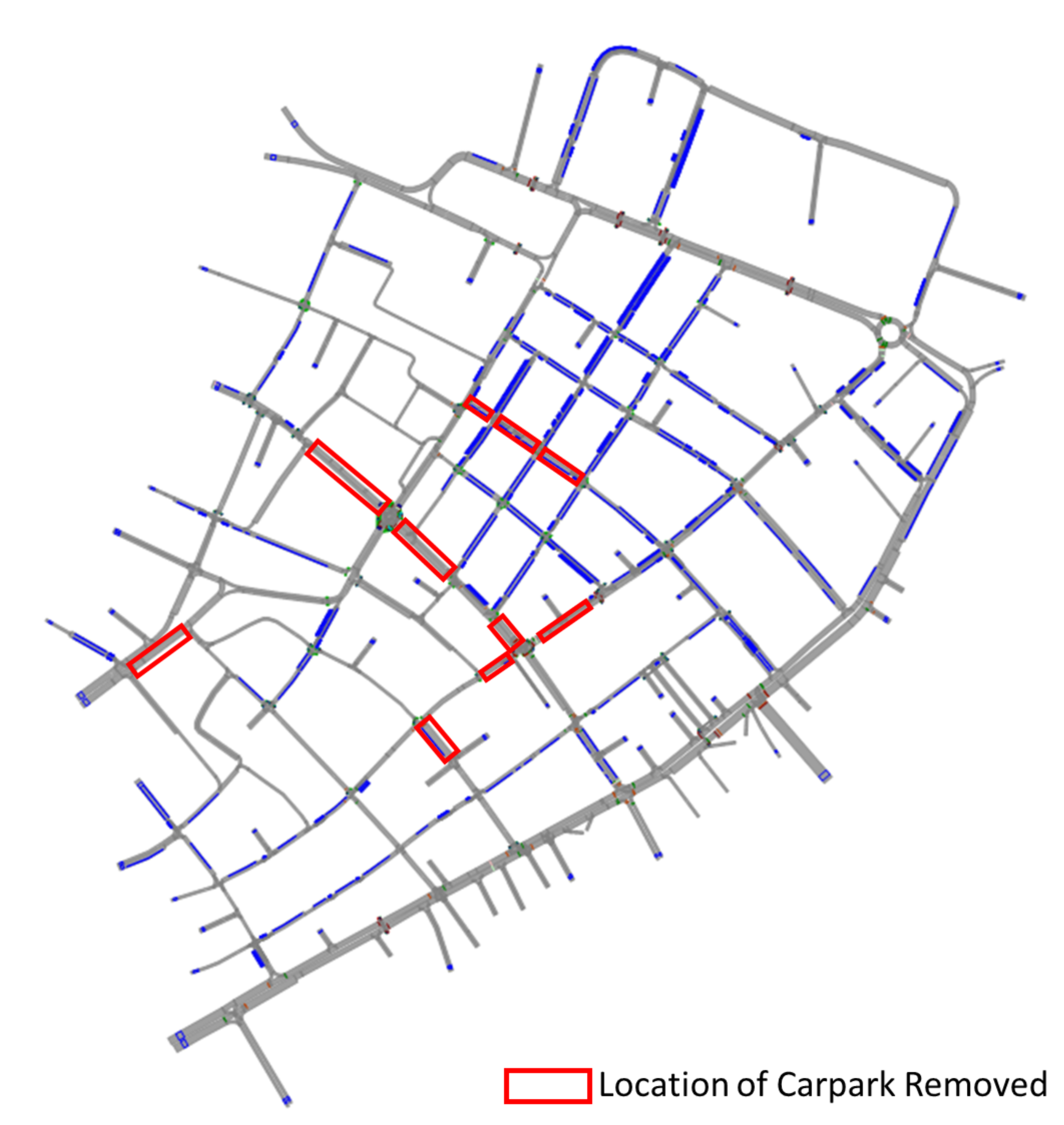


Figure 5-16 Scenario 3-Location of Carpark Removed

5.6 Scenario 4 Traffic Management Improvements

Impact of additional traffic on road network due to new proposed developments is tested in this scenario.

As explained, following major modifications to road network are carried out in Scenario 4

Proposed signalized junction at selected locations.

Below images indicate the location of new proposed signalized junctions adopted in the Scenario 4 in Vissim.

Figure 5-17 Location of Proposed New Signalized Junctions

5.7 Model Verification

5.7.1 Model Parameter Settings

- **Simulation Resolution:** The position of vehicle on the road network of the model is recalculated in simulation second with each times step. The Simulation resolution specifies the number of time steps. In current VISSIM model simulation resolution is set as 10.

- **Vehicle Fleet:** Within the vehicle type, different model of vehicles together with their share can be defined. For example, in this model for vehicle type- car, models like Volkswagen golf, Audi A4, Mercedes C1K, Peugeot 607, Volkswagen Beet, Porsche Cayman and Toyota Yaris are used. Below image shows the vehicle type along with their fleet and share.

Car

Count: 7	Share	Model2D3D
1	0.240	1: Car - Volkswagen Golf
2	0.180	2: Car - Audi A4
3	0.160	3: Car - Mercedes CLK
4	0.160	4: Car - Peugeot 607
5	0.140	5: Car - Volkswagen Beet...
6	0.020	6: Car - Porsche Cayman
7	0.100	7: Car - Toyota Yaris

Taxi

Count: 2	Share	Model2D3D
1	0.500	7: Car - Toyota Yaris
2	0.500	1: Car - Volkswagen Golf

Bike

Count: 1	Share	Model2D3D
1	1.000	313: Bike

LGV

Count: 2	Share	Model2D3D
1	0.500	311: Lt Truck -Ford
2	0.500	312: Lt Truck- Chevrolet

HGV

Count: 1	Share	Model2D3D
1	1.000	21: HGV - EU 04

BUS

Count: 1	Share	Model2D3D
1	1.000	31: Bus - EU Standard

- **Functions and distributions:** as per default

- **Random Seed:** The use of random seeds allows for stochastic variations of traffic arrivals in Vissim, which helps account for variations in real-world traffic conditions. Value of 42 which is default is used for our current model.

5.7.2 Vehicle Speeds at Turn Movements

Generally, reduced speed areas were placed on turn movements at intersections to consider reduced speeds and geometric delays at these locations.

An even speed distribution between 20 and 25 km/h has been adopted to reflect the reduced speeds in a realistic manner. 15 km/h is used for U turns and left turns.

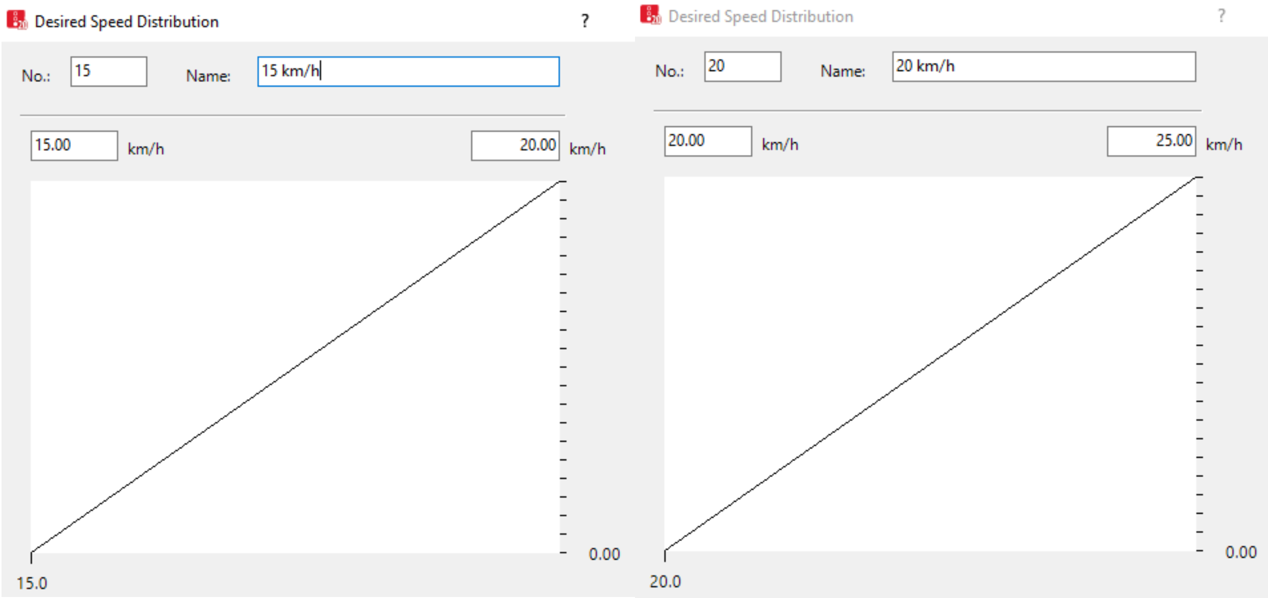


Figure 5-18 Speed Distribution at Turn Movements

The figure above shows a linear distribution of speed between the lower limit and upper limit. For example, the speed distribution of 15 km/h shows a uniformly distributed speed between 15 km/h and 20 km/h. While the speed distribution of 20 km/h shows a uniformly distributed speed between 20 km/h and 25 km/h. Speed distribution allows for more realistic representation of vehicle in the network.

5.7.3 Modelled Speed Limits

Speed limit is the highest achievable speed a vehicle can reach at free-flow state, which means there is no interference felt by the vehicle from road network and other vehicles. Vehicles also cannot meet this speed in the model due to imperfect driving conditions, such as low-speed proceeding vehicles or traffic signal controls.

The road links modelled were assigned speeds in accordance with the posted speed limits on the roads in the study area. Predominantly, 50 km/h is utilized on majority of the road links and on minor road 40 km/h speed is utilized.

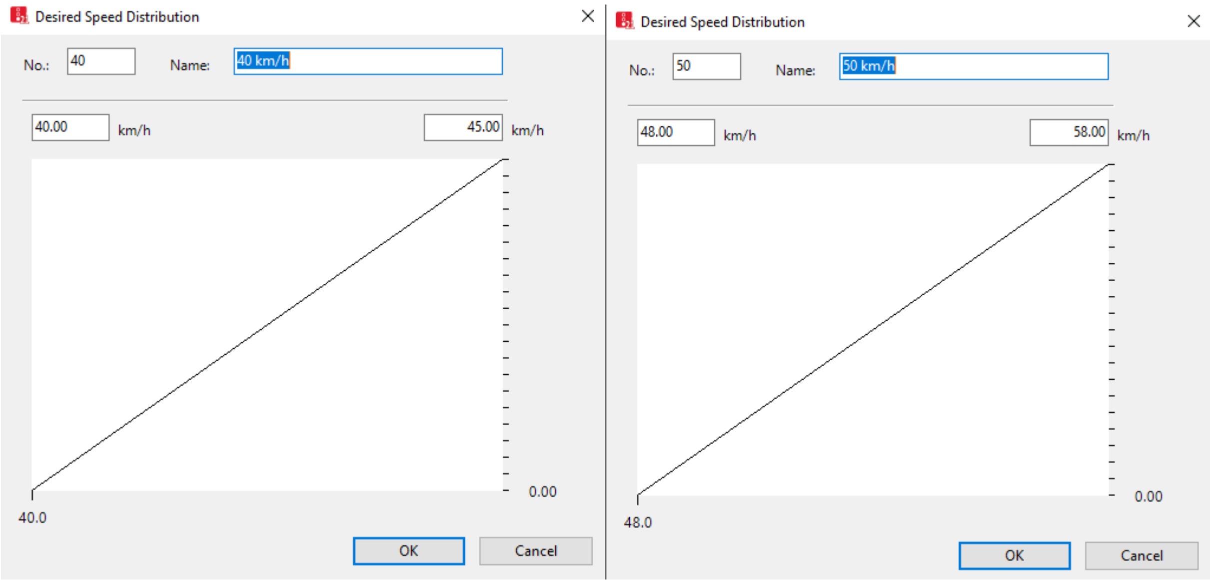


Figure 5-19 Speed Distribution for All Vehicle Types

The figure above shows a linear distribution of speed between the lower limit and upper limit. For example, the speed distribution of 40 km/h shows a uniformly distributed speed between 40 km/h and 45 km/h. While the speed distribution of 50 km/h shows a uniformly distributed speed between 48 km/h and 58 km/h.

Speed distribution allows for more realistic representation of vehicle in the network.

5.7.4 Driving Behavior

Driving parameters for Stage 2 are used from the existing Stage 1 as presented below. Driving behavior forms the foundation of how Vissim simulate each move of vehicles. Vissim traffic flow model is a stochastic, time-step based, microscopic model that treats driver-vehicle units as basic entities, which means:

- Vehicles are not running at fixed assignment with uniformed speed – this is not just a video
- Vehicles are reacting to other vehicles in the model consistently
- When put in origin and destination of traffic, route need to be selected by the model for vehicles

The driving behavior in traffic flow model contains a psycho-physical car following model for vehicle movement, which is based on Wiedemann's extensive research work:

- Wiedemann, R. (1974). Simulation des Straßenverkehrsflusses. Schriftenreihe des Instituts für Verkehrswesen der Universität Karlsruhe (seit 2009 KIT – Karlsruher Institut für Technologie), Heft 8
- Wiedemann, R. (1991). Modeling of RTI-Elements on multi-lane roads. In: Advanced Telematics in Road Transport edited by the Commission of the European Community, DG XIII, Brussels

This makes the simulation model realistic replication of the real-world situation, and thus can be used for testing changes in traffic configurations in the network.

Normally, roads in urban areas are based on Wiedemann, R. (1974) which forms the driving behavior of 1 Urban (motorized). As the Penang model is based on urban settings, the default driving behavior parameters (1 Urban motorized) were selected for intersections and links in the Vissim network.

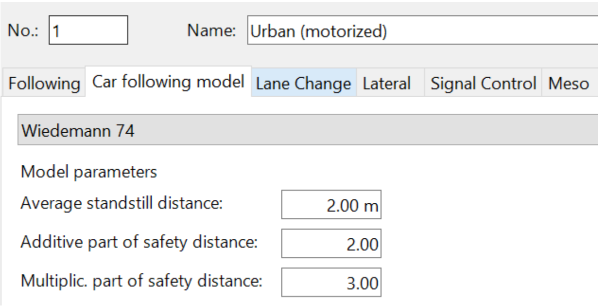
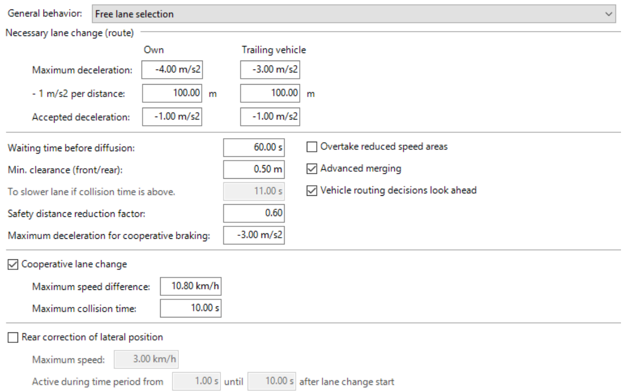
Car Following Model	Lane Change Behavior
	

Figure 5-20 Default Car Following and Lane Change Behavior

5.8 Model Calibration

5.8.1 Turn Volume Calibration

The objective of model calibration is to obtain the best match possible between the modelled performance estimates in Vissim and the field measurements of performance. It should be noted that there are no universally accepted procedures for conducting calibration for complex transportation networks.

In this assessment, we adopted the following calibration targets and general parameters for the calibration, based on FHWA Traffic Analysis Toolbox Volume III, and summarized below:

Hourly Flows (Model Versus Observed)

- Turning movement Flows
- GEH<5 for 85% of the movements

The simulation model was run on dynamic assignment technique. The simulation model was run on dynamic assignment technique in this current model. Dynamic assignment allows vehicles to choose best route possible in the network. Flow chart below shows the steps involved in dynamic assignment.

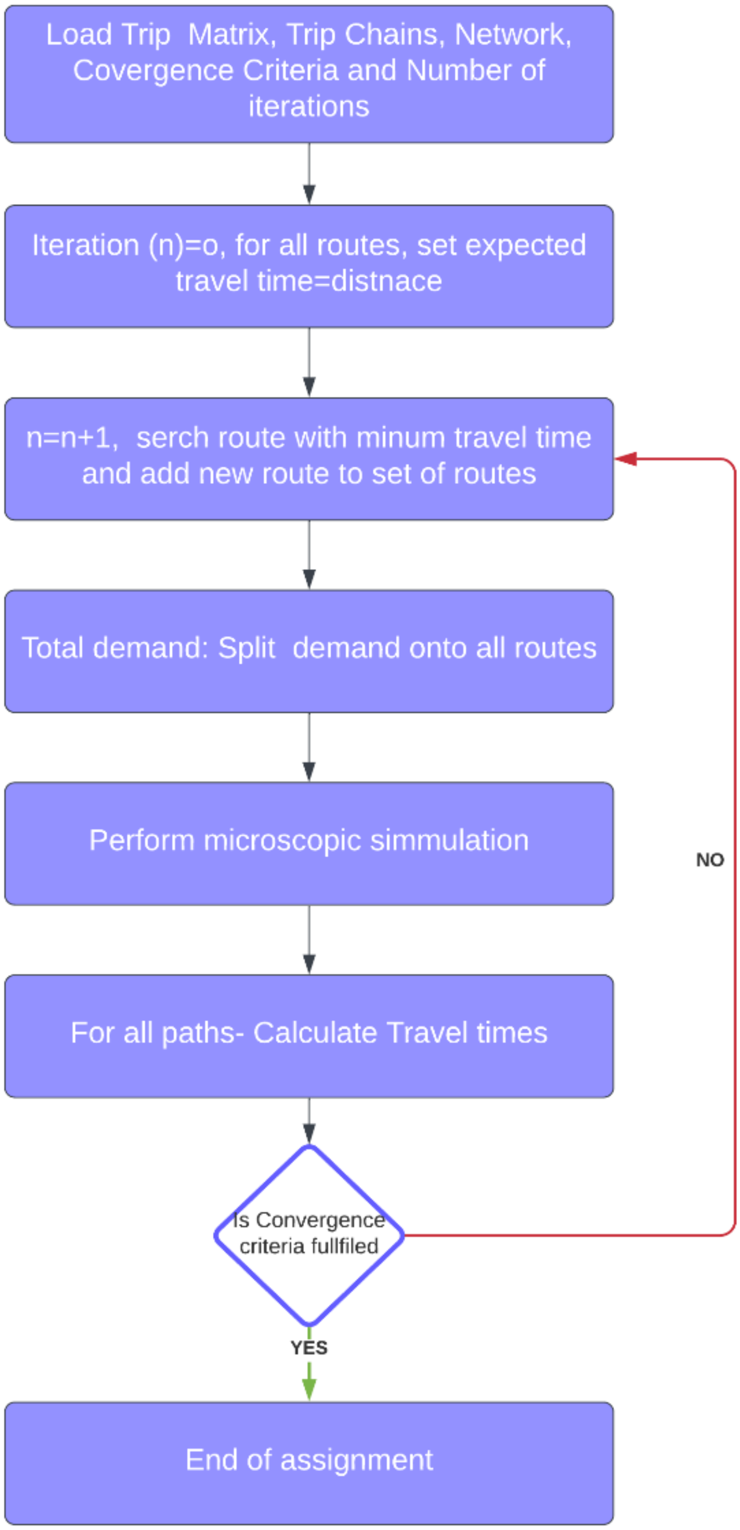


Figure 5-21 Dynamic Assignment Process

To carry out dynamic assignment, initially zones need to be defined. Traffic coming out from zones (origin) to be given relative flow (1) and for the zones where the traffic is coming in (destination) will be given relative flow (0).

Every junction in the model is defined with node to carry out dynamic assignment. The model is run for several iterations with fixed random seed (42) to allow the model to converge.

The stability of the model is measured in terms of convergence. Convergence criterion used is "Travel time on paths" with 15% as percentage change of travel time for all paths compared to the previous simulation run. Also, 90% has utilized for required share of converged paths.

The Cost and Path files are archived for each of the iteration of the model when run on Dynamic assignment in microscopic simulation. Cost file contains weighted sum of travel distance, travel time and link specific costs. Path file contains all the associated paths of the cost file. The final converged path and cost files are then utilized again to run the final iteration on Dynamic assignment in Microsimulation to extract results like GEH, Queue lengths and Delays for both AM and PM peak models.

Observed turning movements from all sites were used to calibrate the traffic volumes for the AM and PM base models. The difference between the modelled and the surveyed turning movements are tabulated in the tables below and converted into GEH statistics, for the purpose of comparison.

Most of the movements have a GEH of below 5 and have satisfied the requirement. The results show that the Vissim model has been well calibrated in turning movements. Observed volumes from the primary survey are compared against the modelled volume and the resulting GEH is estimated. The summary of the same is shown below.

Table 5-9 Turn Volume Calibration for AM Peak

Junction	Approach	Observed	Modelled	GEH	GEH<5
J1	J1-E-Through	1022	909	3.6	YES
	J1-E-Right	304	334	1.7	YES
	J1-W-Left	1452	1333	3.2	YES
J2	J2-E-Through	1016	983	1.1	YES
	J2-W-Left	172	181	0.7	YES
	J2-N-Left	68	53	1.9	YES
	J2-W-Through	1447	1434	0.3	YES
J3	J3-E-Through	1016	977	1.2	YES
	J3-W-Through	1553	1545	0.2	YES
	J3-W-Left	245	82	12.7	NO
	J3-N-Left	65	70	0.6	YES
J4	J4-E-Through	958	878	2.6	YES
	J4-W-Left	38	31	1.2	YES
	J4-N-Left	3	0	2.4	YES
	J4-W-Through	1593	1557	0.9	YES
J5	J5-E-Through	800	814	0.5	YES
	J5-S-Left	15	51	6.3	NO
	J5-W-Through	1537	1509	0.7	YES
	J5-W-Left	411	457	2.2	YES
	J5-N-Left	82	86	0.4	YES
J6	J6-S-Right	4	0	2.8	YES
	J6-W-Through	2045	2096	1.1	YES
	J6-E-Through	810	842	1.1	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J6-W-Left	112	161	4.2	YES
	J6-E-Right	30	92	7.9	NO
	J6-E-Left	2	0	2	YES
	J6-S-Left	12	0	4.9	YES
	J6-S-Through	8	0	4	YES
	J6-W-Right	6	0	3.5	YES
J7	J7-W-Through	2300	2173	2.7	YES
	J7-N-Left	115	86	2.9	YES
	J7-E-Through	912	842	2.4	YES
	J7-N-Right	124	172	3.9	YES
J8	J8-S-Right	12	143	14.9	NO
	J8-E-Left	10	50	7.3	NO
	J8-W-Right	4	2	1.2	YES
	J8-W-Through	2206	2314	2.3	YES
	J8-E-Right	971	931	1.3	YES
	J8-S-Left	19	14	1.2	YES
J9	J9-E-Through	1062	981	2.5	YES
	J9-W-Through	2307	2156	3.2	YES
	J9-W-Left	382	296	4.7	YES
	J9-N-Left	19	47	4.8	YES
J10	J10-S-Through	296	266	1.8	YES
	J10-E-Through	84	88	0.4	YES
	J10-E-Left	63	48	2	YES
	J10-S-Left	47	30	2.7	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J10-E-Right	71	84	1.5	YES
J11	J11-N-Through	116	130	1.3	YES
	J11-E-Through	149	133	1.3	YES
	J11-E-Left	79	129	4.9	YES
	J11-N-Right	94	89	0.5	YES
J12	J12-S-Through	94	149	5	YES
	J12-E-Through	194	162	2.4	YES
	J12-E-Right	24	15	2	YES
	J12-S-Left	53	102	5.6	NO
J13	J13-S-Through	331	300	1.7	YES
	J13-N-Through	118	127	0.8	YES
	J13-N-Right	168	177	0.7	YES
	J13-N-Left	74	93	2.1	YES
	J13-S-Left	50	0	10	NO
	J13-S-Right	208	148	4.5	YES
J14	J14-W-Through	205	193	0.9	YES
	J14-W-Right	4	0	2.8	YES
	J14-S-Right	10	31	4.6	YES
J15	J15-N-Through	29	13	3.5	YES
	J15-S-Through	235	82	12.2	NO
	J15-W-Right	29	57	4.3	YES
	J15-W-Left	165	154	0.9	YES
J16	J16-W-Left	1051	1027	0.7	YES
	J16-N-Through	807	793	0.5	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J16-W-Left+Right	1427	1424	0.1	YES
	J16-E-Left	37	36	0.2	YES
J17	J17-W-Through	434	362	3.6	YES
	J17-S-Left	465	478	0.6	YES
	J17-S-Right	1049	1060	0.4	YES
J18	J18-E-Through	270	212	3.7	YES
	J18-E-Right	235	266	2	YES
	J18-W-Left	219	238	1.3	YES
	J18-W-Through	465	369	4.7	YES
J19	J19-W-Through	441	324	6	NO
	J19-N-Left	317	340	1.3	YES
	J19-E-Through	244	246	0.1	YES
J20	J20-E-Right	53	42	1.6	YES
	J20-E-Left	57	53	0.5	YES
	J20-S-Right	45	109	7.3	NO
	J20-S-Through	76	71	0.6	YES
	J20-W-Left	245	223	1.4	YES
	J20-W-Through	372	220	8.8	NO
	J20-W-Right	41	0	9.1	NO
	J20-E-Through	129	150	1.8	YES
	J20-S-Left	35	0	8.4	NO
J21	J21-S-Uturn	9	13	1.2	YES
	J21-S-Left	135	135	0	YES
	J21-S-Right	188	170	1.3	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J21-E-Through	148	150	0.2	YES
	J21-E-Left	20	0	6.3	NO
	J21-W-Right	9	0	4.2	YES
	J21-W-Through	288	0	24	NO
	J21-N-Right	81	125	4.3	YES
	J21-N-Left	209	273	4.1	YES
	J21-N-Through	20	0	6.3	NO
J22	J22-E-Through	414	343	3.7	YES
	J22-W-Left	185	102	6.9	NO
	J22-W-Through	248	227	1.4	YES
J24	J24-W-Left	124	142	1.6	YES
	J24-S-Through	257	228	1.9	YES
	J24-S-Right	65	66	0.1	YES
	J24-N-Left	128	153	2.1	YES
	J24-N-Through	153	178	1.9	YES
	J24-W-Right	41	40	0.2	YES
	J24-W-Through	195	218	1.6	YES
	J24-E-Right	62	67	0.6	YES
	J24-E-Left	164	181	1.3	YES
J25	J25-W-Through	293	278	0.9	YES
	J25-S-Through	80	92	1.3	YES
	J25-S-Left	30	48	2.9	YES
	J25-W-Left	76	98	2.4	YES
J26	J26-N-Through	86	89	0.3	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J26-W-Through	357	340	0.9	YES
	J26-N-Left	44	37	1.1	YES
	J26-W-Right	131	130	0.1	YES
J27	J27-S-Through	148	144	0.3	YES
	J27-W-Through	366	358	0.4	YES
	J27-S-Right	210	210	0	YES
	J27-W-Left	118	97	2	YES
J28	J28-S-Through	176	179	0.2	YES
	J28-E-Left	30	38	1.4	YES
	J28-W-Left	44	33	1.8	YES
	J28-S-Left	46	62	2.2	YES
	J28-E-Through	14	33	3.9	YES
J30	J30-E-Right	125	174	4	YES
	J30-E-Left	142	126	1.4	YES
J31	J31-N-Right	64	75	1.3	YES
	J31-E-Through	83	84	0.1	YES
	J31-S-Left	145	145	0	YES
J32	J32-N-Left	537	416	5.5	NO
	J32-E-Right	394	312	4.4	YES
	J32-E-Through	105	84	2.2	YES
J33	J33-N-Left	148	107	3.6	YES
J34	J34-W-Through	352	338	0.8	YES
	J34-E-Right	91	114	2.3	YES
	J34-E-Through	151	160	0.7	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J34-E-Left	42	50	1.2	YES
	J34-S-Right	71	47	3.1	YES
	J34-S-Through	186	204	1.3	YES
	J34-S-Left	83	112	2.9	YES
	J34-W-Right	192	224	2.2	YES
	J34-W-Left	33	0	8.1	NO
	J34-N-Right	20	53	5.5	NO
	J34-S-Through	121	119	0.2	YES
	J34-N-Left	45	70	3.3	YES
J35	J35-S-Through	325	277	2.8	YES
	J35-N-Through	249	259	0.6	YES
	J35-S-Left	129	152	1.9	YES
	J35-S-Right	63	76	1.6	YES
	J35-N-Right	48	83	4.3	YES
	J35-N-Left	90	53	4.4	YES
J36	J36-S-Through	487	437	2.3	YES
	J36-E-Left	48	83	4.3	YES
	J36-E-Right	113	68	4.7	YES
	J36-N-Through	269	255	0.9	YES
J37	J37-E-Through	125	113	1.1	YES
	J37-E-Right	102	59	4.8	YES
	J37-S-Through	112	109	0.3	YES
	J37-S-Left	36	41	0.8	YES
J38	J38-W-Through	92	80	1.3	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J38-S-Through	63	91	3.2	YES
	J38-W-Left	53	49	0.6	YES
	J38-S-Right	157	77	7.4	NO
J39	J39-E-Through	50	66	2.1	YES
	J39-S-Through	154	99	4.9	YES
	J39-E-Right	21	34	2.5	YES
	J39-S-Right	61	41	2.8	YES
J40	J40-E-Through	233	283	3.1	YES
	J40-W-Through	410	455	2.2	YES
	J40-S-Left	64	58	0.8	YES
	J40-S-Right	89	75	1.5	YES
J41	J41-N-Right	21	0	6.5	NO
	J41-E-Right	163	0	18.1	NO
	J41-W-Left	31	0	7.9	NO
	J41-W-Through	690	627	2.5	YES
	J41-E-Through	242	288	2.8	YES
	J41-N-Left	116	150	2.9	YES
J42	J42-E-Left	14	29	3.2	YES
	J42-W-Right	197	278	5.3	NO
	J42-W-Through	504	499	0.2	YES
	J42-E-Through	373	288	4.7	YES
J43	J43-E-Through	27	71	6.3	NO
	J43-N-Right	57	29	4.3	YES
	J43-N-Through	324	277	2.7	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J43-E-Left	48	0	9.8	NO
J44	J44-N-Through	258	220	2.5	YES
	J44-W-Through	82	103	2.2	YES
	J44-W-Right	55	53	0.3	YES
	J44-N-Left	108	57	5.6	NO
J45	J45-E-Through	174	173	0.1	YES
	J45-N-Through	235	273	2.4	YES
	J45-N-Right	65	0	11.4	NO
	J45-E-Left	117	128	1	YES
J46	J46-S-Through	216	171	3.2	YES
	J46-E-Through	219	211	0.5	YES
	J46-E-Right	245	244	0.1	YES
	J46-S-Left	98	90	0.8	YES
J47	J47-S-Through	341	313	1.5	YES
	J47-W-Through	94	115	2.1	YES
	J47-W-Left	59	45	1.9	YES
	J47-S-Right	129	100	2.7	YES
J48	J48-S-Left	111	71	4.2	YES
J49	J49-E-Through	310	259	3	YES
	J49-W-Through	467	496	1.3	YES
	J49-S-Left	117	95	2.1	YES
	J49-S-Right	177	191	1	YES
J50	J50-W-Through	529	496	1.5	YES
	J50-W-Left	7	3	1.8	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J50-E-Right	16	35	3.8	YES
J51	J51-E-Left	273	263	0.6	YES
	J51-W-Right	166	203	2.7	YES
	J51-W-Through	479	481	0.1	YES
	J51-E-Through	317	259	3.4	YES
J52	J52-N-Through	265	228	2.4	YES
	J52-W-Through	94	102	0.8	YES
	J52-W-Right	114	113	0.1	YES
	J52-N-Left	127	140	1.1	YES
J53	J53-N-Through	187	184	0.2	YES
	J53-E-Through	286	300	0.8	YES
	J53-E-Left	141	157	1.3	YES
	J53-N-Right	190	157	2.5	YES
J54	J54-E-Through	205	163	3.1	YES
	J54-S-Left	360	296	3.5	YES
J55	J55-S-Through	930	978	1.6	YES
	J55-N-Through	840	802	1.3	YES
	J55-S-Left	92	40	6.4	NO
	J55-N-Right	105	123	1.7	YES
J56	J56-S-Through	1074	974	3.1	YES
	J56-N-Through	905	823	2.8	YES
	J56-W-Left	145	140	0.4	YES
	J56-W-Right	40	102	7.4	NO
J57	J57-N-Through	910	901	0.3	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J57-N-Left	169	132	3	YES
	J57-E-Left	41	0	9.1	NO
J58	J58-N-Through	977	925	1.7	YES
	J58-N-Through	977	955	0.7	YES
	J58-N-Through	977	955	0.7	YES
	J58-N-Right	559	589	1.3	YES
	J58-S-Left	1149	1105	1.3	YES
J59	J59-W-Left	534	480	2.4	YES
	J59-E-Right	1228	1169	1.7	YES
J60	J60-E-Left	70	58	1.5	YES
	J60-N-Through	1558	1486	1.8	YES
	J60-N-Left	231	238	0.5	YES
J61	J61-S-Through	1536	1516	0.5	YES
J62	J62-N-Through	1635	1643	0.2	YES
	J62-N-Left	261	276	0.9	YES
	J62-E-Left	63	92	3.3	YES
J63	J63-S-Through	1167	1060	3.2	YES
	J63-S-Right	522	497	1.1	YES
	J63-N-Left	1510	1439	1.9	YES
J64	J64-N-Through	1423	1230	5.3	NO
	J64-S-Through	1066	1060	0.2	YES
	J64-W-Left	157	184	2.1	YES
J65	J65-W-Through	181	146	2.7	YES
	J65-W-Right	3	0	2.4	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J65-S-Right	1	38	8.4	NO
J66	J66-W-Through	136	112	2.2	YES
	J66-N-Left	35	34	0.2	YES
	J66-N-Through	81	70	1.3	YES
	J66-W-Right	136	104	2.9	YES
J67	J67-N-Through	95	152	5.1	NO
	J67-W-Right	20	0	6.3	NO
	J67-N-Right	26	55	4.6	YES
J68	J68-N-Through	217	207	0.7	YES
	J68-S-Through	640	571	2.8	YES
	J68-N-Left	71	89	2	YES
	J68-S-Right	130	128	0.2	YES
J69	J69-S-Through	392	380	0.6	YES
	J69-W-Right	100	111	1.1	YES
	J69-W-Left	278	319	2.4	YES
J70	J70-N-Through	197	171	1.9	YES
	J70-S-Through	335	310	1.4	YES
	J70-E-Left	21	0	6.5	NO
	J70-E-Right	58	55	0.4	YES
	J70-S-Right	17	0	5.8	NO
	J70-N-Left	124	97	2.6	YES
J71	J71-N-Through	106	74	3.4	YES
	J71-N-Right	1	19	5.7	NO
	J71-N-Left	110	95	1.5	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J71-W-Right	91	106	1.5	YES
	J71-W-Through	297	337	2.2	YES
J72	J72-W-Right	611	629	0.7	YES
	J72-W-Through	422	374	2.4	YES
	J72-W-Left	50	55	0.7	YES
	J72-N-Left	22	72	7.3	NO
	J72-N-Through	75	90	1.7	YES
J74	J74-E-Through	534	498	1.6	YES
	J74-E-left	82	76	0.7	YES
	J74-S-left	191	139	4	YES
J75	J75-E-Right	206	180	1.9	YES
	J75-E-Through	462	419	2	YES
	J75-W-Through	1029	1021	0.2	YES
	J75-W-Left	325	243	4.9	YES
	J75-E-Left	43	36	1.1	YES
	J75-S-Left	4	0	2.8	YES
Proportion of Turns with GEH < 5 - 87%					

It can be observed from the above table that over 87% of 303 links satisfy GEH statistic indicating the model being reflective of field observed traffic volumes.

In addition to GEH, there is also another statistical measurement named “R-Squared” that is used to check the how well the modeled data matches the surveyed value.

R-Squared is a statistical measure in a regression model that determines the proportion of variance in the dependent variable that can be explained by the independent variable. In other words, r-squared shows how well the data fit the regression model (the goodness of fit).

The formula for calculating R-squared is:

$$R - Squared = \frac{SS_{regression}}{SS_{total}}$$

R-squared can take any values between 0 to 1. A higher r-squared indicates a better fit for the model.

Similarly, to GEH, an example of the model calibration with turn volumes are shown in figures below with the respective R-Squared graph represented in the figure below.

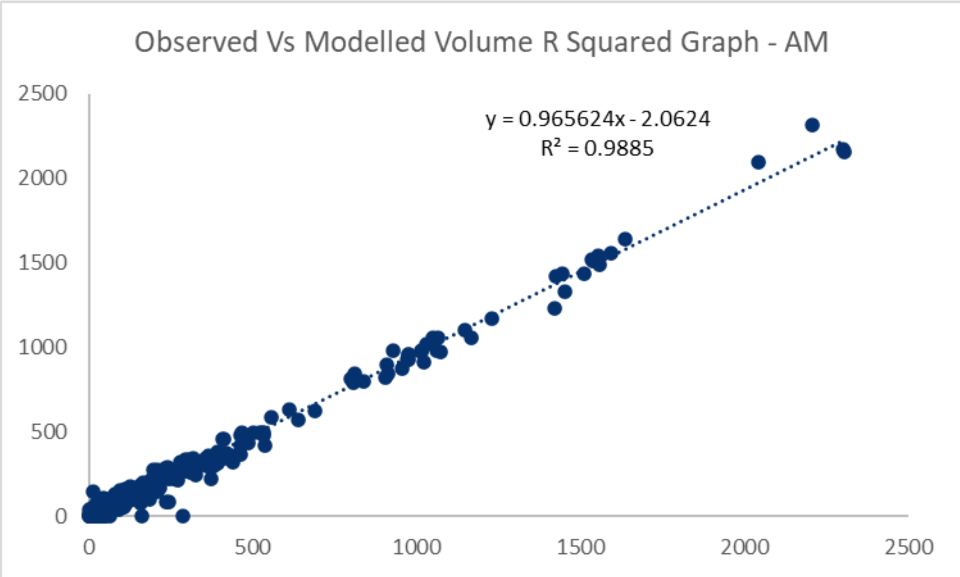


Figure 5-22 AM Peak R-Squared Graph after Turn Volume Calibration

Initially before the matrix estimation process the field turn volumes may not match the modelled flows. Through iterative matrix correction process, modelled volumes are matched with field survey data.

The matrix estimation process as described above is then re-run with the inputs from site surveyed traffic volumes to correct the matrix. After this iterative process, the following graph can be obtained from the calibrated model. As shown in the figure, the R-Square value is at 0.9885, indicating a close match between modeled values and surveyed values.

Table 5-10 Turn Volume Calibration for PM Peak

Junction	Approach	Observed	Modelled	GEH	GEH<5
J1	J1-E-Through	2388	2211	3.7	YES
	J1-E-Right	237	320	5	YES
	J1-W-Left	840	846	0.2	YES
J2	J2-E-Through	2419	2457	0.8	YES
	J2-W-Left	86	110	2.4	YES
	J2-N-Left	60	33	4	YES
	J2-W-Through	777	847	2.5	YES
J3	J3-E-Through	2407	2438	0.6	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J3-W-Through	807	874	2.3	YES
	J3-W-Left	173	194	1.6	YES
	J3-N-Left	91	84	0.7	YES
J4	J4-E-Through	2218	2136	1.8	YES
	J4-W-Left	9	29	4.7	YES
	J4-N-Left	15	0	5.5	NO
	J4-W-Through	928	962	1.1	YES
J5	J5-E-Through	1870	2015	3.3	YES
	J5-S-Left	15	16	0.2	YES
	J5-W-Through	735	713	0.8	YES
	J5-W-Left	274	337	3.6	YES
	J5-N-Left	114	114	0	YES
J6	J6-S-Right	4	0	2.8	YES
	J6-W-Through	1091	1133	1.3	YES
	J6-E-Through	2163	2266	2.2	YES
	J6-W-Left	128	105	2.1	YES
	J6-E-Right	31	92	7.8	NO
	J6-E-Left	3	0	2.4	YES
	J6-S-Left	10	0	4.5	YES
	J6-S-Through	3	0	2.4	YES
	J6-W-Right	12	0	4.9	YES
J7	J7-W-Through	1248	1148	2.9	YES
	J7-N-Left	121	90	3	YES
	J7-E-Through	2437	2266	3.5	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J7-N-Right	401	195	11.9	NO
J8	J8-S-Right	10	76	10	NO
	J8-E-Left	15	9	1.6	YES
	J8-W-Right	9	5	1.4	YES
	J8-W-Through	1192	1219	0.8	YES
	J8-E-Right	2515	2529	0.3	YES
	J8-S-Left	11	7	1.2	YES
J9	J9-E-Through	2788	2539	4.8	YES
	J9-W-Through	1223	1128	2.8	YES
	J9-W-Left	195	164	2.3	YES
	J9-N-Left	26	166	14.3	NO
J10	J10-S-Through	170	155	1.1	YES
	J10-E-Through	190	184	0.5	YES
	J10-E-Left	258	166	6.3	NO
	J10-S-Left	23	8	3.7	YES
	J10-E-Right	139	129	0.9	YES
J11	J11-N-Through	172	161	0.9	YES
	J11-E-Through	394	336	3	YES
	J11-E-Left	289	126	11.3	NO
	J11-N-Right	161	148	1	YES
J12	J12-S-Through	91	105	1.4	YES
	J12-E-Through	569	372	9.1	NO
	J12-E-Right	54	0	10.4	NO
	J12-S-Left	60	92	3.7	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
J13	J13-S-Through	305	293	0.7	YES
	J13-N-Through	155	152	0.2	YES
	J13-N-Right	440	374	3.3	YES
	J13-N-Left	66	79	1.5	YES
	J13-S-Left	104	0	14.4	NO
	J13-S-Right	93	44	5.9	NO
J14	J14-W-Through	205	209	0.3	YES
	J14-W-Right	6	0	3.5	YES
	J14-S-Right	6	29	5.6	NO
J15	J15-N-Through	27	11	3.8	YES
	J15-S-Through	170	194	1.8	YES
	J15-W-Right	37	74	4.9	YES
	J15-W-Left	153	150	0.2	YES
J16	J16-W-Left	1038	1116	2.4	YES
	J16-N-Through	1509	1433	2	YES
	J16-W-Left+Right	1483	1495	0.3	YES
	J16-E-Left	262	263	0	YES
J17	J17-W-Through	644	669	1	YES
	J17-S-Left	241	273	2	YES
	J17-S-Right	837	819	0.6	YES
J18	J18-E-Through	196	209	0.9	YES
	J18-E-Right	66	63	0.4	YES
	J18-W-Left	156	186	2.3	YES
	J18-W-Through	686	680	0.2	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
J19	J19-W-Through	518	315	9.9	NO
	J19-N-Left	353	341	0.6	YES
	J19-E-Through	233	261	1.8	YES
J20	J20-E-Right	28	29	0.3	YES
	J20-E-Left	33	33	0.1	YES
	J20-S-Right	25	103	9.7	NO
	J20-S-Through	51	7	8.1	NO
	J20-W-Left	194	203	0.6	YES
	J20-W-Through	459	217	13.1	NO
	J20-W-Right	24	0	6.9	NO
	J20-E-Through	176	198	1.6	YES
	J20-S-Left	27	0	7.3	NO
J21	J21-S-Uturn	4	0	2.8	YES
	J21-S-Left	168	198	2.2	YES
	J21-S-Right	137	131	0.5	YES
	J21-E-Through	207	198	0.6	YES
	J21-E-Left	16	0	5.7	NO
	J21-W-Right	13	11	0.7	YES
	J21-W-Through	340	0	26.1	NO
	J21-N-Right	143	140	0.3	YES
	J21-N-Left	197	290	5.9	NO
	J21-N-Through	18	0	6	NO
J22	J22-E-Through	584	513	3	YES
	J22-W-Left	185	169	1.2	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J22-W-Through	187	184	0.2	YES
J24	J24-W-Left	123	170	3.9	YES
	J24-S-Through	281	257	1.4	YES
	J24-S-Right	59	33	3.9	YES
	J24-N-Left	206	204	0.2	YES
	J24-N-Through	300	291	0.5	YES
	J24-W-Right	74	69	0.6	YES
	J24-W-Through	168	213	3.3	YES
	J24-E-Right	162	173	0.9	YES
	J24-E-Left	298	252	2.8	YES
J25	J25-W-Through	299	276	1.3	YES
	J25-S-Through	101	105	0.4	YES
	J25-S-Left	59	70	1.4	YES
	J25-W-Left	123	137	1.2	YES
J26	J26-N-Through	170	120	4.2	YES
	J26-W-Through	309	322	0.8	YES
	J26-N-Left	114	91	2.2	YES
	J26-W-Right	158	191	2.5	YES
J27	J27-S-Through	158	169	0.9	YES
	J27-W-Through	337	350	0.7	YES
	J27-S-Right	170	162	0.6	YES
	J27-W-Left	81	84	0.3	YES
J28	J28-S-Through	214	222	0.5	YES
	J28-E-Left	51	59	1.1	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J28-W-Left	33	29	0.6	YES
	J28-S-Left	27	32	0.8	YES
	J28-E-Through	20	44	4.3	YES
J30	J30-E-Right	254	295	2.5	YES
	J30-E-Left	274	213	3.9	YES
J31	J31-N-Right	128	67	6.2	NO
	J31-E-Through	154	159	0.4	YES
	J31-S-Left	236	282	2.9	YES
J32	J32-N-Left	487	415	3.4	YES
	J32-E-Right	756	672	3.1	YES
	J32-E-Through	169	159	0.8	YES
J33	J33-N-Left	200	165	2.6	YES
J34	J34-W-Through	317	345	1.6	YES
	J34-E-Right	197	233	2.5	YES
	J34-E-Through	375	331	2.3	YES
	J34-E-Left	100	65	3.8	YES
	J34-S-Right	84	65	2.2	YES
	J34-S-Through	311	309	0.1	YES
	J34-S-Left	138	118	1.8	YES
	J34-W-Right	245	273	1.7	YES
	J34-W-Left	72	0	12	NO
	J34-N-Right	36	36	0.1	YES
	J34-S-Through	161	189	2.1	YES
	J34-N-Left	132	36	10.5	NO

Junction	Approach	Observed	Modelled	GEH	GEH<5
J35	J35-S-Through	428	415	0.6	YES
	J35-N-Through	378	375	0.1	YES
	J35-S-Left	173	155	1.4	YES
	J35-S-Right	81	132	5	YES
	J35-N-Right	69	71	0.3	YES
	J35-N-Left	187	71	10.2	NO
J36	J36-S-Through	583	601	0.7	YES
	J36-E-Left	128	129	0.1	YES
	J36-E-Right	158	102	4.9	YES
	J36-N-Through	382	371	0.6	YES
J37	J37-E-Through	176	139	3	YES
	J37-E-Right	197	123	5.9	NO
	J37-S-Through	178	211	2.4	YES
	J37-S-Left	78	98	2.1	YES
J38	J38-W-Through	155	106	4.3	YES
	J38-S-Through	134	166	2.6	YES
	J38-W-Left	120	98	2.1	YES
	J38-S-Right	262	167	6.5	NO
J39	J39-E-Through	101	42	7	NO
	J39-S-Through	222	211	0.7	YES
	J39-E-Right	68	34	4.8	YES
	J39-S-Right	127	53	7.9	NO
J40	J40-E-Through	476	512	1.6	YES
	J40-W-Through	434	446	0.6	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J40-S-Left	169	128	3.4	YES
	J40-S-Right	125	114	1	YES
J41	J41-N-Right	57	0	10.7	NO
	J41-E-Right	149	0	17.3	NO
	J41-W-Left	37	0	8.6	NO
	J41-W-Through	749	676	2.7	YES
	J41-E-Through	474	522	2.1	YES
	J41-N-Left	158	186	2.1	YES
J42	J42-E-Left	26	30	0.8	YES
	J42-W-Right	269	276	0.4	YES
	J42-W-Through	545	586	1.7	YES
	J42-E-Through	567	522	1.9	YES
J43	J43-E-Through	50	46	0.5	YES
	J43-N-Right	88	30	7.5	NO
	J43-N-Through	287	275	0.7	YES
	J43-E-Left	43	0	9.3	NO
J44	J44-N-Through	245	219	1.7	YES
	J44-W-Through	139	201	4.7	YES
	J44-W-Right	148	71	7.3	NO
	J44-N-Left	87	55	3.9	YES
J45	J45-E-Through	217	263	2.9	YES
	J45-N-Through	222	291	4.3	YES
	J45-N-Right	174	0	18.7	NO
	J45-E-Left	136	140	0.3	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
J46	J46-S-Through	213	202	0.8	YES
	J46-E-Through	244	250	0.4	YES
	J46-E-Right	229	230	0.1	YES
	J46-S-Left	84	153	6.4	NO
J47	J47-S-Through	371	361	0.5	YES
	J47-W-Through	123	117	0.6	YES
	J47-W-Left	110	138	2.5	YES
	J47-S-Right	68	70	0.3	YES
J48	J48-S-Left	84	46	4.7	YES
J49	J49-E-Through	406	365	2.1	YES
	J49-W-Through	563	585	0.9	YES
	J49-S-Left	196	197	0.1	YES
	J49-S-Right	247	254	0.4	YES
J50	J50-W-Through	614	585	1.2	YES
	J50-W-Left	8	0	4	YES
	J50-E-Right	17	6	3.1	YES
J51	J51-E-Left	159	84	6.8	NO
	J51-W-Right	151	142	0.8	YES
	J51-W-Through	667	697	1.2	YES
	J51-E-Through	400	366	1.7	YES
J52	J52-N-Through	243	274	1.9	YES
	J52-W-Through	85	105	2.1	YES
	J52-W-Right	105	82	2.4	YES
	J52-N-Left	66	187	10.8	NO

Junction	Approach	Observed	Modelled	GEH	GEH<5
J53	J53-N-Through	180	182	0.1	YES
	J53-E-Through	300	308	0.4	YES
	J53-E-Left	158	161	0.2	YES
	J53-N-Right	174	173	0.1	YES
J54	J54-E-Through	153	133	1.6	YES
	J54-S-Left	310	337	1.5	YES
J55	J55-S-Through	931	1072	4.5	YES
	J55-N-Through	1420	1448	0.7	YES
	J55-S-Left	58	35	3.4	YES
	J55-N-Right	79	99	2.1	YES
J56	J56-S-Through	1092	1067	0.8	YES
	J56-N-Through	1456	1446	0.3	YES
	J56-W-Left	168	187	1.4	YES
	J56-W-Right	67	105	4.1	YES
J57	J57-N-Through	1415	1401	0.4	YES
	J57-N-Left	77	57	2.5	YES
	J57-E-Left	149	99	4.5	YES
J58	J58-N-Through	1433	1360	1.9	YES
	J58-N-Through	1433	1404	0.8	YES
	J58-N-Through	1433	1404	0.8	YES
	J58-N-Right	643	687	1.7	YES
	J58-S-Left	1276	1244	0.9	YES
J59	J59-W-Left	726	697	1.1	YES
	J59-E-Right	1490	1475	0.4	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
J60	J60-E-Left	138	149	0.9	YES
	J60-N-Through	2019	1943	1.7	YES
	J60-N-Left	400	352	2.5	YES
J61	J61-S-Through	2104	2042	1.4	YES
J62	J62-N-Through	2078	2202	2.7	YES
	J62-N-Left	96	118	2.1	YES
	J62-E-Left	193	101	7.5	NO
J63	J63-S-Through	1836	1752	2	YES
	J63-S-Right	461	473	0.6	YES
	J63-N-Left	1848	1869	0.5	YES
J64	J64-N-Through	1733	1599	3.3	YES
	J64-S-Through	1705	1748	1	YES
	J64-W-Left	170	183	1	YES
J65	J65-W-Through	193	176	1.2	YES
	J65-W-Right	6	0	3.5	YES
	J65-S-Right	5	6	0.5	YES
J66	J66-W-Through	129	123	0.5	YES
	J66-N-Left	37	54	2.5	YES
	J66-N-Through	137	88	4.6	YES
	J66-W-Right	129	107	2	YES
J67	J67-N-Through	166	186	1.5	YES
	J67-W-Right	30	0	7.7	NO
	J67-N-Right	26	36	1.7	YES
J68	J68-N-Through	343	305	2.1	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J68-S-Through	997	878	3.9	YES
	J68-N-Left	80	105	2.6	YES
	J68-S-Right	131	126	0.4	YES
J69	J69-S-Through	697	646	2	YES
	J69-W-Right	91	80	1.2	YES
	J69-W-Left	312	359	2.6	YES
J70	J70-N-Through	322	232	5.4	NO
	J70-S-Through	614	537	3.2	YES
	J70-E-Left	27	0	7.3	NO
	J70-E-Right	99	35	7.9	NO
	J70-S-Right	12	0	4.9	YES
	J70-N-Left	109	131	2	YES
J71	J71-N-Through	138	152	1.2	YES
	J71-N-Right	112	137	2.2	YES
	J71-N-Left	122	139	1.5	YES
	J71-W-Right	66	49	2.2	YES
	J71-W-Through	260	302	2.5	YES
J72	J72-W-Right	563	558	0.2	YES
	J72-W-Through	312	317	0.3	YES
	J72-W-Left	63	66	0.4	YES
	J72-N-Left	15	36	4.2	YES
	J72-N-Through	147	171	1.9	YES
J74	J74-E-Through	939	984	1.4	YES
	J74-E-left	115	68	4.9	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	J74-S-left	296	235	3.7	YES
J75	J75-E-Right	343	316	1.5	YES
	J75-E-Through	813	858	1.6	YES
	J75-W-Through	891	867	0.8	YES
	J75-W-Left	283	260	1.4	YES
	J75-E-Left	66	44	3	YES
	J75-S-Left	6	0	3.5	YES
Proportion of Turns with GEH < 5 - 85%					

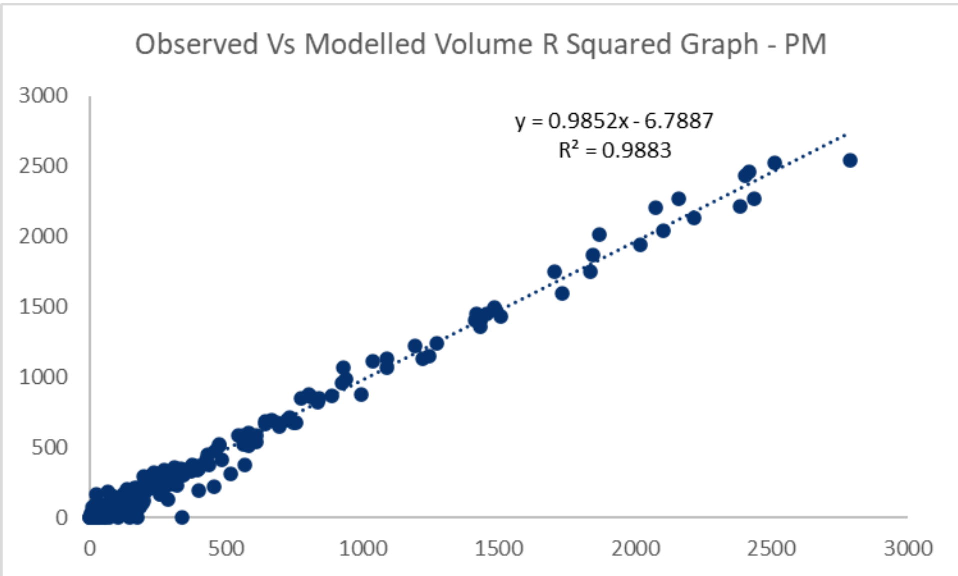


Figure 5-23 R-Squared Graph for PM after Turn Volume Calibration

It can be observed from both the GEH values as well as R Squared analysis that, the obtained model is calibrated for turn volumes.

Table 5-11 PCU Matrix AM Peak

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
1	0	0	8	0	1	1	1	0	135	0	0	0	1	2	0	0	0	0	1	0	0	1	1	9	0	6	6	0	0	0	0	1	1	0	0	0	1	1	1	1	0	1	1	1	0	1	0	1	0	1	0
2	1	1	1	1	1	1	1	12	181	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	0	0	0	0	1	0	0	0	40	0	0	1	1	1	0	1	0	0	1	0	7	1	0	0	1	0	0	0	3	0	0	1	1	1	0	0	0	1	1	1	0	1	0	0	0	0	0	1	0	1	1
4	0	0	1	0	1	20	0	0	85	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	0	0	1	0	0	1	0	0	0
5	0	0	1	0	1	1	0	0	62	0	0	1	1	1	0	0	0	0	1	0	0	1	1	0	1	0	0	0	0	0	0	1	23	1	0	0	1	1	1	1	0	1	101	0	0	1	0	1	0	1	0
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	0	0	0	0	1	1	1	0	52	0	0	0	1	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	0	1	1	1	1	0	0	1	0	1	0
8	15	0	1	0	1	4	0	0	14	0	0	0	1	0	0	0	0	0	1	1	0	1	0	24	8	21	21	0	1	0	0	1	45	0	0	0	0	1	1	1	0	1	1	1	1	1	0	1	8	1	0
9	140	0	148	1	1	125	24	2	13	69	30	25	1	43	38	88	36	110	1	48	97	1	1	148	134	146	146	9	75	88	12	1	1	15	33	71	36	1	1	1	104	1	1	33	1	1	67	1	134	1	31
10	0	0	0	1	1	1	0	0	16	0	4	8	1	26	0	19	4	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	2	2	0	1	1	1	3	1	1	0	1	1	0	1	0	0	0
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	0	0	1	1	1	0	0	0	0	0	5	38	1	18	6	0	6	1	1	1	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	28	0	0	0	0	1	0	4	0
13	0	0	1	0	1	0	1	0	48	9	36	40	1	58	24	74	35	1	1	1	0	1	0	0	0	0	0	0	1	16	0	1	2	13	32	35	1	1	1	1	33	1	1	0	1	0	0	1	2	0	0
14	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	40	1	1	0	1	19	1	1	1	15	1	1	1	1	1	3	1	0	0	1	1	1	0	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	0	0	108	0	1	1	1	0	36	2	25	49	1	67	1	15	84	0	1	10	0	1	36	0	0	0	1	0	1	28	21	1	69	244	10	3	45	57	54	1	114	1	48	41	22	0	0	1	0	22	54
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	0	1	0	0	1	0	0	1	40	1	1	76	1	0	0	1	0	0	1	1	7	1	91	1	1	1	0	1	3	1	0	1	0	1	1	1	0	1	1	1	0	1	1	0	0	0	1	1	1	0	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	204	1	1	1	1	1	1	1	0	1	1	1	0	0	1	0	0	1	1	9	1	1	1	1	0	1	1	3	1	18	1	1	10	1	0	1	1	1	1	1	1	1	1	1	168	1	1	1	1	0
23	1	1	1	13	1	1	1	1	29	1	1	1	1	0	1	1	10	1	1	1	1	1	1	1	1	1	1	20	170	1	2	1	3	1	1	1	1	1	1	1	1	1	2	1	0	0	1	1	1	0	1
24	0	0	2	1	1	1	1	0	39	1	1	1	1	1	1	1	1	80	1	0	0	1	1	1	1	1	1	1	0	1	1	1	23	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
25	1	1	1	1	1	1	1	1	9	1	1	1	1	6	1	1	1	48	1	1	0	1	27	13	22	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
26	1	0	1	0	1	0	1	0	42	1	1	1	1	0	1	1	1	82	1	1	0	1	1	3	1	1	1	0	0	1	1	1	1	28	1	1	1	1	1	1	3	1	103	1	1	1	1	1	1	1	1
27	1	1	3	1	1	0	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1	3	1	1	0	1	0	0	0	1	1	0	1	1	0	1	1	1	1	1	103	1	1	0	1	1	1	1	1
28	0	0	0	0	1	1	1	0	22	1	1	1	1	0	1	1	0	63	1	0	0	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
29	1	0	4	1	1	0	1	0	41	1	1	1	1	0	0	0	25	57	1	0	1	1	1	0	1	0	0	1	1	0	13	1	35	2	0	1	11	1	1	1	2	1	12	10	0	0	0	1	0	0	25
30	0	0	59	0	1	0	1	0	0	0	4	0	1	0	0	0	19	1	1	1	0	1	0	0	0	0	0	0	1	0	0	1	0	2	0	20	0	1	1	1	0	1	0	0	0	0	0	1	5	0	0
31	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	1	1	152	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	2	1	0	0	0	0	0	1	0	0	0
32	1	1	1	1	1	1	1	1	1	1	1	0	1	0	13	23	27	3	1	0	1	67	25	1	1	1	1	0	1	2	0	1	47	6	1	1	23	1	1	1	13	1	23	21	0	4	1	1	1	0	0
33	0	1	0	1	1	0	1	1	1	1	0	1	1	69	0	0	7	4	1	0	1	67	1	0	11	0	0	36	1	41	0	1	27	0	0	0	0	1	1	1	1	1	105	0	0	0	1	1	0	0	0
34	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35	0	0	1	1	1	0	1	0	4	0	0	0	1	9	0	0	3	1	1	1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	0	19	1	1	0	1	0	1	0
36	0	0	1	1	1	0	0	0	13	0	3	6	1	24	0	0	2	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1	2	1	1	35	1	0	0	1	0	0	0
37	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	1	1	1	0	1	45	0	0	0	1	1	1	0	0
38	0	0	0	0	1	1	1	0	0	0	0	1	1	0	0	0	28	0	1	0	1	1	0	0	0	0	0	0	1	0	0	1	0	7	0	0	0	1	1	1	58	1	1	0	0	0	0	1	0	0	1
39	0	0	1	0	1	0	1	0	0	0	0	3	1	0	0	0	36	14	1	0	0	75	0	0	0	0	0	0	1	0	0	1	21	15	0	0	1	1	1	1	0	1	0	0	0	0	0	1	0	0	0
40	0	0	0	0	1	0	0	0	0	0	0	5	1	0	0	0	17	1	1	1	0	1	3	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	1	1	72	1	8	29	0	0	2	1	40	0	10
41	0	0	0	1	1	1	1	0	15	0	3	0	1	0	0	0	17	36	1	1	1	1	0	0	0	0	0	0	53	3	21	1	0	2	0	42	0	1	1	1	19	1	49	0	0	0	3	1	4	0	29
42	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0	0	1	0	0	0	1	0	36	1	0	0	0	0	0	1	1	1	34	1	34	0	0	0	0	1	0	0	0
43	73	27	168	123	1	1	44	42	1	1	0	1	1	2	0	0	84	11	1	69	1	78	0	0	0	0	0	34	1	9	0	1	103	63	0	0	0	1	1	1	65	1	181	103	41	82	0	1	1	41	1
44	1	0	24	1	1	1	0	1	1	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	1	0	1	1	0	0	1	0	30	0	1	0	1	1	1	0	1	38	0	0	0	0	1	1	0	0
45	0	1	12	0	1	1	0	1	1	0	0	1	1	0	0	0	0	0	1	1	19	0	0	1	0	0	1	0	3	0	0	1	0	0	0	1	0	1	1	1	0	1	27	0	0	1	1	1	0	1	0
46	1	0	0	0	1	0	0	0	36	1	0	76	1	0	1	0	5	0	1	0	7	1	1	0	1	1	0	0	3	4	0	1	23	0	0	0	0	1	1	1	0	1	101	0	0	0	1	1	0	0	22
47	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	48	0	0	0	0	1	0	0	0
48	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
49	6	0	14	1	1	1	1	0	0	0	0	0	1	7	0	0	0	1	1	0	0	1	1	15	2	12	12	0	0	0	0	1	1	0	0	0	0	1	1	1	0	1	115	1	1	0	0	1	0	1	0
50	0	0	0	1	1	0	1	0	1	1	1	1	1	1	17	0	2	0	1	0	7	1	1	0	1	0	1	0	1	0	0	1	23	0	0	1	0	1	1	1	0	1	101	0	0	1	1	1	1	0	0
51	0	0	0	1	1	0	0	0	0	0	13	0	1	0	0	0	0	7	1	1	1	1	0	0	0	0	0	0	1	0	0	1	13	0	0	10	0	1	1	1	73	1	7	0	0	0	0	1	1	0	0

Table 5-12 PCU Matrix AM Peak

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
1	0	0	0	0	0	0	0	0	339	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0
2	0	0	0	0	0	0	0	9	410	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	71	0	0	0	0	175	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	115	0	0	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	6	0	0	0	0	44	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
9	81	0	0	0	0	122	0	5	0	35	8	9	0	23	22	87	58	100	0	0	0	0	0	85	44	24	75	0	7	81	11	0	0	14	28	4	0	0	0	0	152	0	0	0	0	0	0	0	80	0	9
10	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	61	79	0	9	25	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0	0	0	0	58	0
13	0	0	0	0	0	0	0	0	0	20	57	47	0	64	6	74	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	25	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66	0	0	0	0	7	0	0	0	100	0	0	0	0	0	0	12	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	239	0	0	0	0	0	18	0	16	30	0	47	0	0	62	0	0	55	0	0	13	0	0	0	0	0	0	8	0	0	2	248	31	0	0	37	63	0	123	0	14	50	0	0	0	0	0	0	19
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	175	0	0	98	0	0	0	0	0	0	0	0	0	0	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	226	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	1	0	0	29	0	0	0	0	0	0	0	0	454	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	35	0	0	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	125	0	26	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	79	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	71	0	0	0	0	0	0	0	0	0	0	0	0	0	40	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	88	0	0	0	0	0	0	0	0	20	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	16	0	60	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
29	0	0	0	0	0	0	0	0	41	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	28	0	49	56	0	0	11	0	0	0	10	0	0	0	0	0	0	0	0	0	90
30	0	0	59	0	0	0	0	0	0	0	44	0	0	0	0	0	176	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	181	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	58	1	4	0	0	0	94	45	0	0	0	0	0	0	0	0	0	45	0	0	0	7	0	0	0	61	0	6	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	53	0	0	27	0	0	0	0	96	0	0	1	0	0	47	0	65	0	0	2	0	0	0	0	0	0	0	3	0	146	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	39	0	0	0	0	30	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	69	0	5	2	0	11	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	0	0	9	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	179	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	46	0	0	0	0	78	2	0	0	0	35	0	0	0	0	0	0	0	0	0	0	7	32	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	88	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	43	0	0	0	0	0	0	116	0	8	25	0	0	0	0	99	0	5
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	42	0	0	0	0	0	0	0	0	0	0	71	2	23	0	0	0	0	110	0	0	0	0	17	0	61	0	0	0	0	0	0	0	30
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69	0	0	0	0	0	0	0	0	0	15	0	51	0	0	0	0	0	0	0	0
43	29	108	0	212	0	0	123	0	367	0	0	0	0	0	0	0	100	0	0	10	0	58	0	0	0	0	0	38	0	0	0	0	70	54	0	0	0	0	0	0	63	0	216	0	170	0	0	0	0	170	0
44	0	0	154	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122	0	0	0	0	0	0	0	0	185	0	0	0	0	0	0	0	0
45	0	0	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	252	0	0	98	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	147	0	0	0	0	0	0	0	14
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	5	0	0	0	0	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	147	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	147	0	35	0	0	0	0	0	0	0	0

5.8.2 Queue Length Comparison

Comparison of queue length between the observed and modelled is done and is presented in the tables below.

Table 5-13 Queue Length Results-Base AM

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
1	J1-W-Left	13	0	35	J35-N-Left	19	0
	J1-E-Through	17	0		J35-N-Through	19	0
	J1-E-Right	17	0		J35-N-Right	37	0
2	J2-W-Left	34	0		J35-S-Left	21	0
	J2-W-Through	34	0		J35-S-Through	21	0
	J2-N-Left	12	0		J35-S-Right	21	0
3	J3-W-Left	0	0	36	J36-N-Through	54	0
	J3-W-Through	0	0		J36-E-Left	23	5
	J3-N-Left	12	5		J36-E-Right	23	5
4	J4-W-Left	85	0		J36-S-Through	0	0
	J4-W-Through	85	0	37	J37-E-Through	6	0
	J4-N-Left	0	0		J37-E-Right	6	0
	J4-E-Through	52	0		J37-S-Left	6	0
5	J5-W-Left	43	0		J37-S-Through	6	0
	J5-W-Through	43	0	38	J38-W-Left	17	5
	J5-N-Left	11	5		J38-W-Through	18	5
	J5-E-Through	27	15		J38-S-Through	11	0
	J5-S-Left	0	0		J38-S-Right	11	0
6	J6-W-Left	56	0	39	J39-E-Through	6	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	J6-W-Through	56	0		J39-E-Right	6	0
	J6-W-Right	56	0		J39-S-Left	12	0
	J6-E-Left	45	0		J39-S-Through	12	0
	J6-E-Through	45	0	40	J40-W-Through	37	0
	J6-E-Right	45	0		J40-E-Through	43	0
	J6-S-Left	0	0		J40-S-Left	12	5
	J6-S-Through	56	0		J40-S-Right	20	5
	J6-S-Right	0	0	41	J41-W-Left	71	0
7	J7-W-Through	92	0		J41-W-Through	71	0
	J7-N-Left	58	5		J41-N-Left	13	5
	J7-N-Right	58	5		J41-N-Right	13	5
	J7-E-Through	6	0		J41-E-Through	0	0
8	J8-W-Through	37	0		J41-E-Right	0	0
	J8-W-Right	61	0	42	J42-W-Through	22	0
	J8-E-Left	0	0		J42-W-Right	26	0
	J8-E-Through	0	0		J42-E-Left	15	0
	J8-S-Left	0	0		J42-E-Through	16	0
	J8-S-Right	12	0	43	J43-N-Through	0	0
9	J9-W-Left	18	0		J43-N-Right	6	0
	J9-W-Through	18	0		J43-E-Through	0	0
	J9-N-Left	41	5		J43-E-Right	6	0
	J9-E-Through	0	0	44	J44-W-Through	12	0
10	J10-E-Left	0	0		J44-W-Right	12	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	J10-E-Through	0	0		J44-N-Left	23	0
	J10-E-Right	0	0		J44-N-Through	23	0
	J10-S-Left	18	0	45	J45-N-Through	17	0
	J10-S-Through	18	0		J45-N-Right	17	0
11	J11-N-Through	24	0		J45-E-Left	17	5
	J11-N-Right	7	0		J45-E-Through	17	5
	J11-E-Left	0	0	46	J46-E-Through	12	0
	J11-E-Through	0	0		J46-E-Right	12	0
12	J12-E-Through	0	0		J46-S-Left	30	5
	J12-E-Right	0	0		J46-S-Through	30	5
	J12-S-Left	23	0	47	J47-W-Left	11	5
	J12-S-Through	23	0		J47-W-Through	12	5
13	J13-N-Left	111	0		J47-S-Through	0	0
	J13-N-Through	111	0		J47-S-Right	0	0
	J13-N-Right	111	0	48	J48-S-Left	0	0
	J13-S-Left	19	0	49	J49-W-Through	42	0
	J13-S-Through	17	0		J49-E-Through	12	0
	J13-S-Right	20	0		J49-S-Left	50	0
14	J14-W-Through	32	0		J49-S-Right	50	0
	J14-W-Right	0	0	50	J50-W-Left	0	0
	J14-S-Right	11	0		J50-W-Through	0	0
15	J15-W-Left	11	0		J50-E-Right	18	0
	J15-W-Right	6	0	51	J51-W-Through	59	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	J15-N-Through	0	0		J51-W-Right	74	0
	J15-S-Through	11	0		J51-E-Left	0	0
16	J16-W	100	5		J51-E-Through	0	0
	J16-N	52	5	52	J52-W-Through	0	0
	J16-E	6	0		J52-W-Right	6	0
17	J17-W-Through	0	0		J52-N-Left	27	0
	J17-S-Left	62	0		J52-N-Through	0	0
	J17-S-Right	62	0	53	J53-E-Left	42	0
18	J18-W-Left	11	0		J53-E-Through	42	0
	J18-W-Through	29	0		J53-N-Through	6	0
	J18-E-Through	32	0		J53-N-Right	6	0
	J18-E-Right	32	0	54	J54-E-Through	12	0
19	J19-W-Through	47	0		J54-S-Left	15	0
	J19-N-Left	48	0	55	J55-N-Through	37	0
	J19-E-Through	52	0		J55-N-Right	37	0
20	J20-W-Left	14	0		J55-S-Left	0	0
	J20-W-Through	8	0		J55-S-Through	0	0
	J20-W-Right	7	0	56	J56-W-Left	41	0
	J20-E-Left	12	0		J56-W-Right	42	0
	J20-E-Through	16	0		J56-N-Through	27	0
	J20-E-Right	18	0		J56-S-Through	31	0
	J20-S-Left	26	0	57	J57-N-Left	6	0
	J20-S-Through	25	0		J57-N-Through	0	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	J20-S-Right	23	0		J57-E-Left	0	0
21	J21-W-Through	0	0	58	J58-N-Through	35	0
	J21-W-Right	0	0		J58-N-Right	59	0
	J21-N-Left	14	0		J58-S-Left	58	0
	J21-N-Through	12	0	59	J59-W-Left	13	0
	J21-N-Right	12	0		J59-E-Right	42	0
	J21-E-Left	0	0	60	J60-N-Left	66	0
	J21-E-Through	0	0		J60-N-Through	66	0
	J21-S-Left	29	0		J60-E-Left	18	0
	J21-S-Right	30	0	61	J61-S-Through	19	0
	J21-S-U-turn	30	0	62	J62-N-Left	174	0
22	J22-W-Left	88	0		J62-N-Through	174	0
	J22-W-Through	88	0		J62-E-Left	14	0
	J22-E-Through	73	0	63	J63-N-Left	17	0
23	J23-W-Left	70	15		J63-S-Through	0	0
	J23-W-Through	70	15		J63-S-Right	0	0
	J23-W-Right	70	15	64	J64-W-Left	0	10
	J23-N-Left	63	20		J64-N-Through	0	0
	J23-N-Through	63	20		J64-S-Through	0	0
	J23-E-Left	83	10	65	J65-W-Through	0	0
	J23-E-Right	83	10		J65-W-Right	0	0
	J23-S-Through	119	10		J65-S-Right	6	0
	J23-S-Right	119	10	66	J66-W-Through	6	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
25	J25-W-Left	0	0		J66-W-Right	6	0
	J25-W-Through	0	0		J66-N-Left	6	0
	J25-S-Through	15	0		J66-N-Through	6	0
	J25-S-Right	14	0	67	J67-W-Right	0	0
26	J26-W-Through	0	0		J67-N-Through	0	0
	J26-W-Right	0	0		J67-N-Right	0	0
	J26-N-Left	8	0	68	J68-N-Left	12	0
	J26-N-Through	8	0		J68-N-Through	12	0
27	J27-W-Left	0	0		J68-S-Through	28	0
	J27-W-Through	0	0		J68-S-Right	28	0
	J27-S-Through	25	0	69	J69-W-Left	31	0
	J27-S-Right	24	0		J69-W-Right	31	0
28	J28-W-Left	0	0		J69-S-Through	38	0
	J28-E-Through	6	0	70	J70-N-Left	12	0
	J28-E-Right	6	0		J70-N-Through	12	0
	J28-S-Left	0	0		J70-E-Left	21	0
	J28-S-Through	0	0		J70-E-Right	19	0
30	J30-E-Left	6	0		J70-S-Through	33	0
	J30-E-Right	6	0		J70-S-Right	31	0
31	J31-N-Right	6	0	71	J71-W-Through	17	0
	J31-E-Through	0	0		J71-W-Right	16	0
	J31-S-Left	6	0		J71-N-Left	5	0
32	J32-N-Left	19	0		J71-N-Through	0	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	J32-E-Through	0	0		J71-N-Right	0	0
	J32-E-Right	0	0	72	J72-W-Left	17	0
33	J33-N-Left	5	0		J72-W-Through	17	0
34	J34-W-Left	81	0		J72-W-Right	17	0
	J34-W-Through	81	0		J72-N-Left	40	0
	J34-W-Right	81	0		J72-N-Through	40	0
	J34-N-Left	96	0	74	J74-E-Left	0	0
	J34-N-Through	96	0		J74-E-Through	0	0
	J34-N-Right	96	0		J74-S-Left	12	0
	J34-E-Left	106	0	75	J75-W-Left	15	0
	J34-E-Through	106	0		J75-W-Through	15	0
	J34-E-Right	106	0		J75-E-Left	20	0
	J34-S-Left	69	0		J75-E-Through	20	0
	J34-S-Through	69	0		J75-E-Right	43	0
	J34-S-Right	69	0		J75-S-Left	0	0

Table 5-14 Queue Length Results-Base PM

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
1	J1-W-Left	0	0	35	J35-N-Left	43	0
	J1-E-Through	46	0		J35-N-Through	43	0
	J1-E-Right	46	0		J35-N-Right	60	0
2	J2-W-Left	29	0		J35-S-Left	55	0
	J2-W-Through	29	0		J35-S-Through	55	0
	J2-N-Left	6	0		J35-S-Right	55	0
3	J3-W-Left	0	0	36	J36-N-Through	85	0
	J3-W-Through	0	0		J36-E-Left	54	10
	J3-N-Left	12	5		J36-E-Right	54	10
4	J4-W-Left	55	0		J36-S-Through	12	0
	J4-W-Through	55	0	37	J37-E-Through	6	0
	J4-N-Left	0	0		J37-E-Right	6	0
	J4-E-Through	51	0		J37-S-Left	25	10
5	J5-W-Left	30	25		J37-S-Through	24	10
	J5-W-Through	30	25	38	J38-W-Left	36	10
	J5-N-Left	6	20		J38-W-Through	36	10
	J5-E-Through	71	55		J38-S-Through	15	0
	J5-S-Left	0	0		J38-S-Right	15	0
6	J6-W-Left	18	20	39	J39-E-Through	11	10
	J6-W-Through	18	20		J39-E-Right	11	10
	J6-W-Right	18	20		J39-S-Left	22	0
	J6-E-Left	154	0		J39-S-Through	22	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	J6-E-Through	154	0	40	J40-W-Through	29	0
	J6-E-Right	154	0		J40-E-Through	59	0
	J6-S-Left	0	0		J40-S-Left	36	3
	J6-S-Through	18	0		J40-S-Right	45	3
	J6-S-Right	0	0	41	J41-W-Left	90	15
7	J7-W-Through	9	0		J41-W-Through	81	15
	J7-N-Left	51	25		J41-N-Left	45	20
	J7-N-Right	51	25		J41-N-Right	44	20
	J7-E-Through	58	0		J41-E-Through	16	0
8	J8-W-Through	0	0		J41-E-Right	21	0
	J8-W-Right	20	0	42	J42-W-Through	22	15
	J8-E-Left	0	0		J42-W-Right	34	15
	J8-E-Through	0	0		J42-E-Left	72	0
	J8-S-Left	20	10		J42-E-Through	72	0
	J8-S-Right	41	10	43	J43-N-Through	0	0
9	J9-W-Left	11	0		J43-N-Right	0	0
	J9-W-Through	11	0		J43-E-Through	0	0
	J9-N-Left	51	25		J43-E-Right	6	0
	J9-E-Through	0	0	44	J44-W-Through	17	0
10	J10-E-Left	0	0		J44-W-Right	17	0
	J10-E-Through	0	0		J44-N-Left	18	0
	J10-E-Right	0	0		J44-N-Through	18	0
	J10-S-Left	23	0	45	J45-N-Through	6	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	J10-S-Through	23	0		J45-N-Right	6	0
11	J11-N-Through	12	0		J45-E-Left	6	10
	J11-N-Right	12	0		J45-E-Through	6	10
	J11-E-Left	0	0	46	J46-E-Through	11	0
	J11-E-Through	0	0		J46-E-Right	11	0
12	J12-E-Through	0	0		J46-S-Left	29	10
	J12-E-Right	0	0		J46-S-Through	29	10
	J12-S-Left	24	0	47	J47-W-Left	18	10
	J12-S-Through	24	0		J47-W-Through	18	10
13	J13-N-Left	82	0		J47-S-Through	0	0
	J13-N-Through	82	0		J47-S-Right	0	0
	J13-N-Right	82	0	48	J48-S-Left	17	0
	J13-S-Left	60	0	49	J49-W-Through	14	0
	J13-S-Through	68	0		J49-E-Through	6	0
	J13-S-Right	61	0		J49-S-Left	59	35
14	J14-W-Through	25	0		J49-S-Right	59	35
	J14-W-Right	0	0	50	J50-W-Left	0	0
	J14-S-Right	11	0		J50-W-Through	0	0
15	J15-W-Left	37	0		J50-E-Right	52	0
	J15-W-Right	37	0	51	J51-W-Through	31	5
	J15-N-Through	6	0		J51-W-Right	46	5
	J15-S-Through	6	0		J51-E-Left	0	0
16	J16-W	99	10		J51-E-Through	0	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	J16-N	181	20	52	J52-W-Through	0	0
	J16-E	4	0		J52-W-Right	6	0
17	J17-W-Through	0	0		J52-N-Left	26	0
	J17-S-Left	57	0		J52-N-Through	13	0
	J17-S-Right	57	0	53	J53-E-Left	25	5
18	J18-W-Left	5	0		J53-E-Through	25	5
	J18-W-Through	23	0		J53-N-Through	0	0
	J18-E-Through	24	0		J53-N-Right	6	0
	J18-E-Right	24	0	54	J54-E-Through	11	0
19	J19-W-Through	54	0		J54-S-Left	17	5
	J19-N-Left	33	0	55	J55-N-Through	65	0
	J19-E-Through	52	0		J55-N-Right	65	0
20	J20-W-Left	28	0		J55-S-Left	99	0
	J20-W-Through	22	0		J55-S-Through	99	0
	J20-W-Right	22	0	56	J56-W-Left	46	5
	J20-E-Left	22	0		J56-W-Right	47	5
	J20-E-Through	26	0		J56-N-Through	35	0
	J20-E-Right	29	0		J56-S-Through	84	0
	J20-S-Left	13	0	57	J57-N-Left	16	0
	J20-S-Through	12	0		J57-N-Through	0	0
	J20-S-Right	10	0		J57-E-Left	21	0
21	J21-W-Through	0	0	58	J58-N-Through	37	0
	J21-W-Right	5	0		J58-N-Right	60	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	J21-N-Left	28	0		J58-S-Left	71	0
	J21-N-Through	26	0	59	J59-W-Left	37	0
	J21-N-Right	26	0		J59-E-Right	88	0
	J21-E-Left	0	0	60	J60-N-Left	83	0
	J21-E-Through	0	0		J60-N-Through	83	0
	J21-S-Left	15	0		J60-E-Left	56	10
	J21-S-Right	16	0	61	J61-S-Through	0	30
	J21-S-U-turn	16	0	62	J62-N-Left	157	30
22	J22-W-Left	93	0		J62-N-Through	157	30
	J22-W-Through	93	0		J62-E-Left	140	10
	J22-E-Through	92	0	63	J63-N-Left	57	0
23	J23-W-Left	71	25		J63-S-Through	8	0
	J23-W-Through	71	25		J63-S-Right	8	0
	J23-W-Right	71	25	64	J64-W-Left	0	20
	J23-N-Left	63	40		J64-N-Through	0	0
	J23-N-Through	63	40		J64-S-Through	0	0
	J23-E-Left	106	40	65	J65-W-Through	0	0
	J23-E-Right	106	40		J65-W-Right	0	0
	J23-S-Through	105	40		J65-S-Right	0	0
	J23-S-Right	105	40	66	J66-W-Through	23	0
25	J25-W-Left	22	0		J66-W-Right	23	0
	J25-W-Through	22	0		J66-N-Left	6	10
	J25-S-Through	23	10		J66-N-Through	6	10

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	J25-S-Right	22	10	67	J67-W-Right	0	0
26	J26-W-Through	0	0		J67-N-Through	0	0
	J26-W-Right	0	0		J67-N-Right	0	0
	J26-N-Left	13	0	68	J68-N-Left	10	0
	J26-N-Through	13	0		J68-N-Through	10	0
27	J27-W-Left	0	0		J68-S-Through	32	0
	J27-W-Through	0	0		J68-S-Right	32	0
	J27-S-Through	56	0	69	J69-W-Left	36	20
	J27-S-Right	55	0		J69-W-Right	36	20
28	J28-W-Left	6	0		J69-S-Through	47	0
	J28-E-Through	17	0	70	J70-N-Left	24	0
	J28-E-Right	17	0		J70-N-Through	24	0
	J28-S-Left	0	0		J70-E-Left	14	0
	J28-S-Through	0	0		J70-E-Right	12	0
30	J30-E-Left	0	0		J70-S-Through	80	0
	J30-E-Right	6	0		J70-S-Right	74	0
31	J31-N-Right	12	5	71	J71-W-Through	34	0
	J31-E-Through	6	0		J71-W-Right	33	0
	J31-S-Left	11	5		J71-N-Left	6	0
32	J32-N-Left	72	0		J71-N-Through	0	0
	J32-E-Through	35	0		J71-N-Right	0	0
	J32-E-Right	35	0	72	J72-W-Left	0	0
33	J33-N-Left	23	5		J72-W-Through	0	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
34	J34-W-Left	97	40		J72-W-Right	0	0
	J34-W-Through	97	40		J72-N-Left	35	0
	J34-W-Right	97	40		J72-N-Through	36	0
	J34-N-Left	82	50	74	J74-E-Left	29	0
	J34-N-Through	82	50		J74-E-Through	29	0
	J34-N-Right	82	50		J74-S-Left	24	0
	J34-E-Left	106	25	75	J75-W-Left	0	0
	J34-E-Through	106	25		J75-W-Through	0	0
	J34-E-Right	106	25		J75-E-Left	42	0
	J34-S-Left	88	40		J75-E-Through	42	0
	J34-S-Through	88	40		J75-E-Right	65	0
	J34-S-Right	88	40		J75-S-Left	0	0

From above tables it can inferred that most of modeled queue lengths are matching with observed queue lengths.

5.9 Model Assessment

5.9.1 Assessment Criteria

With the base model fully calibrated through the steps mentioned above, the model is ready to be used as a base for testing the impacts of various traffic measures and proposals.

To show the implications of such impact, there are key measurements that can be taken from the model as assessment criteria. The criterion considered in this study are as follows:

- Delays (Level of Service)
- Queue Lengths
- Vehicle Travel Time

Out of all the assessment criterion, delays / Level of Service is the most commonly used indicator of junction performance.

5.9.2 Delays (Level of Service)

Level of Service (LOS) criteria for delay as per HCM 2010 is shown in table below.

The Highway Capacity Manual (HCM) uses the concept of level of service (LOS) as a qualitative measure to describe operational conditions of vehicular traffic. The criterion for determining LOS at signalized and unsignalized intersections is delay per vehicle, in seconds per vehicle.

Vehicular LOS analysis is based on a scale from A through F, with A representing the best and F representing the worst traveling conditions.

LOS	Controlled Intersections	Uncontrolled Intersections
A	0-10	0-10
B	11-25	11-15
C	26-35	16-25
D	36-55	26-35
E	56-80	36-50
F	>80	>50

Figure 5-24 LOS Criteria

5.9.3 Assessment Result

Delay results obtained from the model for the junctions in study area are shown in tables below.

Table 5-15 Delay Results Base AM Peak

Jn	Movement	Volume	Delay	LOS	Jn	Movement	Volume	Delay	LOS
1	J1-W-Left	1333	1	A	36	J36-N-Through	255	11	B
	J1-E-Through	909	0	A		J36-E-Left	83	11	B
	J1-E-Right	334	0	A		J36-E-Right	68	3	A
	Total	**2576**	**1**	**A**		J36-S-Through	437	0	A
2	J2-W-Left	181	1	A		**Total**	**843**	**5**	**A**
	J2-W-Through	1434	0	A	37	J37-E-Through	113	0	A
	J2-N-Left	53	3	A		J37-E-Right	59	0	A
	Total	**1668**	**1**	**A**		J37-S-Left	41	1	A
3	J3-W-Left	82	0	A		J37-S-Through	109	1	A
	J3-W-Through	1545	5	A		**Total**	**322**	**0**	**A**
	J3-N-Left	70	4	A	38	J38-W-Left	49	2	A
	Total	**1697**	**5**	**A**		J38-W-Through	80	1	A
4	J4-W-Left	31	14	B		J38-S-Through	91	0	A
	J4-W-Through	1557	6	A		J38-S-Right	77	1	A
	J4-N-Left	0	0	A		**Total**	**297**	**1**	**A**
	J4-E-Through	878	2	A	39	J39-E-Through	66	0	A
	Total	**2466**	**5**	**A**		J39-E-Right	34	1	A
5	J5-W-Left	457	1	A		J39-S-Left	41	1	A
	J5-W-Through	1509	1	A		J39-S-Through	99	1	A
	J5-N-Left	86	8	A		**Total**	**240**	**1**	**A**
	J5-E-Through	814	0	A	40	J40-W-Through	455	2	A
	J5-S-Left	51	1	A		J40-E-Through	283	3	A

Jn	Movement	Volume	Delay	LOS	Jn	Movement	Volume	Delay	LOS
	Total	**2917**	**1**	**A**		J40-S-Left	58	2	A
6	J6-W-Left	161	1	A		J40-S-Right	75	8	A
	J6-W-Through	2096	2	A		**Total**	**871**	**3**	**A**
	J6-W-Right	0	0	A	41	J41-W-Left	0	0	A
	J6-E-Left	0	0	A		J41-W-Through	627	5	A
	J6-E-Through	842	1	A		J41-N-Left	150	4	A
	J6-E-Right	92	43	D		J41-N-Right	0	0	A
	J6-S-Left	0	0	A		J41-E-Through	288	0	A
	J6-S-Through	0	1	A		J41-E-Right	0	0	A
	J6-S-Right	0	0	A		**Total**	**1065**	**4**	**A**
	Total	**3191**	**3**	**A**	42	J42-W-Through	499	0	A
7	J7-W-Through	2173	3	A		J42-W-Right	278	1	A
	J7-N-Left	86	10	A		J42-E-Left	29	0	A
	J7-N-Right	172	28	C		J42-E-Through	288	0	A
	J7-E-Through	842	0	A		**Total**	**1094**	**0**	**A**
	Total	**3273**	**4**	**A**	43	J43-N-Through	277	0	A
8	J8-W-Through	2314	3	A		J43-N-Right	29	0	A
	J8-W-Right	2	1	A		J43-E-Through	71	0	A
	J8-E-Left	50	0	A		J43-E-Right	0	1	A
	J8-E-Through	931	0	A		**Total**	**377**	**0**	**A**
	J8-S-Left	14	0	A	44	J44-W-Through	103	0	A
	J8-S-Right	143	3	A		J44-W-Right	53	1	A
	Total	**3454**	**2**	**A**		J44-N-Left	57	1	A
9	J9-W-Left	296	1	A		J44-N-Through	220	1	A

Jn	Movement	Volume	Delay	LOS	Jn	Movement	Volume	Delay	LOS
	J9-W-Through	2156	0	A		**Total**	**433**	**1**	**A**
	J9-N-Left	47	82	F	45	J45-N-Through	273	1	A
	J9-E-Through	981	0	A		J45-N-Right	0	0	A
	Total	**3480**	**1**	**A**		J45-E-Left	128	1	A
10	J10-E-Left	48	0	A		J45-E-Through	173	0	A
	J10-E-Through	88	0	A		**Total**	**574**	**1**	**A**
	J10-E-Right	84	0	A	46	J46-E-Through	211	0	A
	J10-S-Left	30	2	A		J46-E-Right	244	1	A
	J10-S-Through	266	1	A		J46-S-Left	90	2	A
	Total	**516**	**1**	**A**		J46-S-Through	171	2	A
11	J11-N-Through	130	2	A		**Total**	**716**	**1**	**A**
	J11-N-Right	89	0	A	47	J47-W-Left	45	1	A
	J11-E-Left	129	0	A		J47-W-Through	115	1	A
	J11-E-Through	133	0	A		J47-S-Through	313	0	A
	Total	**481**	**1**	**A**		J47-S-Right	100	0	A
12	J12-E-Through	162	0	A		**Total**	**573**	**0**	**A**
	J12-E-Right	15	0	A	48	J48-S-Left	71	0	A
	J12-S-Left	102	1	A		**Total**	**71**	**0**	**A**
	J12-S-Through	149	1	A	49	J49-W-Through	496	0	A
	Total	**428**	**1**	**A**		J49-E-Through	259	1	A
13	J13-N-Left	93	5	A		J49-S-Left	95	3	A
	J13-N-Through	127	5	A		J49-S-Right	191	4	A
	J13-N-Right	177	8	A		**Total**	**1041**	**1**	**A**
	J13-S-Left	0	0	A	50	J50-W-Left	3	0	A

Jn	Movement	Volume	Delay	LOS	Jn	Movement	Volume	Delay	LOS
	J13-S-Through	300	0	A		J50-W-Through	496	0	A
	J13-S-Right	148	1	A		J50-E-Right	35	4	A
	Total	**845**	**3**	**A**		**Total**	**534**	**0**	**A**
14	J14-W-Through	193	2	A	51	J51-W-Through	481	2	A
	J14-W-Right	0	0	A		J51-W-Right	203	2	A
	J14-S-Right	31	1	A		J51-E-Left	263	0	A
	Total	**224**	**2**	**A**		J51-E-Through	259	0	A
15	J15-W-Left	154	1	A		**Total**	**1206**	**1**	**A**
	J15-W-Right	57	1	A	52	J52-W-Through	102	0	A
	J15-N-Through	13	0	A		J52-W-Right	113	1	A
	J15-S-Through	82	0	A		J52-N-Left	140	1	A
	Total	**306**	**1**	**A**		J52-N-Through	228	1	A
16	J16-W	1424	2	A		**Total**	**583**	**1**	**A**
	J16-N	793	5	A	53	J53-E-Left	157	2	A
	J16-E	36	1	A		J53-E-Through	300	2	A
	Total	**2254**	**3**	**A**		J53-N-Through	184	0	A
17	J17-W-Through	362	0	A		J53-N-Right	157	0	A
	J17-S-Left	478	2	A		**Total**	**798**	**1**	**A**
	J17-S-Right	1060	1	A	54	J54-E-Through	163	1	A
	Total	**1901**	**1**	**A**		J54-S-Left	296	1	A
18	J18-W-Left	238	1	A		**Total**	**459**	**1**	**A**
	J18-W-Through	369	2	A	55	J55-N-Through	802	1	A
	J18-E-Through	212	2	A		J55-N-Right	123	14	B
	J18-E-Right	266	3	A		J55-S-Left	40	1	A

Jn	Movement	Volume	Delay	LOS	Jn	Movement	Volume	Delay	LOS
	Total	**1085**	**2**	**A**		J55-S-Through	978	0	A
19	J19-W-Through	324	12	B		**Total**	**1943**	**2**	**A**
	J19-N-Left	340	6	A	56	J56-W-Left	140	10	A
	J19-E-Through	246	8	A		J56-W-Right	102	7	A
	Total	**910**	**9**	**A**		J56-N-Through	823	2	A
20	J20-W-Left	223	1	A		J56-S-Through	974	4	A
	J20-W-Through	220	0	A		**Total**	**2039**	**4**	**A**
	J20-W-Right	0	0	A	57	J57-N-Left	132	8	A
	J20-E-Left	53	1	A		J57-N-Through	901	7	A
	J20-E-Through	150	0	A		J57-E-Left	0	0	A
	J20-E-Right	42	2	A		**Total**	**1033**	**5**	**A**
	J20-S-Left	0	0	A	58	J58-N-Through	955	2	A
	J20-S-Through	71	6	A		J58-N-Right	589	10	B
	J20-S-Right	109	4	A		J58-S-Left	1105	6	A
	Total	**868**	**2**	**A**		**Total**	**2649**	**5**	**A**
21	J21-W-Through	0	0	A	59	J59-W-Left	480	0	A
	J21-W-Right	0	0	A		J59-E-Right	1169	2	A
	J21-N-Left	273	1	A		**Total**	**1649**	**2**	**A**
	J21-N-Through	0	0	A	60	J60-N-Left	238	2	A
	J21-N-Right	125	2	A		J60-N-Through	1486	2	A
	J21-E-Left	0	0	A		J60-E-Left	58	14	B
	J21-E-Through	150	1	A		**Total**	**1782**	**3**	**A**
	J21-S-Left	135	3	A	61	J61-S-Through	1516	1	A
	J21-S-Right	170	2	A		**Total**	**1516**	**1**	**A**

Jn	Movement	Volume	Delay	LOS	Jn	Movement	Volume	Delay	LOS
	J21-S-U-turn	13	4	A	62	J62-N-Left	276	6	A
	Total	**866**	**1**	**A**		J62-N-Through	1643	5	A
22	J22-W-Left	102	5	A		J62-E-Left	92	8	A
	J22-W-Through	227	7	A		**Total**	**2011**	**6**	**A**
	J22-E-Through	343	9	A	63	J63-N-Left	1439	1	A
	Total	**672**	**8**	**A**		J63-S-Through	1060	0	A
23	J23-W-Left	142	77	F		J63-S-Right	497	1	A
	J23-W-Through	218	69	F		**Total**	**2996**	**1**	**A**
	J23-W-Right	40	77	F	64	J64-W-Left	184	0	A
	J23-N-Left	153	53	F		J64-N-Through	1230	0	A
	J23-N-Through	178	46	E		J64-S-Through	1060	0	A
	J23-E-Left	181	58	F		**Total**	**2474**	**0**	**A**
	J23-E-Right	67	66	F	65	J65-W-Through	146	0	A
	J23-S-Through	228	63	F		J65-W-Right	0	0	A
	J23-S-Right	66	64	F		J65-S-Right	38	1	A
	Total	**1273**	**62**	**E**		**Total**	**184**	**0**	**A**
25	J25-W-Left	98	0	A	66	J66-W-Through	112	0	A
	J25-W-Through	278	0	A		J66-W-Right	104	0	A
	J25-S-Through	92	2	A		J66-N-Left	34	1	A
	J25-S-Right	48	2	A		J66-N-Through	70	1	A
	Total	**516**	**1**	**A**		**Total**	**320**	**0**	**A**
26	J26-W-Through	340	0	A	67	J67-W-Right	0	0	A
	J26-W-Right	130	0	A		J67-N-Through	152	0	A
	J26-N-Left	37	2	A		J67-N-Right	55	0	A

Jn	Movement	Volume	Delay	LOS	Jn	Movement	Volume	Delay	LOS
	J26-N-Through	89	3	A		**Total**	**207**	**0**	**A**
	Total	**596**	**1**	**A**	68	J68-N-Left	89	1	A
27	J27-W-Left	97	0	A		J68-N-Through	207	0	A
	J27-W-Through	358	0	A		J68-S-Through	571	0	A
	J27-S-Through	144	3	A		J68-S-Right	128	1	A
	J27-S-Right	210	3	A		**Total**	**995**	**0**	**A**
	Total	**809**	**1**	**A**	69	J69-W-Left	319	3	A
28	J28-W-Left	1	0	A		J69-W-Right	111	2	A
	J28-E-Through	33	1	A		J69-S-Through	380	2	A
	J28-E-Right	38	1	A		**Total**	**810**	**2**	**A**
	J28-S-Left	62	0	A	70	J70-N-Left	97	1	A
	J28-S-Through	179	0	A		J70-N-Through	171	0	A
	Total	**313**	**0**	**A**		J70-E-Left	0	0	A
30	J30-E-Left	126	0	A		J70-E-Right	55	4	A
	J30-E-Right	174	0	A		J70-S-Through	310	1	A
	Total	**300**	**0**	**A**		J70-S-Right	0	0	A
31	J31-N-Right	75	1	A		**Total**	**633**	**1**	**A**
	J31-E-Through	84	0	A	71	J71-W-Through	337	1	A
	J31-S-Left	145	1	A		J71-W-Right	106	1	A
	Total	**304**	**1**	**A**		J71-N-Left	95	0	A
32	J32-N-Left	416	0	A		J71-N-Through	74	0	A
	J32-E-Through	84	0	A		J71-N-Right	19	0	A
	J32-E-Right	312	0	A		**Total**	**631**	**1**	**A**
	Total	**812**	**0**	**A**	72	J72-W-Left	55	1	A

Jn	Movement	Volume	Delay	LOS	Jn	Movement	Volume	Delay	LOS
33	J33-N-Left	107	1	A		J72-W-Through	374	1	A
	Total	**107**	**1**	**A**		J72-W-Right	629	1	A
34	J34-W-Left	0	0	A		J72-N-Left	72	3	A
	J34-W-Through	338	38	E		J72-N-Through	90	7	A
	J34-W-Right	224	46	E		**Total**	**1220**	**1**	**A**
	J34-N-Left	70	54	F	74	J74-E-Left	76	0	A
	J34-N-Through	119	62	F		J74-E-Through	498	0	A
	J34-N-Right	53	55	F		J74-S-Left	139	2	A
	J34-E-Left	50	84	F		**Total**	**713**	**0**	**A**
	J34-E-Through	160	77	F	75	J75-W-Left	243	1	A
	J34-E-Right	114	74	F		J75-W-Through	1021	0	A
	J34-S-Left	112	64	F		J75-E-Left	36	0	A
	J34-S-Through	204	43	E		J75-E-Through	419	0	A
	J34-S-Right	47	37	E		J75-E-Right	180	11	B
	Total	**1491**	**53**	**D**		J75-S-Left	0	0	A
35	J35-N-Left	53	1	A		**Total**	**1899**	**1**	**A**
	J35-N-Through	259	1	A					
	J35-N-Right	83	4	A					
	J35-S-Left	152	3	A					
	J35-S-Through	277	1	A					
	J35-S-Right	76	1	A					
	Total	**900**	**1**	**A**					

Table 5-16 Delay Results Base PM Peak

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
1	J1-W-Left	846	0	A	36	J36-N-Through	371	21	B
	J1-E-Through	2211	0	A		J36-E-Left	129	14	B
	J1-E-Right	320	0	A		J36-E-Right	102	10	B
	Total	**3377**	**0**	**A**		J36-S-Through	601	1	A
2	J2-W-Left	110	1	A		**Total**	**1203**	**9**	**A**
	J2-W-Through	847	0	A	37	J37-E-Through	139	0	A
	J2-N-Left	33	1	A		J37-E-Right	123	0	A
	Total	**990**	**0**	**A**		J37-S-Left	98	1	A
3	J3-W-Left	194	2	A		J37-S-Through	211	1	A
	J3-W-Through	874	6	A		**Total**	**570**	**1**	**A**
	J3-N-Left	84	2	A	38	J38-W-Left	98	2	A
	Total	**1152**	**5**	**A**		J38-W-Through	106	2	A
4	J4-W-Left	29	9	A		J38-S-Through	166	0	A
	J4-W-Through	962	5	A		J38-S-Right	167	1	A
	J4-N-Left	0	0	A		**Total**	**537**	**1**	**A**
	J4-E-Through	2136	2	A	39	J39-E-Through	42	2	A
	Total	**3127**	**3**	**A**		J39-E-Right	34	4	A
5	J5-W-Left	337	1	A		J39-S-Left	53	1	A
	J5-W-Through	713	0	A		J39-S-Through	211	1	A
	J5-N-Left	114	2	A		**Total**	**339**	**2**	**A**
	J5-E-Through	2015	1	A	40	J40-W-Through	446	3	A
	J5-S-Left	16	7	A		J40-E-Through	512	3	A
	Total	**3195**	**1**	**A**		J40-S-Left	128	2	A
6	J6-W-Left	105	1	A		J40-S-Right	114	10	A

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	J6-W-Through	1133	1	A		**Total**	**1201**	**3**	**A**
	J6-W-Right	0	0	A	41	J41-W-Left	0	0	A
	J6-E-Left	0	0	A		J41-W-Through	676	11	B
	J6-E-Through	2266	2	A		J41-N-Left	186	13	B
	J6-E-Right	92	8	A		J41-N-Right	0	0	A
	J6-S-Left	0	0	A		J41-E-Through	522	1	A
	J6-S-Through	0	1	A		J41-E-Right	0	0	A
	J6-S-Right	0	0	A		**Total**	**1384**	**7**	**A**
	Total	**3596**	**2**	**A**	42	J42-W-Through	586	0	A
7	J7-W-Through	1148	0	A		J42-W-Right	276	0	A
	J7-N-Left	90	9	A		J42-E-Left	30	6	A
	J7-N-Right	195	25	C		J42-E-Through	522	14	B
	J7-E-Through	2266	1	A		**Total**	**1414**	**5**	**A**
	Total	**3699**	**2**	**A**	43	J43-N-Through	275	0	A
8	J8-W-Through	1219	0	A		J43-N-Right	30	0	A
	J8-W-Right	5	19	B		J43-E-Through	46	0	A
	J8-E-Left	9	0	A		J43-E-Right	0	0	A
	J8-E-Through	2529	0	A		**Total**	**352**	**0**	**A**
	J8-S-Left	7	6	A	44	J44-W-Through	201	0	A
	J8-S-Right	76	25	B		J44-W-Right	71	1	A
	Total	**3846**	**1**	**A**		J44-N-Left	55	0	A
9	J9-W-Left	164	0	A		J44-N-Through	219	1	A
	J9-W-Through	1128	0	A		**Total**	**546**	**1**	**A**
	J9-N-Left	166	15	B	45	J45-N-Through	291	0	A

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	J9-E-Through	2539	0	A		J45-N-Right	0	0	A
	Total	**3996**	**1**	**A**		J45-E-Left	140	0	A
10	J10-E-Left	166	1	A		J45-E-Through	263	0	A
	J10-E-Through	184	0	A		**Total**	**693**	**2**	**A**
	J10-E-Right	129	0	A	46	J46-E-Through	250	0	A
	J10-S-Left	8	3	A		J46-E-Right	230	1	A
	J10-S-Through	155	4	A		J46-S-Left	153	3	A
	Total	**643**	**1**	**A**		J46-S-Through	202	3	A
11	J11-N-Through	161	4	A		**Total**	**835**	**2**	**A**
	J11-N-Right	148	2	A	47	J47-W-Left	138	1	A
	J11-E-Left	126	0	A		J47-W-Through	117	1	A
	J11-E-Through	336	0	A		J47-S-Through	361	0	A
	Total	**771**	**1**	**A**		J47-S-Right	70	0	A
12	J12-E-Through	372	0	A		**Total**	**686**	**0**	**A**
	J12-E-Right	0	0	A	48	J48-S-Left	46	0	A
	J12-S-Left	92	3	A		**Total**	**46**	**1**	**A**
	J12-S-Through	105	2	A	49	J49-W-Through	585	0	A
	Total	**569**	**1**	**A**		J49-E-Through	365	0	A
13	J13-N-Left	79	2	A		J49-S-Left	197	3	A
	J13-N-Through	152	2	A		J49-S-Right	254	7	A
	J13-N-Right	374	3	A		**Total**	**1402**	**2**	**A**
	J13-S-Left	0	0	A	50	J50-W-Left	0	0	A
	J13-S-Through	293	4	A		J50-W-Through	585	0	A
	J13-S-Right	44	3	A		J50-E-Right	6	1	A

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	Total	**942**	**3**	**A**		**Total**	**591**	**2**	**A**
14	J14-W-Through	209	1	A	51	J51-W-Through	697	1	A
	J14-W-Right	0	0	A		J51-W-Right	142	2	A
	J14-S-Right	29	2	A		J51-E-Left	84	0	A
	Total	**238**	**1**	**A**		J51-E-Through	366	0	A
15	J15-W-Left	150	2	A		**Total**	**1289**	**1**	**A**
	J15-W-Right	74	2	A	52	J52-W-Through	105	0	A
	J15-N-Through	11	0	A		J52-W-Right	82	1	A
	J15-S-Through	194	0	A		J52-N-Left	187	1	A
	Total	**428**	**1**	**A**		J52-N-Through	274	1	A
16	J16-W	1495	3	A		**Total**	**648**	**1**	**A**
	J16-N	1433	12	B	53	J53-E-Left	161	2	A
	J16-E	263	1	A		J53-E-Through	308	2	A
	Total	**3191**	**6**	**A**		J53-N-Through	182	0	A
17	J17-W-Through	669	0	A		J53-N-Right	173	0	A
	J17-S-Left	273	0	A		**Total**	**824**	**1**	**A**
	J17-S-Right	819	1	A	54	J54-E-Through	133	0	A
	Total	**1760**	**0**	**A**		J54-S-Left	337	1	A
18	J18-W-Left	186	1	A		**Total**	**470**	**1**	**A**
	J18-W-Through	680	1	A	55	J55-N-Through	1448	2	A
	J18-E-Through	209	1	A		J55-N-Right	99	14	B
	J18-E-Right	63	4	A		J55-S-Left	35	1	A
	Total	**1138**	**1**	**A**		J55-S-Through	1072	1	A
19	J19-W-Through	315	11	B		**Total**	**2654**	**2**	**A**

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	J19-N-Left	341	4	A	56	J56-W-Left	187	10	B
	J19-E-Through	261	10	B		J56-W-Right	105	12	B
	Total	**918**	**8**	**A**		J56-N-Through	1446	2	A
20	J20-W-Left	203	2	A		J56-S-Through	1067	6	A
	J20-W-Through	217	0	A		**Total**	**2805**	**4**	**A**
	J20-W-Right	0	0	A	57	J57-N-Left	57	6	A
	J20-E-Left	33	1	A		J57-N-Through	1401	7	A
	J20-E-Through	198	1	A		J57-E-Left	99	21	B
	J20-E-Right	29	3	A		**Total**	**1556**	**6**	**A**
	J20-S-Left	0	0	A	58	J58-N-Through	1404	4	A
	J20-S-Through	7	4	A		J58-N-Right	687	15	B
	J20-S-Right	103	3	A		J58-S-Left	1244	7	A
	Total	**791**	**1**	**A**		**Total**	**3335**	**7**	**A**
21	J21-W-Through	0	0	A	59	J59-W-Left	697	1	A
	J21-W-Right	11	1	A		J59-E-Right	1475	4	A
	J21-N-Left	290	1	A		**Total**	**2172**	**2**	**A**
	J21-N-Through	0	0	A	60	J60-N-Left	352	2	A
	J21-N-Right	140	2	A		J60-N-Through	1943	3	A
	J21-E-Left	0	0	A		J60-E-Left	149	37	D
	J21-E-Through	198	1	A		**Total**	**2443**	**5**	**A**
	J21-S-Left	198	2	A	61	J61-S-Through	2042	2	A
	J21-S-Right	131	2	A		**Total**	**2042**	**3**	**A**
	J21-S-U-turn	0	0	A	62	J62-N-Left	118	6	A
	Total	**968**	**1**	**A**		J62-N-Through	2202	6	A

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
22	J22-W-Left	169	6	A		J62-E-Left	101	350	F
	J22-W-Through	184	6	A		**Total**	**2421**	**20**	**B**
	J22-E-Through	513	10	A	63	J63-N-Left	1869	3	A
	Total	**866**	**8**	**A**		J63-S-Through	1752	0	A
23	J23-W-Left	170	86	F		J63-S-Right	473	1	A
	J23-W-Through	213	76	F		**Total**	**4095**	**2**	**A**
	J23-W-Right	69	67	F	64	J64-W-Left	183	0	A
	J23-N-Left	204	40	E		J64-N-Through	1599	0	A
	J23-N-Through	291	37	E		J64-S-Through	1748	0	A
	J23-E-Left	252	52	F		**Total**	**3530**	**0**	**A**
	J23-E-Right	173	67	F	65	J65-W-Through	176	0	A
	J23-S-Through	257	63	F		J65-W-Right	0	0	A
	J23-S-Right	33	48	E		J65-S-Right	6	0	A
	Total	**1663**	**58**	**E**		**Total**	**183**	**0**	**A**
25	J25-W-Left	137	1	A	66	J66-W-Through	123	0	A
	J25-W-Through	276	1	A		J66-W-Right	107	1	A
	J25-S-Through	105	3	A		J66-N-Left	54	1	A
	J25-S-Right	70	4	A		J66-N-Through	88	1	A
	Total	**588**	**1**	**A**		**Total**	**372**	**1**	**A**
26	J26-W-Through	322	0	A	67	J67-W-Right	0	0	A
	J26-W-Right	191	0	A		J67-N-Through	186	0	A
	J26-N-Left	91	2	A		J67-N-Right	36	0	A
	J26-N-Through	120	2	A		**Total**	**222**	**0**	**A**
	Total	**725**	**1**	**A**	68	J68-N-Left	105	0	A

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
27	J27-W-Left	84	0	A		J68-N-Through	305	0	A
	J27-W-Through	350	0	A		J68-S-Through	878	0	A
	J27-S-Through	169	3	A		J68-S-Right	126	1	A
	J27-S-Right	162	3	A		**Total**	**1413**	**0**	**A**
	Total	**764**	**1**	**A**	69	J69-W-Left	359	6	A
28	J28-W-Left	29	1	A		J69-W-Right	80	3	A
	J28-E-Through	44	2	A		J69-S-Through	646	3	A
	J28-E-Right	59	1	A		**Total**	**1085**	**3**	**A**
	J28-S-Left	32	0	A	70	J70-N-Left	131	3	A
	J28-S-Through	222	0	A		J70-N-Through	232	0	A
	Total	**385**	**1**	**A**		J70-E-Left	0	0	A
30	J30-E-Left	213	0	A		J70-E-Right	35	4	A
	J30-E-Right	295	0	A		J70-S-Through	537	1	A
	Total	**508**	**0**	**A**		J70-S-Right	0	0	A
31	J31-N-Right	67	2	A		**Total**	**935**	**1**	**A**
	J31-E-Through	159	0	A	71	J71-W-Through	302	4	A
	J31-S-Left	282	2	A		J71-W-Right	49	3	A
	Total	**508**	**1**	**A**		J71-N-Left	139	1	A
32	J32-N-Left	415	4	A		J71-N-Through	152	0	A
	J32-E-Through	159	0	A		J71-N-Right	137	0	A
	J32-E-Right	672	0	A		**Total**	**779**	**2**	**A**
	Total	**1247**	**2**	**A**	72	J72-W-Left	66	1	A
33	J33-N-Left	165	9	A		J72-W-Through	317	1	A
	Total	**165**	**6**	**A**		J72-W-Right	558	1	A

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
34	J34-W-Left	0	0	A		J72-N-Left	36	2	A
	J34-W-Through	345	56	F		J72-N-Through	171	7	A
	J34-W-Right	273	48	E		**Total**	**1148**	**2**	**A**
	J34-N-Left	36	69	F	74	J74-E-Left	68	1	A
	J34-N-Through	189	89	F		J74-E-Through	984	0	A
	J34-N-Right	36	64	F		J74-S-Left	235	4	A
	J34-E-Left	65	58	F		**Total**	**1287**	**1**	**A**
	J34-E-Through	331	61	F	75	J75-W-Left	260	1	A
	J34-E-Right	233	56	F		J75-W-Through	867	0	A
	J34-S-Left	118	90	F		J75-E-Left	44	0	A
	J34-S-Through	309	57	F		J75-E-Through	858	0	A
	J34-S-Right	65	54	F		J75-E-Right	316	12	B
	Total	**2000**	**61**	**E**		J75-S-Left	0	0	A
35	J35-N-Left	71	1	A		**Total**	**2346**	**2**	**A**
	J35-N-Through	375	3	A					
	J35-N-Right	71	8	A					
	J35-S-Left	155	7	A					
	J35-S-Through	415	2	A					
	J35-S-Right	132	1	A					
	Total	**1221**	**3**	**A**					

Based on summary of delay performance as presented above, all the junctions besides Junction 23 and Junction 34 are performing with an overall LOS A. Junction 23 are assessed to perform under LOS E for both AM and PM peaks. Junction 34 are assessed to perform under LOS D for AM peak and under LOS E for PM peak. This would form the base model performance for future testing in the next stage of the study.

5.9.4 Vehicular Measurement: Delay /Level of Service

Level of Service (LOS) criteria for delay as per HCM 2010 is shown in table below.

The Highway Capacity Manual (HCM) uses the concept of level of service (LOS) as a qualitative measure to describe operational conditions of vehicular traffic. The criterion for determining LOS at signalized and unsignalized intersections is delay per vehicle, in seconds per vehicle. Delay is the time loss of a traveler while crossing an intersection or while travelling on a road network.

Vehicular LOS analysis is based on a scale from A through F, with A representing the best and F representing the worst traveling conditions.

LOS	Controlled Intersections	Uncontrolled Intersections
A	0-10	0-10
B	11-25	11-15
C	21-35	16-25
D	36-55	26-35
E	56-80	36-50
F	>80	>50

Figure 5-25 LOS Criteria

Figure below showed the example of color scheme used to present delay and LOS results of the network.

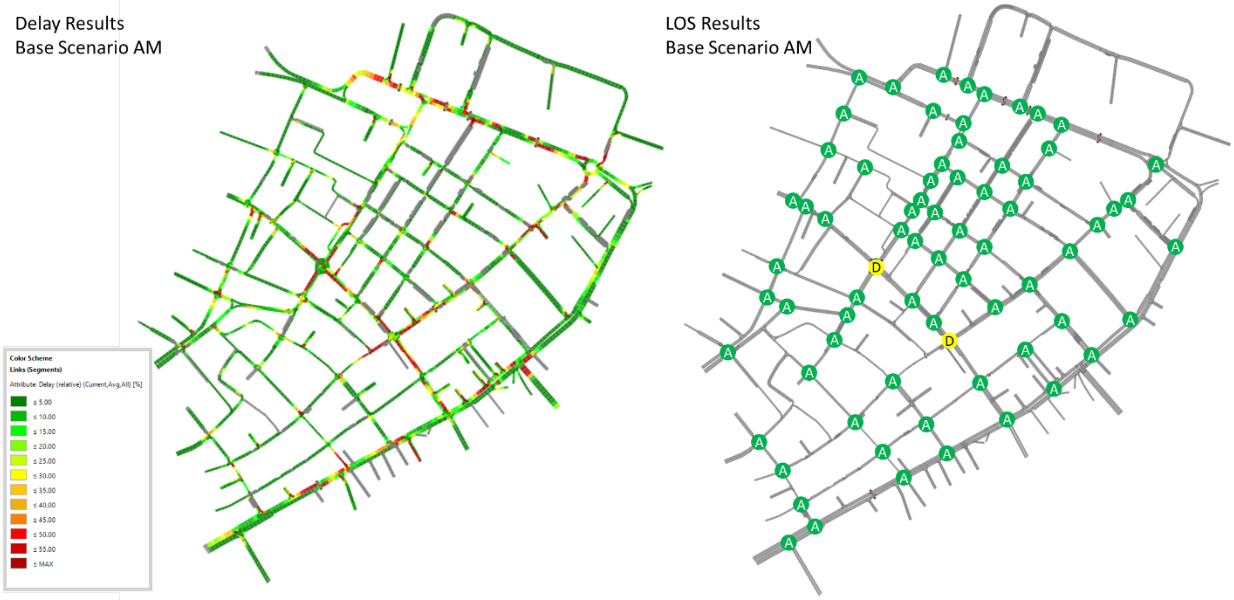


Figure 5-26 Example of Delay and LOS Results

5.9.5 Vehicular Measurement: Density

Traffic density is defined as the number of vehicles occupying a unit length of roadway. The easiest way to visualize traffic density is to consider an aerial photograph of a highway section and count of number of vehicles in 1 mile of a single lane. This will be the density per lane-mile. Traffic densities vary from 0 (no flow) to values representing stopped, bumper to bumper traffic. This upper limit, called jam density, depends on the traffic composition and the clear gaps between vehicles.

Figure below showed the example of color scheme used to present density results of the network.

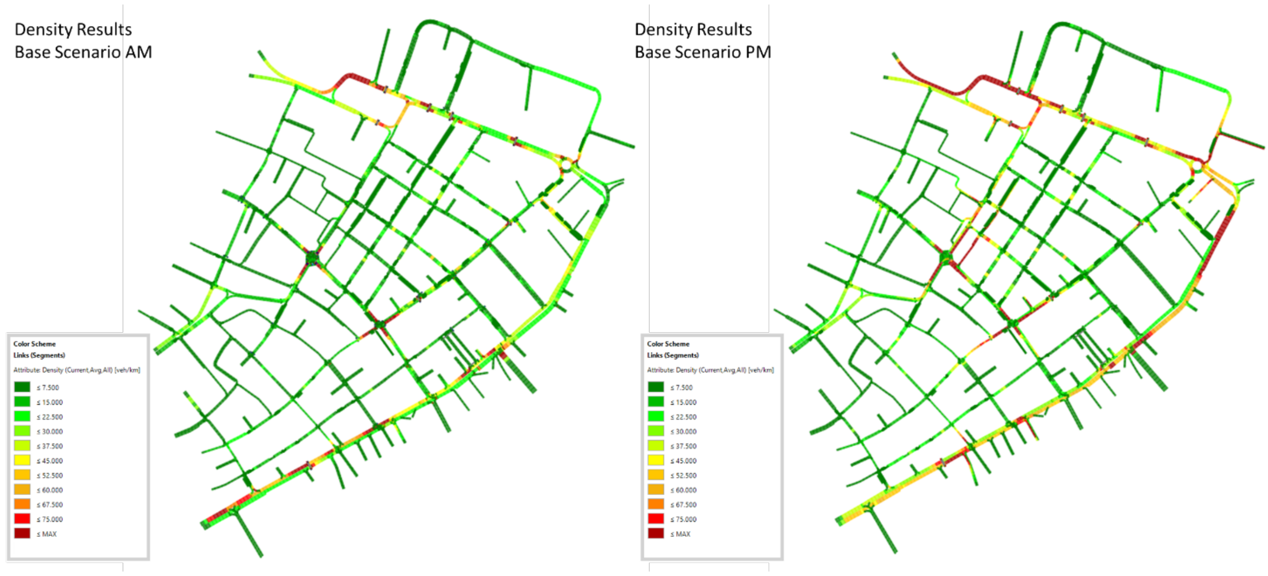


Figure 5-27 Example of Density Results

5.9.6 Vehicular Measurement: Speed

Speed id defined as distance covered by a vehicle in a specific time period. Average speed is defined as speed maintained by a vehicle over a given stretch of road while the vehicle is in motion. Figure below showed the example of color scheme used to present average speed results of the network.

Figure 5-28 Example of Average Speed Results

5.9.7 Vehicular Measurement: Vehicle Travel Time

Average time taken for a vehicle to travel from one section to other section of the road is defined as vehicle travel time.

Figure below showed the example of result comparison of the vehicle travel time from each scenario.

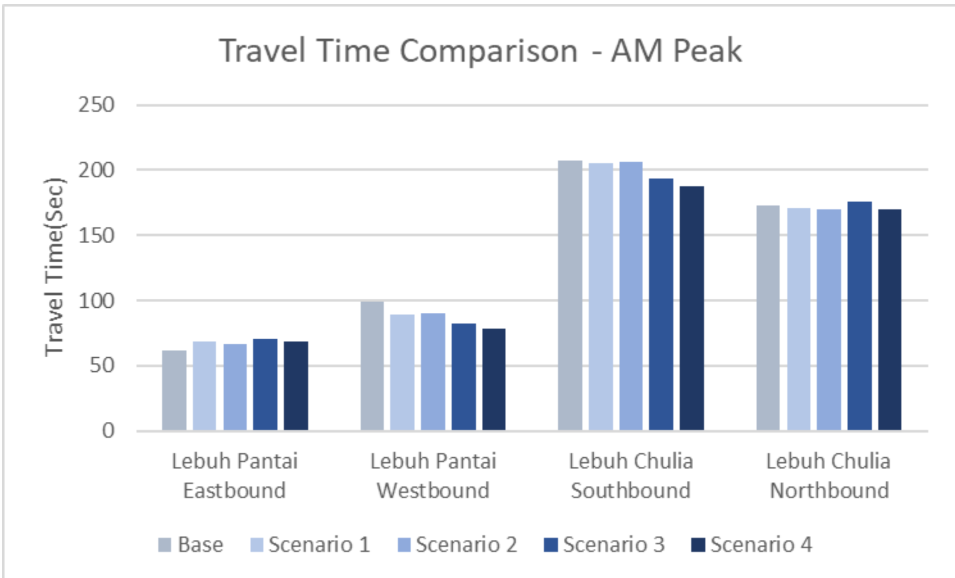


Figure 5-29 Example of Travel Time Results Comparison

5.9.8 Vehicular Measurement: Queue Lengths

Queue length is defined as a length of vehicles waiting to move in the road network in which the flow rate is depreciated either by bottle necks or by priority/signalized junctions. Queue lengths for all the scenarios and network performance are presented in Appendix 4 and Appendix 5 of the report respectively.

5.10 Base Scenario

Results obtained for Base Scenario in study area are presented in below sections.

5.10.1 Vehicular Measurement: Delay/Level of Service

The criterion for determining LOS at signalized and unsignalized intersections is delay per vehicle as explained in section 5.10.2. Below image shows the LOS for junctions in trial study area.

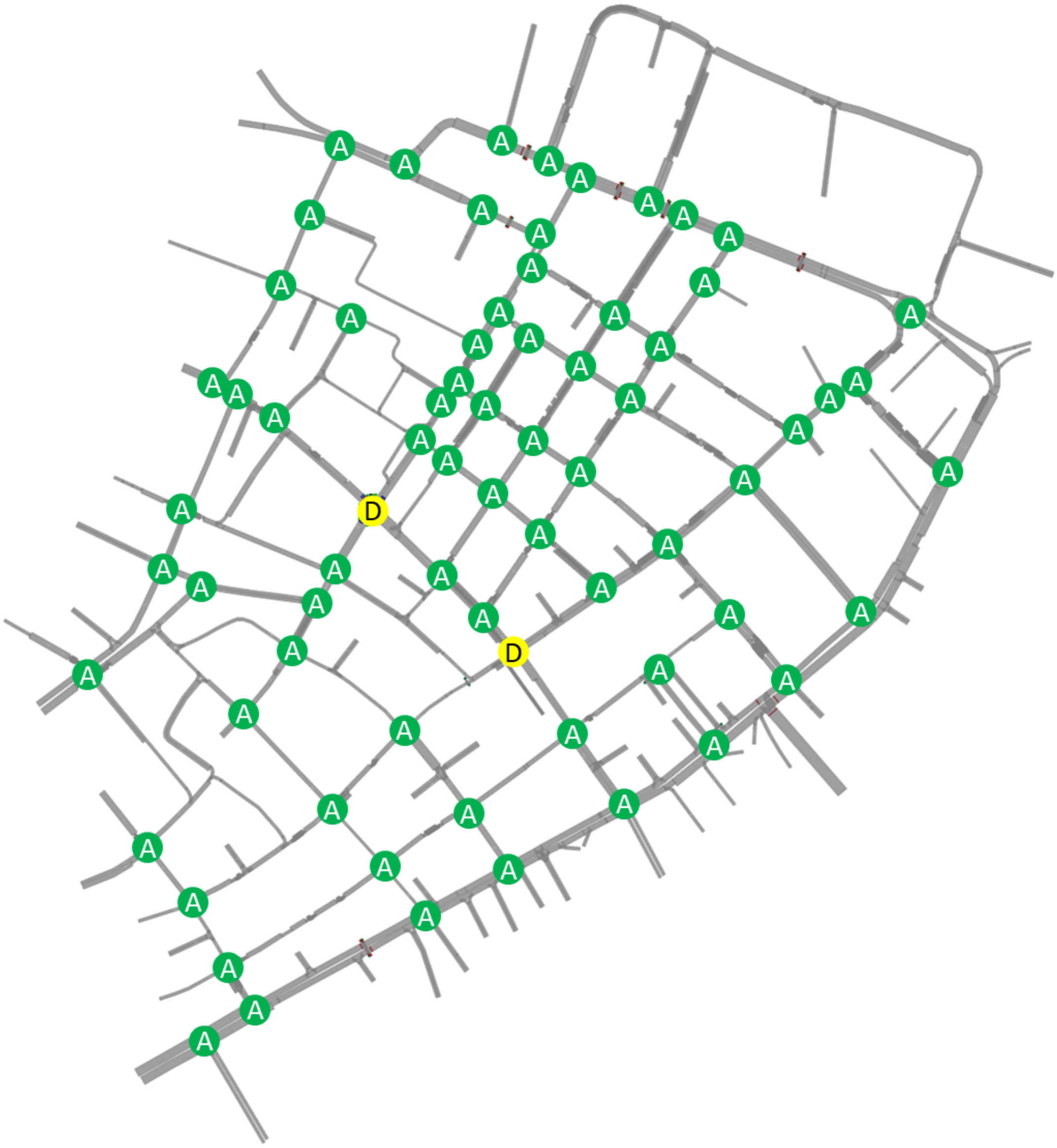


Figure 5-30 Level of Service-Scenario1 - AM peak

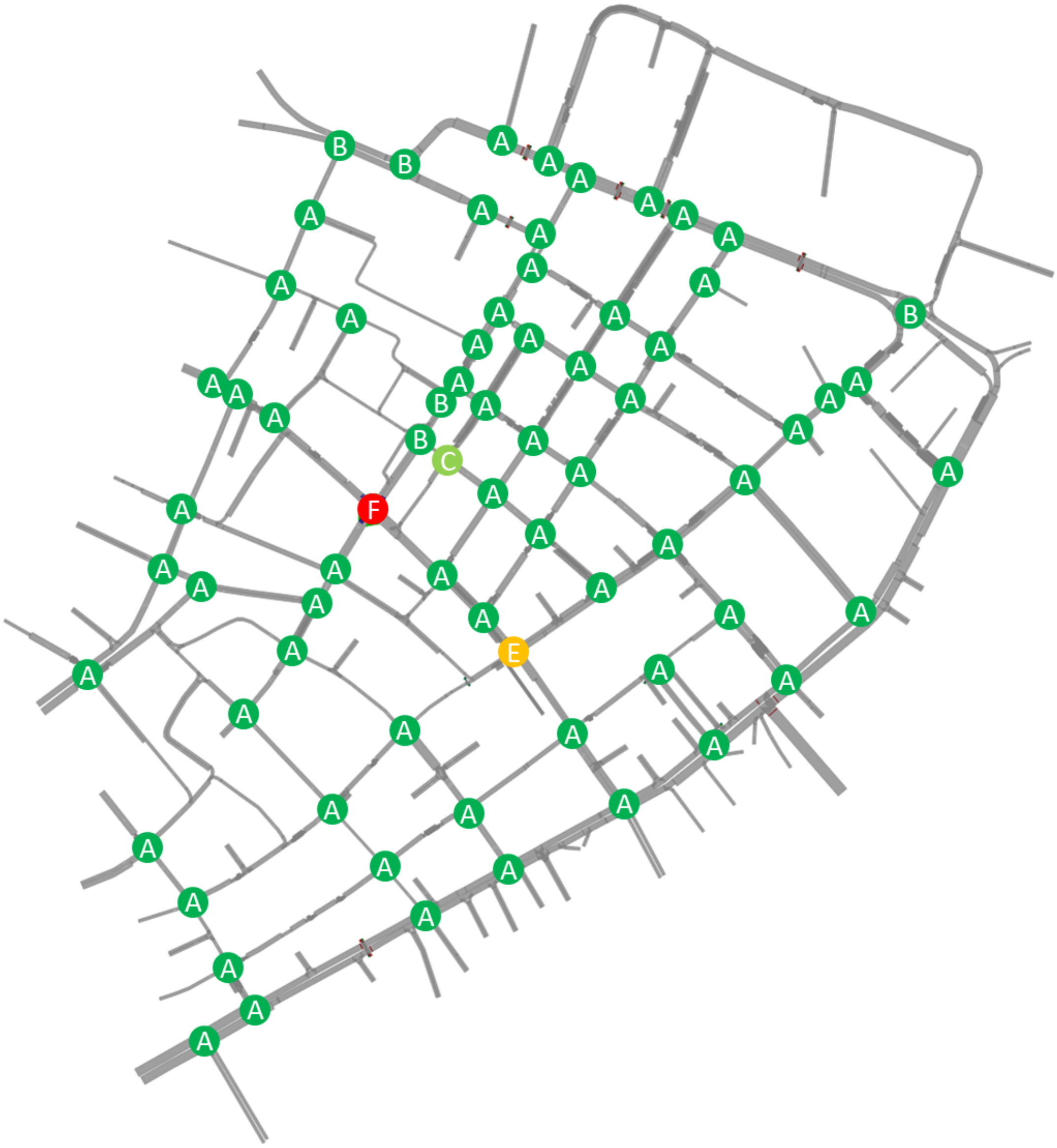


Figure 5-31 Level of Service-Scenario1 - PM peak

All the junctions in AM Base scenario are performing with LOS A expect J23 and J34 which is performing at LOS D. In PM peak, J23 is performing LOS E, J34 is performing LOS F and J39 is performing LOS C with all the other junctions performing LOS A or LOS B.

The diagram below presents the delay (in unit of seconds) experienced by vehicular traffic at each section of the road. In below image, sections with green indicates that delay is less and driving conditions are ideal and sections with yellow and lite orange indicates that congestions is noticeable and sections with red indicates that higher delay is experienced, and vehicles are moving slowly or stopping for reasonable amount of time. Irrespective of color in below image, higher the width of bar higher is the delay experienced by the vehicle.

Figure 5-32 Delay-Base Scenario – AM peak

Figure 5-33 Delay-Base Scenario – PM peak

From above graphs it can be observed, dark red plots which indicates higher delay are majorly present on section near J23, J34 and along Lebuh Light in both the peaks. Higher delay is also presented along Pengkalan Weld in PM peak.

5.10.2 Vehicular Measurement: Density

Density as explained in earlier sections is the number of vehicles occupying unit length of roadway. Green color bar in below image indicates sections with low density and sections with yellow and orange indicates reasonable density and sections with red and pink indicates higher density, and it is generally experienced near to signalized sections. Width of the bar is proportional to the density experienced at those sections.

Figure 5-34 Density-Base Scenario – AM Peak

Figure 5-35 Density-Base Scenario – PM peak

Higher density is usually observed near to priority/signalized junction or when there is a bottle necks in the road network. From above graphs it can be observed that higher densities are observed at sections near J23, J34, along Lebuh Light and along Pengakalan Weld.

5.10.3 Vehicular Measurement: Speed

Average speed on road network in scenario-1 is demonstrated in below images. Red color bar indicates sections on the road network with speed around 50 kmph and yellow bars indicates speed around 30 kmph.

Figure 5-36 Speed- Base Scenario-AM Peak

Figure 5-37 Speed- Base Scenario-PM Peak

From above graphs it can be observed that average speed on Pengkalan Weld is around 50kmph and on other roads it is 40 kmph in AM peak. Average speed in PM peak is lower especially at Jalan Masjid Kapitan Keling and Lebuh Pasar where vehicles can only travel around 10 kmph.

5.11 Scenario 1

In this scenario, emphasis is given to understand the network performance after adding PT lanes on Jalan Masjid Kapitan Keling. Below sections provide the results of the assessment for Scenario 1.

5.11.1 Vehicular Measurement: Delay/Level of Service

The criterion for determining LOS at signalized and unsignalized intersections is delay per vehicle as explained in section 5.10.2. Below image shows the LOS for junctions in trial study area for scenario 1.

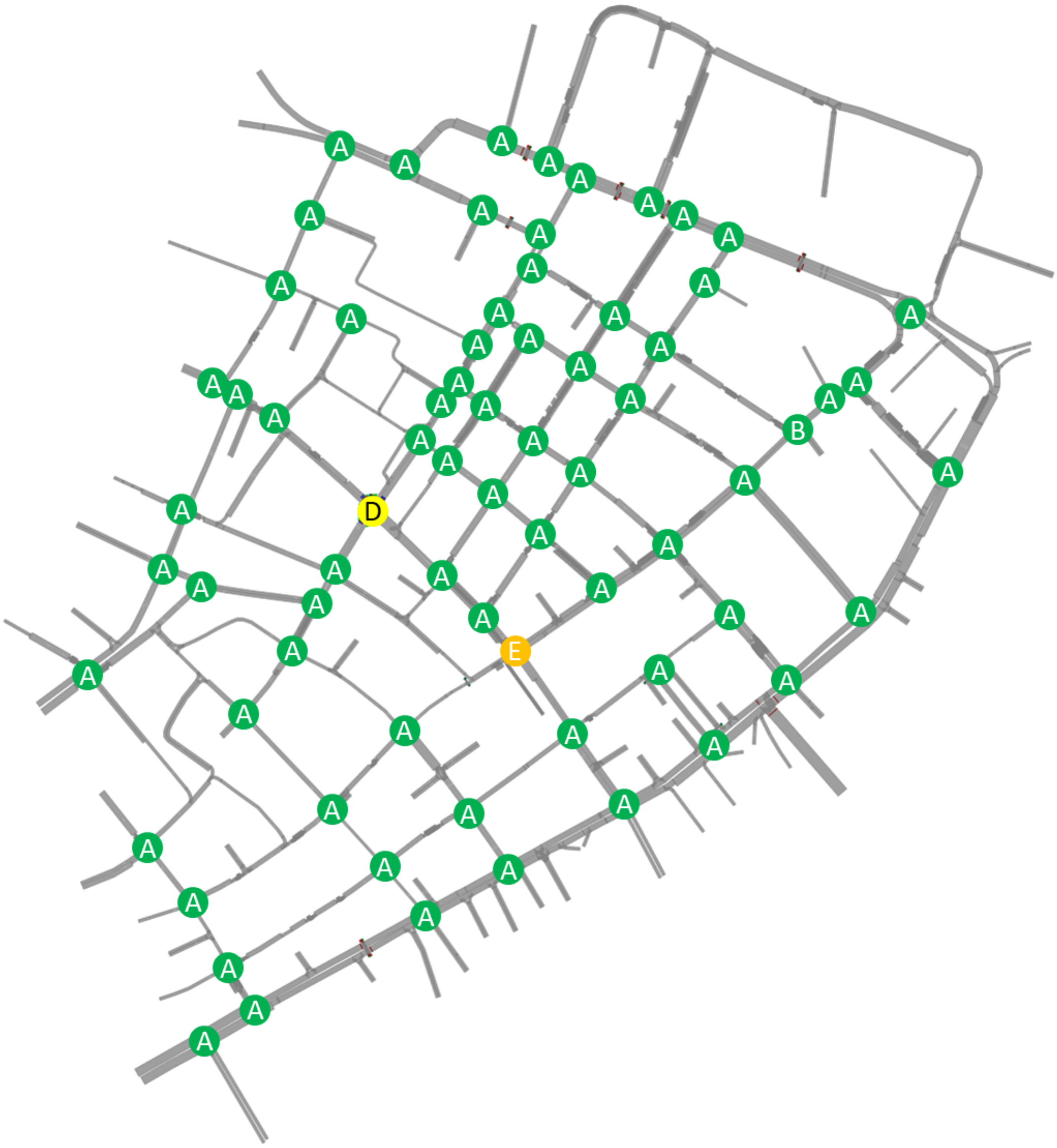


Figure 5-38 Level of Service-Scenario1 - AM Peak

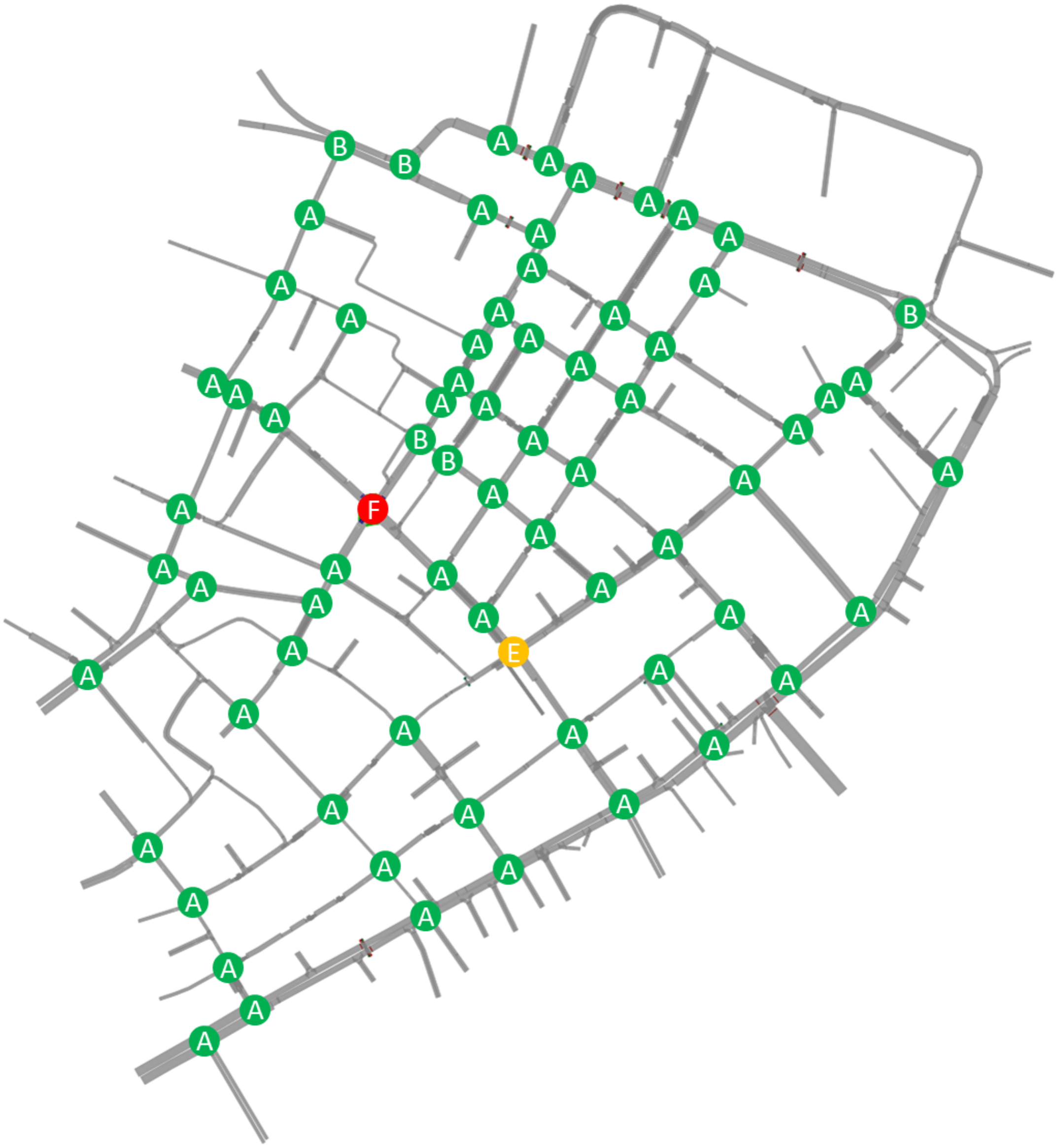


Figure 5-39 Level of Service-Scenario1 - PM Peak

All the junctions in AM scenario-1 are performing with LOS A or LOS B expect J23 and J34 which is performing at LOS E and LOS D respectively. In PM peak, J23 is performing LOS E and J34 is performing LOS F with all the other junctions performing LOS A or LOS B.

The diagram below presents the delay (in unit of seconds) experienced by vehicular traffic at each section of the road. In below image, sections with green indicates that delay is less and driving conditions are ideal and sections with yellow and lite orange indicates that congestions is noticeable and sections with red indicates that higher delay is experienced, and vehicles are moving slowly or stopping for reasonable amount of time. Irrespective of color in below image, higher the width of bar higher is the delay experienced by the vehicle.

Figure 5-40 Delay-Scenario1 – AM peak

Figure 5-41 Delay-Scenario1 – PM Peak

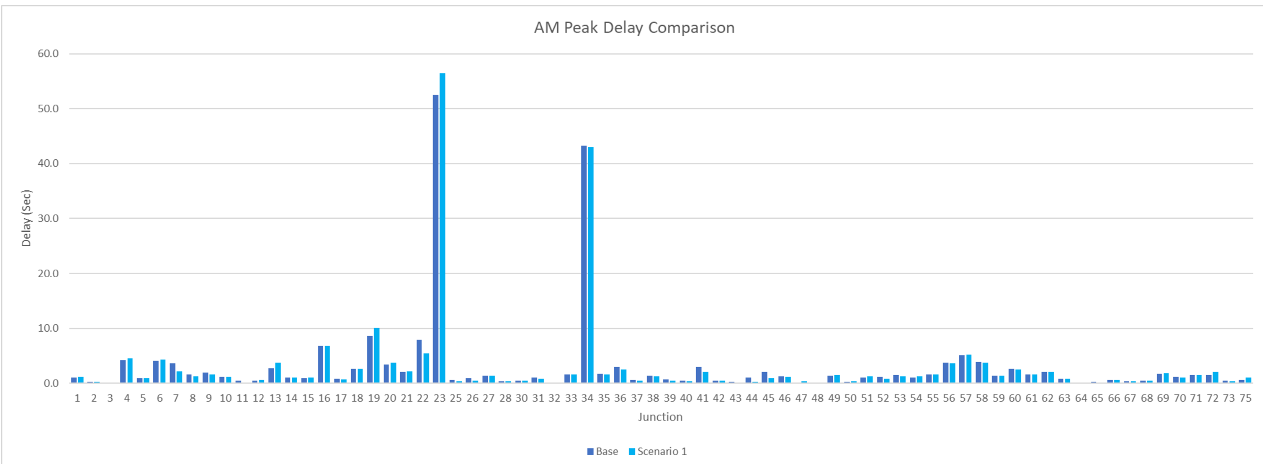


Figure 5-42 Scenario 1 - Delay Comparison -AM Peak

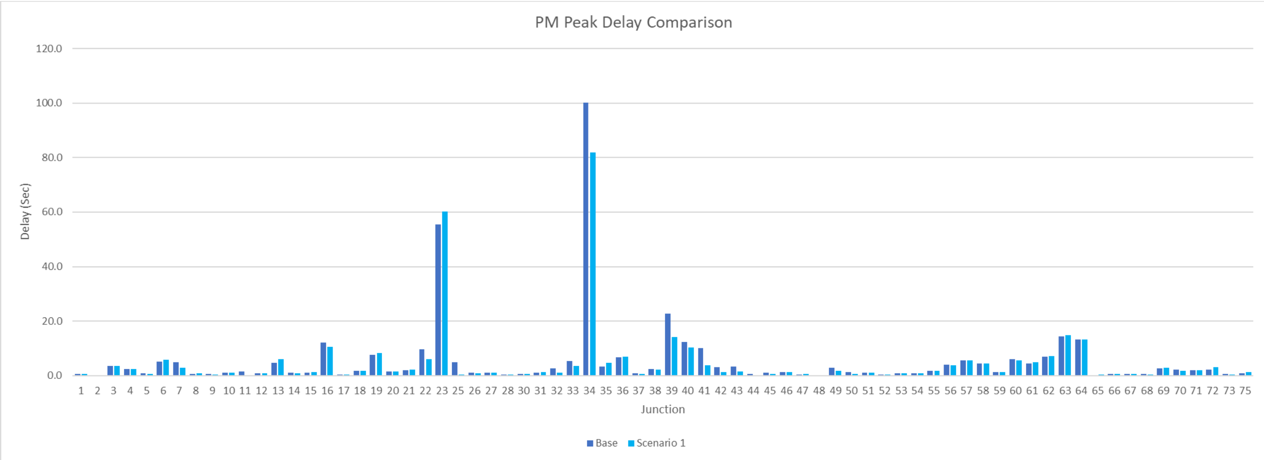


Figure 5-43 Scenario 1 - Delay Comparison -PM peak

From above graphs it can be inferred that all junctions are experiencing more or less same delay as in base scenario expect J34. Though delay in J34 decreased in scenario-1, J34 is still considered performing at same level as base scenario. The implementation of bus priority along Jalan Masjid Kapitan Keling does not cause extra delay.

There is almost 4% and 14% decrease in average delay on the road network in scenario-1 when compared with base scenario in AM and PM peak respectively.

5.11.2 Vehicular Measurement: Density

Density as explained in earlier sections is the number of vehicles occupying unit length of roadway. Green color bar in below image indicates sections with low density and sections with yellow and orange indicates reasonable density and sections with red and pink indicates higher density, and it is generally experienced near to signalized sections. Width of the bar is proportional to the density experienced at those sections.

Figure 5-44 Density- Scenario 1-AM Peak

Figure 5-45 Density- Scenario 1-PM Peak

The implementation of bus priority along Jalan Masjid Kapitan Keling does not make the network density higher in both AM and PM peaks in scenario-1.

5.11.3 Vehicular Measurement: Speed

Average speed on road network in scenario-1 is demonstrated in below images. Red color bar indicates sections on the road network with speed around 50 kmph and yellow bars indicates speed around 30 kmph.

Figure 5-46 Speed- Scenario 1-AM Peak

Figure 5-47 Speed- Scenario 1-PM Peak

From above graphs it can be observed that average speed on Pengkalan Weld is around 50kmph and on other roads it is 40 kmph in AM peak. Average speed along Jalan Masjid Kapitan Keling is higher than base scenario to 35kmph in PM peak.

5.11.4 Public Bus Measurement: Travel Time

Time taken for public bus to travel from one end of Jalan Masjid Kapitan Keling to other end in study area is measured as shown in figure below.

Figure 5-48 Public Bus travel time sections

For better understanding the public bus performance in scenario-1 a comparison between base scenario and scenario-1 is done and is presented below.

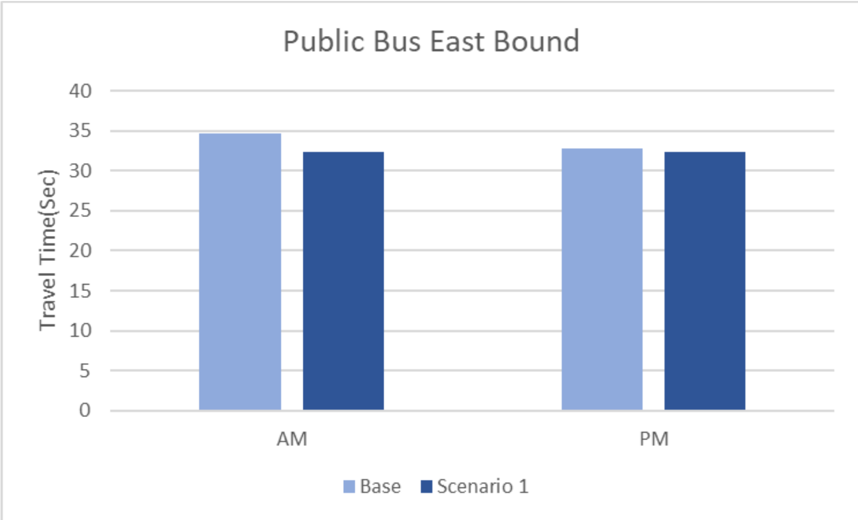


Figure 5-49 Public Bus travel time-East Bound

There is certainly as decrease of public bus travel time in scenario-1 and following points can be inferred from above graphs:

- In east bound direction, pedestrian travel time in Scenario 1 is decreased by 6% and 1% respectively in AM and PM peak when compared with base scenario.

5.12 Scenario 2

In this scenario, emphasis is given to understand the network performance after adopting improvement to pedestrian and cyclist infrastructure. Below sections provide the results of the assessment for Scenario 2.

5.12.1 Vehicular Measurement: Delay/Level of service

Based on LOS criteria for signalized and unsignalized intersections, LOS for junctions is determined and presented in below images.

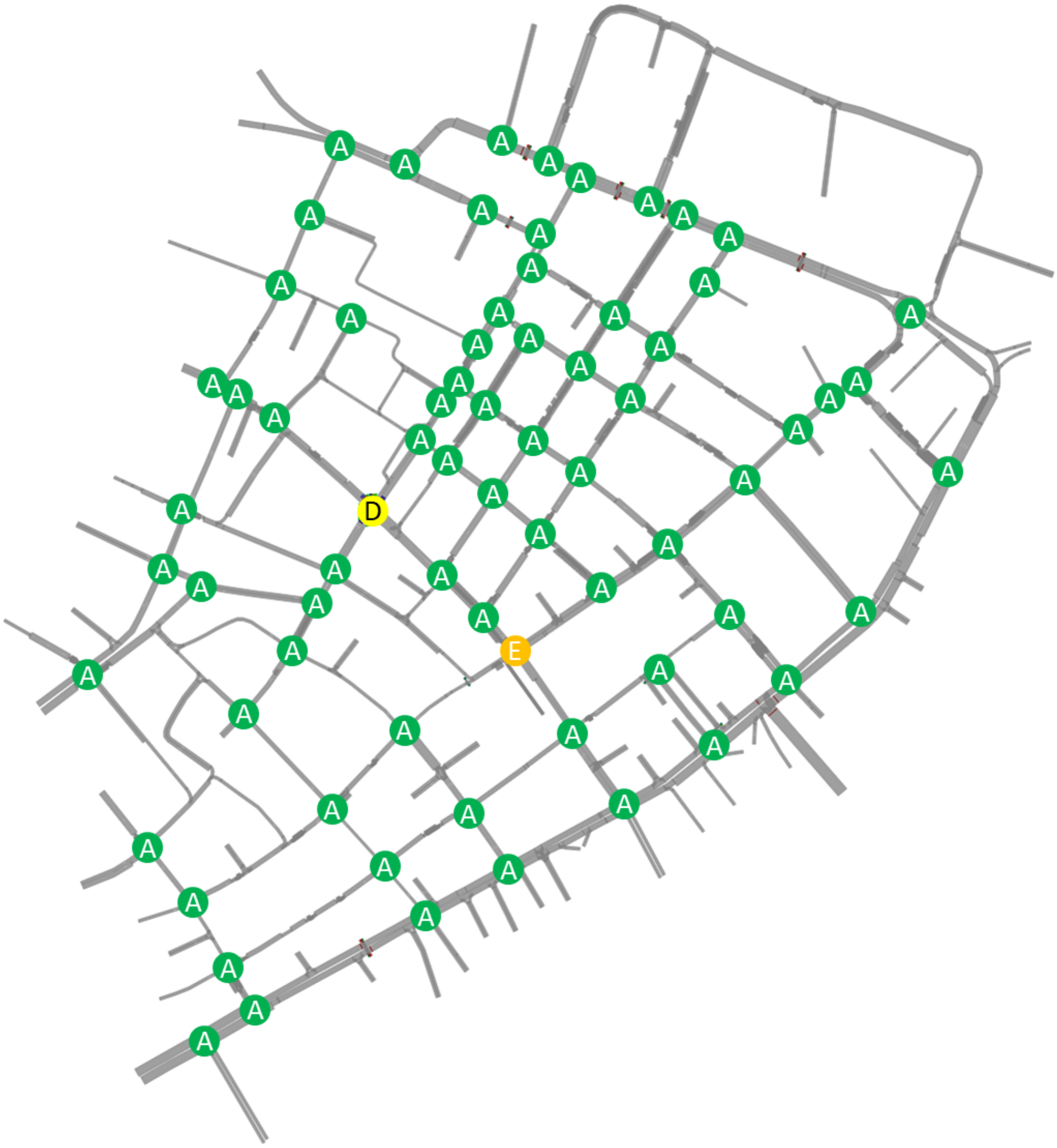


Figure 5-50 Level of Service-Scenario2 - AM Peak

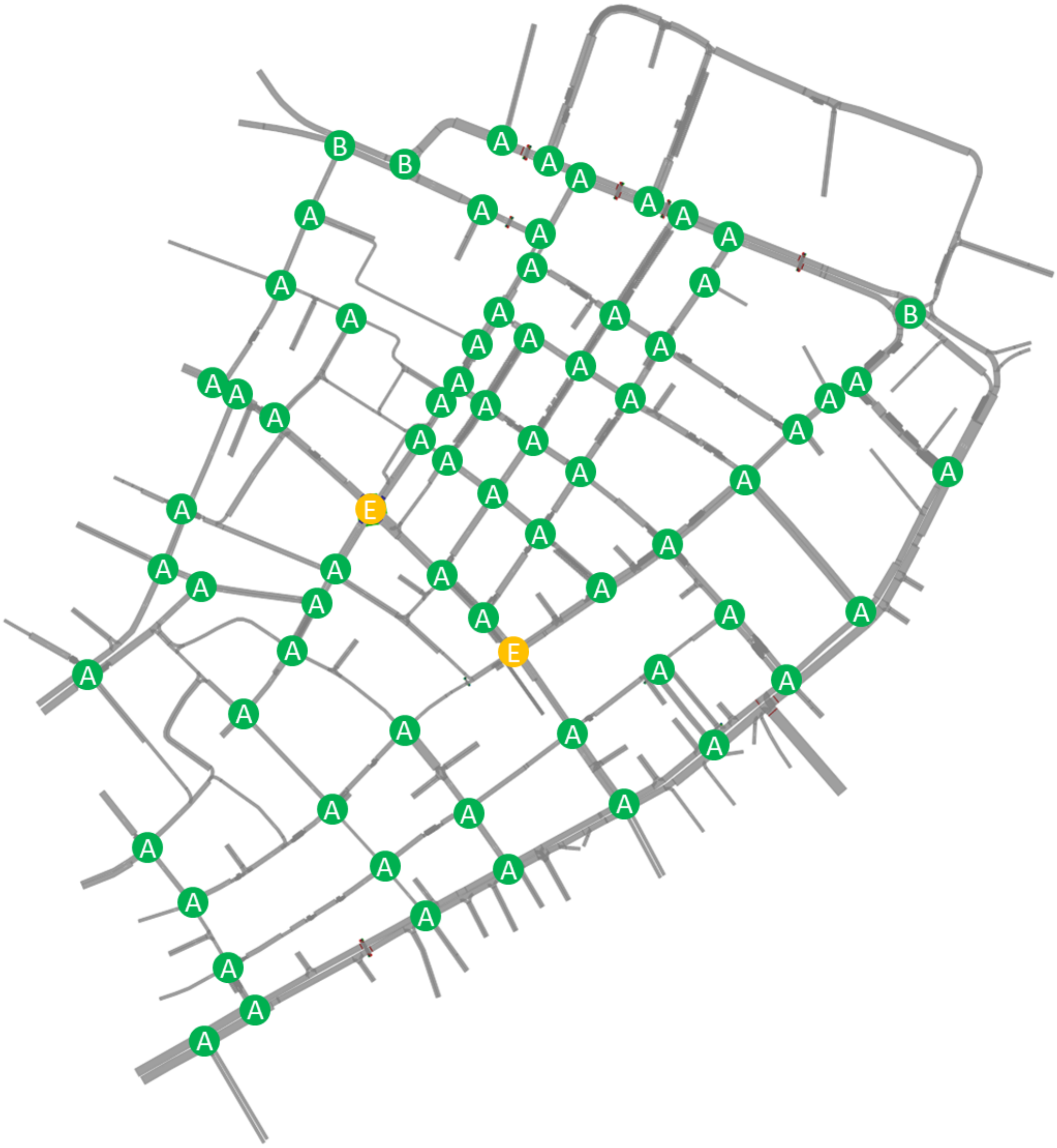


Figure 5-51 Level of Service-Scenario2 - PM peak

From the above images following observation can be done:

- All the junctions in scenario-2 are performing with LOS A expect J23 which is performing at LOS E and J34 which is performing at LOS D in AM peak;
- In PM peak, J23 and J34 is operating at LOS E. Remaining junctions are operating with LOS A or LOS B.

In below image, sections with green indicates that delay is less and driving conditions are ideal and sections with yellow and lite orange indicates that congestions is noticeable and sections with red indicates that higher delay is experienced, and vehicles are moving slowly or stopping for reasonable amount of time. Irrespective of color in below image, higher the width of bar higher is the delay experienced by the vehicle.

Delay experienced on trial area road network in scenario-2 is displayed in below graphs.

Figure 5-52 Delay-Scenario 2 – AM peak

Figure 5-53 Delay-Scenario2 – PM peak

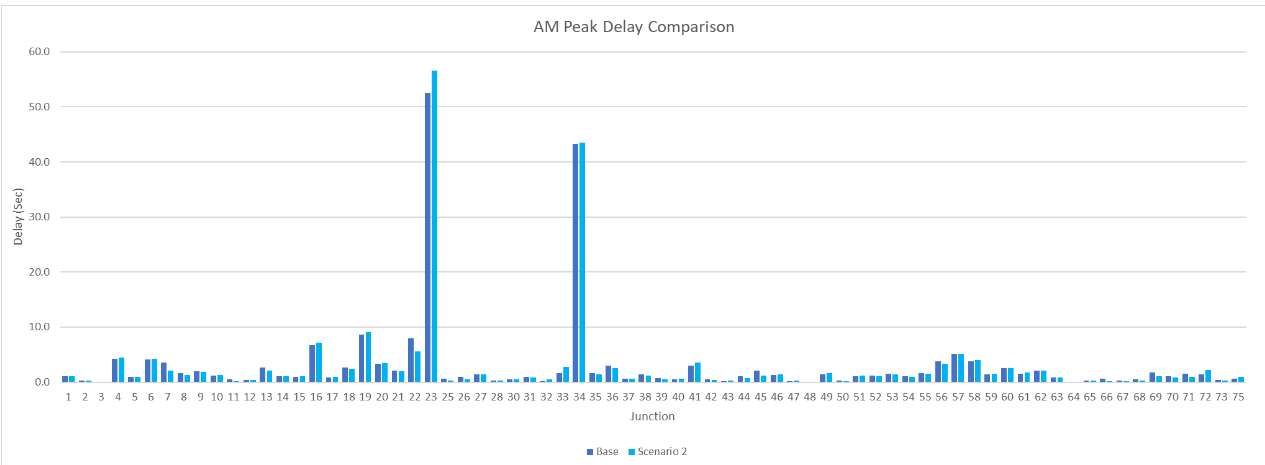


Figure 5-54 Scenario 2 - Delay Comparison -AM peak

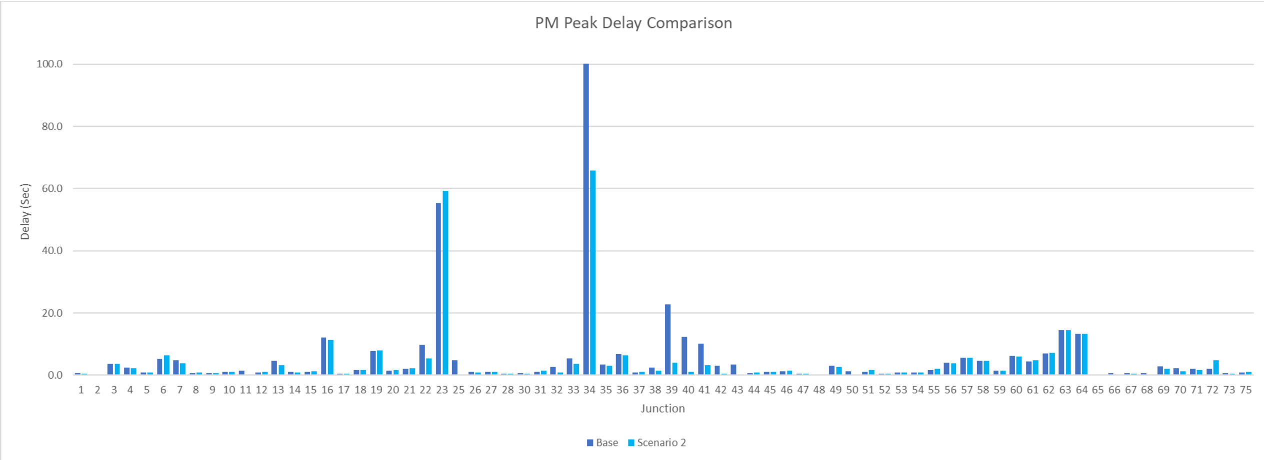


Figure 5-55 Scenario 2 - Delay Comparison -PM peak

Following observation can be made from above delay graphs and plots:

- For all the junctions expect J23 and J34, average delay is more or less same as of base scenario;
- Average Delay for J23 increased in scenario-2 due to implementing pedestrian infrastructure. But J23 is still considered performing at the same level as base scenario;
- Average Delay for J34 is reduced in scenario-2;
- Overall average delay is reduced in scenario-2 by 1% and 14% in AM and PM peak respectively.

5.12.2 Vehicular Measurement: Density

Density of the road network in scenario-2 is shown in below images. Green color bar in below image indicates sections with low density and sections with yellow and orange indicates reasonable density and sections with red and pink indicates higher density, and it is generally experienced near to signalized sections. Width of the bar is proportional to the density experienced at those sections.

Figure 5-56 Density- Scenario 2-AM Peak

Figure 5-57 Density- Scenario 2-PM Peak

The implementation of improved pedestrian and cyclist infrastructure does not make the network density higher in both AM and PM peaks in scenario-2.

5.12.3 Vehicular Measurement: Speed

Average speed on road network in scenario-2 is demonstrated in below images. Red color bar indicates sections on the road network with speed around 50 kmph and yellow bars indicates speed around 30 kmph.

Figure 5-58 Speed - Scenario 2-AM Peak

Figure 5-59 Speed - Scenario 2-PM Peak

From above graphs it can be observed that average speed on Pengkalan Weld is around 50kmph and on other roads it is 40 kmph in AM peak. Average speed along Jalan Masjid Kapitan Keling is higher than base scenario to 40kmph in PM peak.

5.13 Scenario 3

In this scenario, as explained, on-street carpark in selected sections of the road in the study area and the impact is analyzed in below section of the report.

5.13.1 Vehicular Measurement: Delay/Level of service

LOS for all the junctions in trial study area for scenario3 are shown in below images.

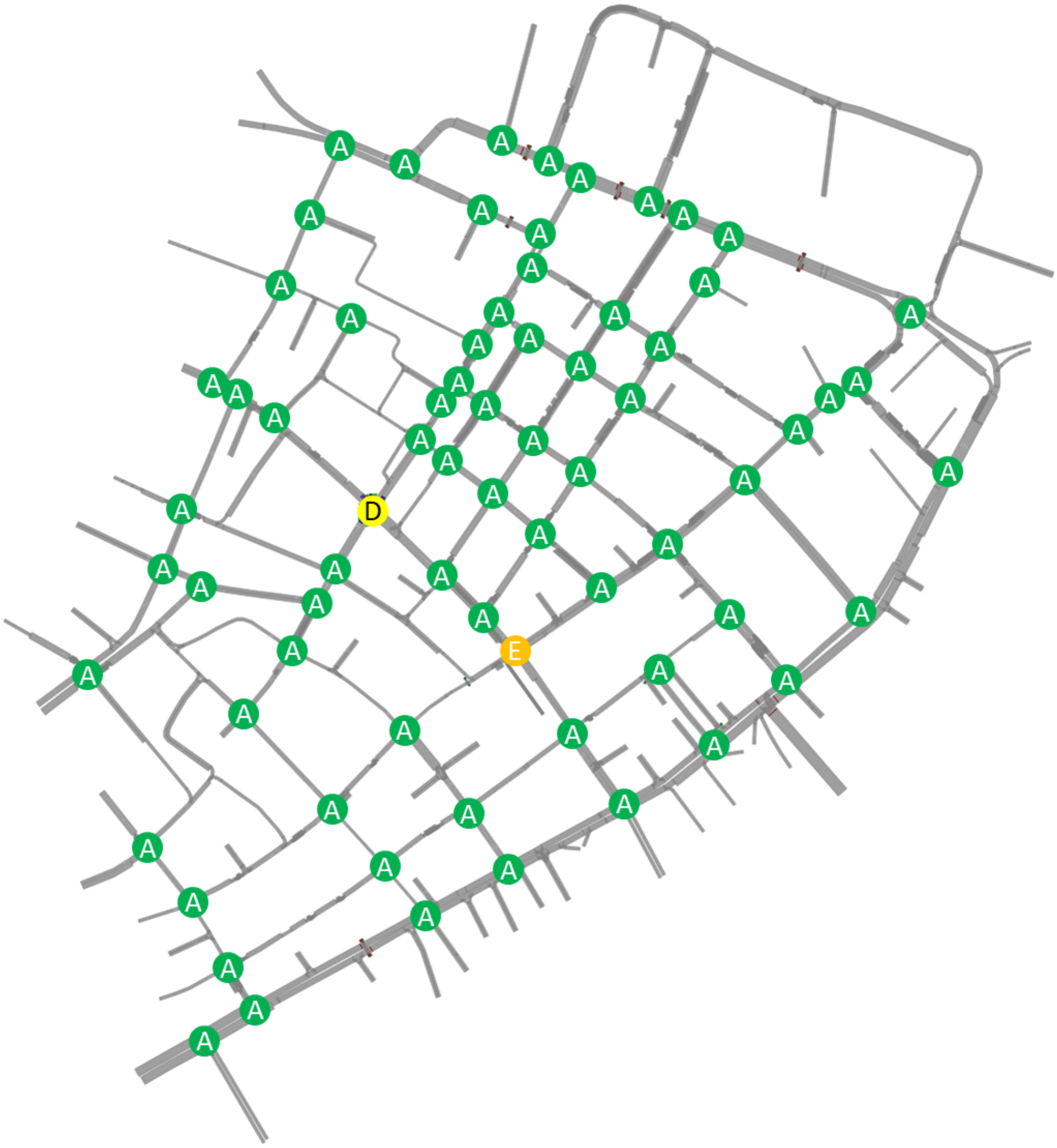


Figure 5-60 Level of Service-Scenario3 – AM Peak

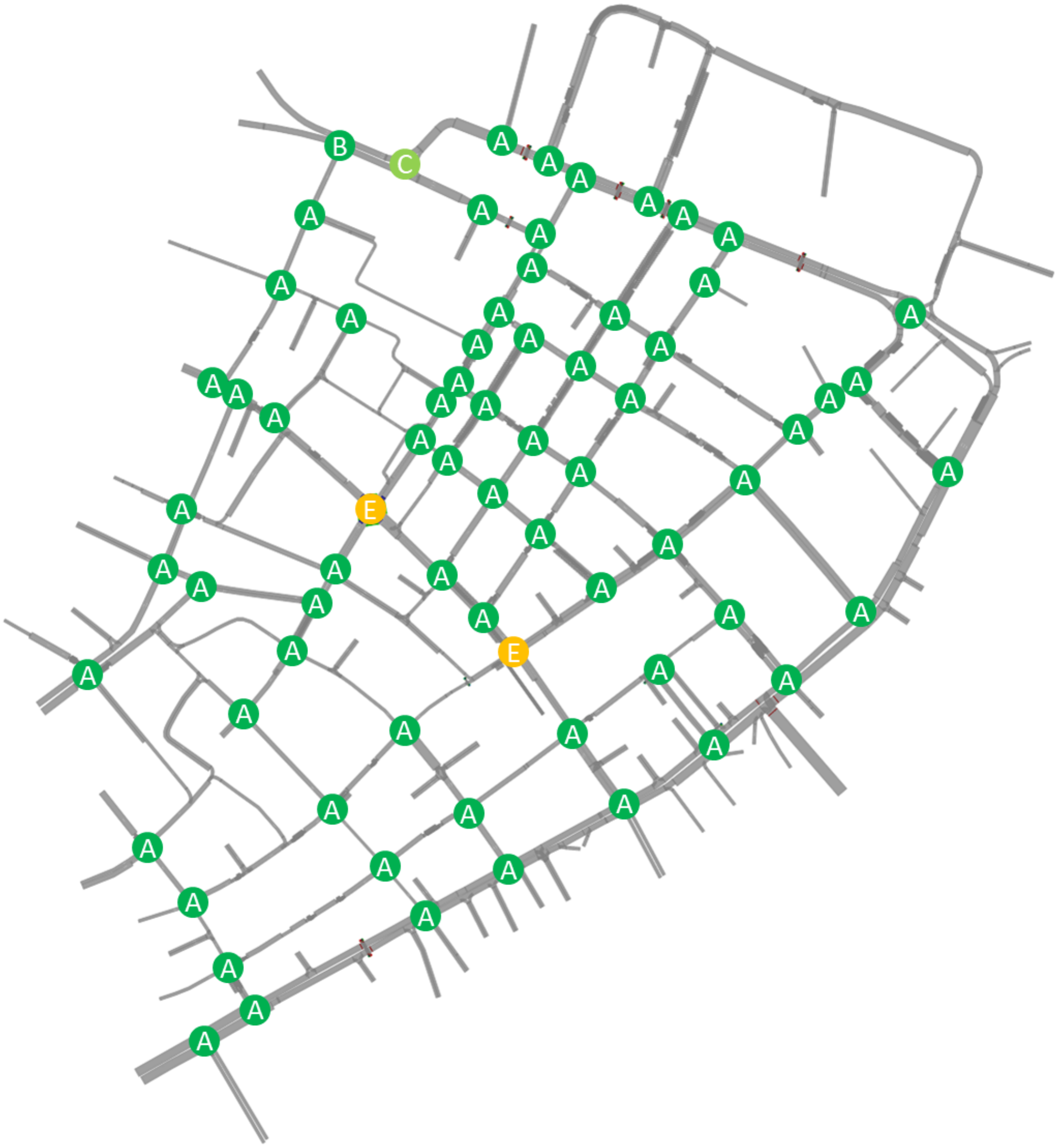


Figure 5-61 Level of Service-Scenario3 – PM peak

From the above images following observation can be done:

- All the junctions in scenario-3 are performing with LOS A expect J23 which is performing at LOS E and J34 which is performing at LOS D in AM peak;
- In PM peak, J23 and J34 is operating at LOS E. Remaining junctions are operating with LOS A or LOS B.

Delay experienced on trial area road network in scenario-3 is displayed in below graphs.

Figure 5-62 Delay-Scenario3 – AM Peak

Figure 5-63 Delay-Scenario3 – PM Peak

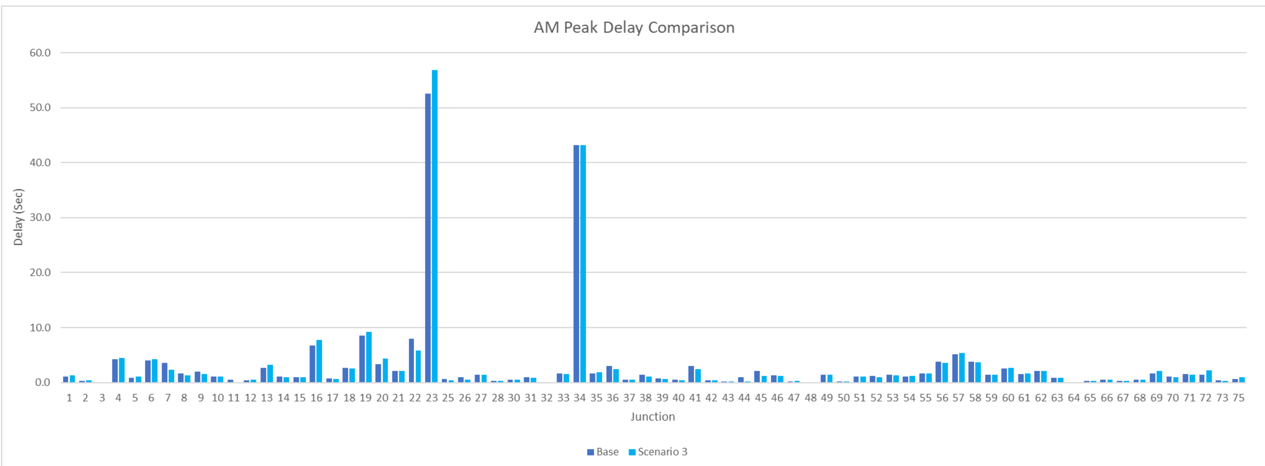


Figure 5-64 Scenario 3 - Delay Comparison -AM peak

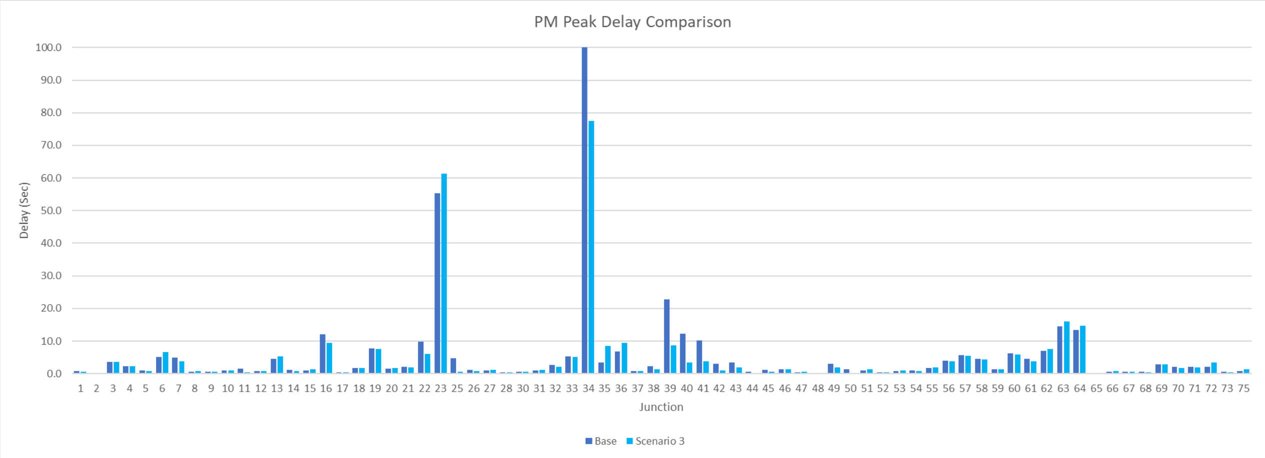


Figure 5-65 Scenario 3 - Delay Comparison -PM Peak

Following observation can be made from above delay graphs and plots:

- For all the junctions expect J23, J34, J39, J40, J41, J42 and J43, average delay is more or less same as of base scenario;
- Average Delay for J23 increased in scenario-3;
- Average Delay for J34, J39, J40, J41, J41, J42 and J43 are reduced in scenario-3 especially in PM peak;
- Overall average delay is reduced in scenario-3 by 2% and 12% in AM and PM peak respectively.

5.13.2 Vehicular-Density

Density of the road network in scenario-3 is shown in below images.

Figure 5-66 Density- Scenario 3-AM Peak

Figure 5-67 Density- Scenario 3-PM Peak

The removal of on-street parking does not impact the network density higher in both AM and PM peaks in scenario-3.

5.13.3 Vehicular Measurement: Speed

Average speed on road network in scenario-3 is demonstrated in below images.

Figure 5-68 Speed - Scenario 3 - AM Peak

Figure 5-69 Speed - Scenario 3 - PM Peak

From above graphs it can be observed that average speed on Pengkalan Weld is around 50kmph and on other roads it is 40 kmph in AM peak. Average speed along Jalan Masjid Kapitan Keling is higher than base scenario to 40kmph in PM peak.

5.14 Scenario 4

In this scenario, emphasis is given to understand the network performance after adopting road network improvement. Below sections provide the results of the assessment for scenario-4.

5.14.1 Vehicular Measurement: Delay/Level of service

LOS for all the junctions in trial study are for scenario4 are shown in below images.

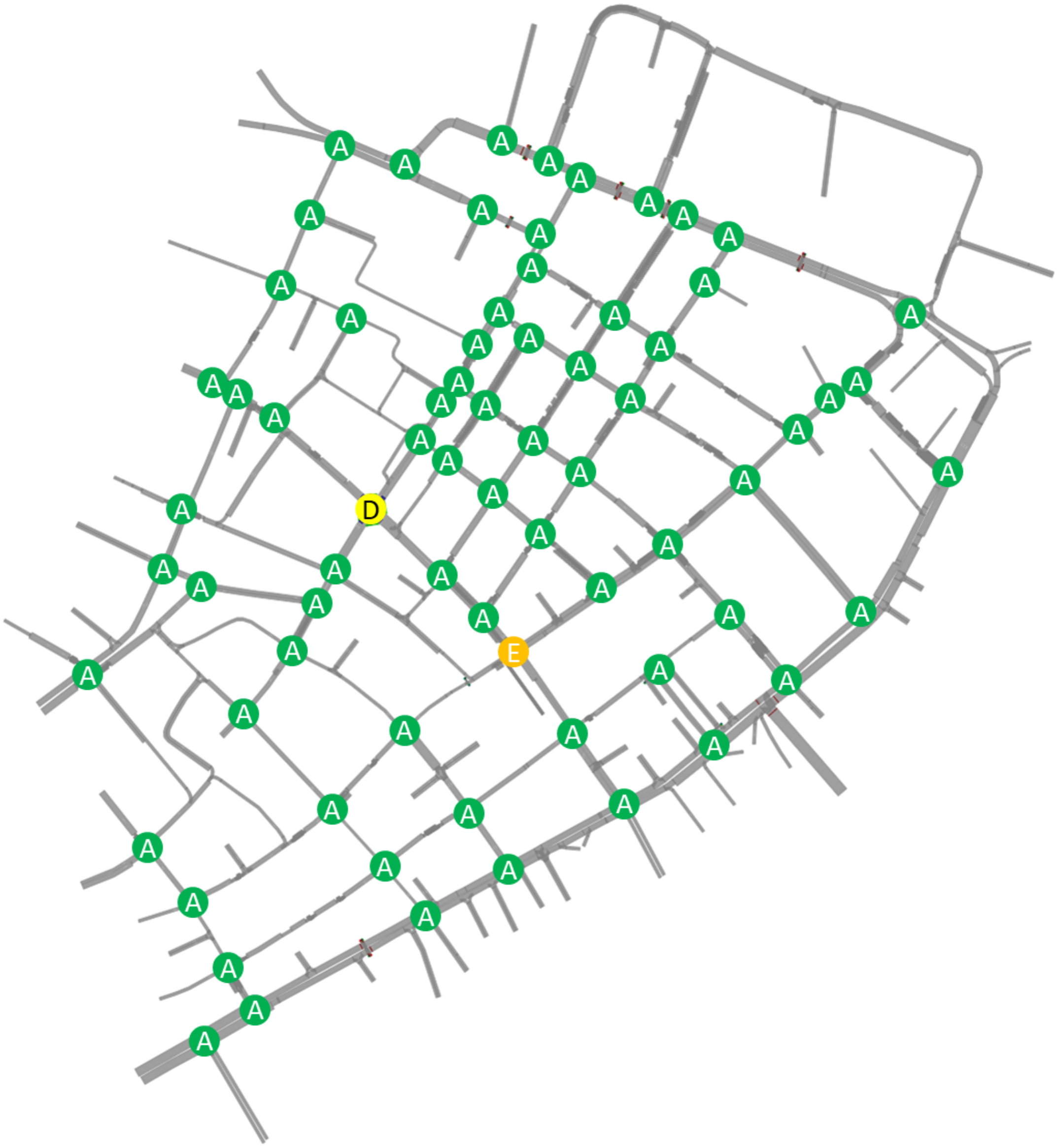


Figure 5-70 Level of Service-Scenario4 – AM Peak

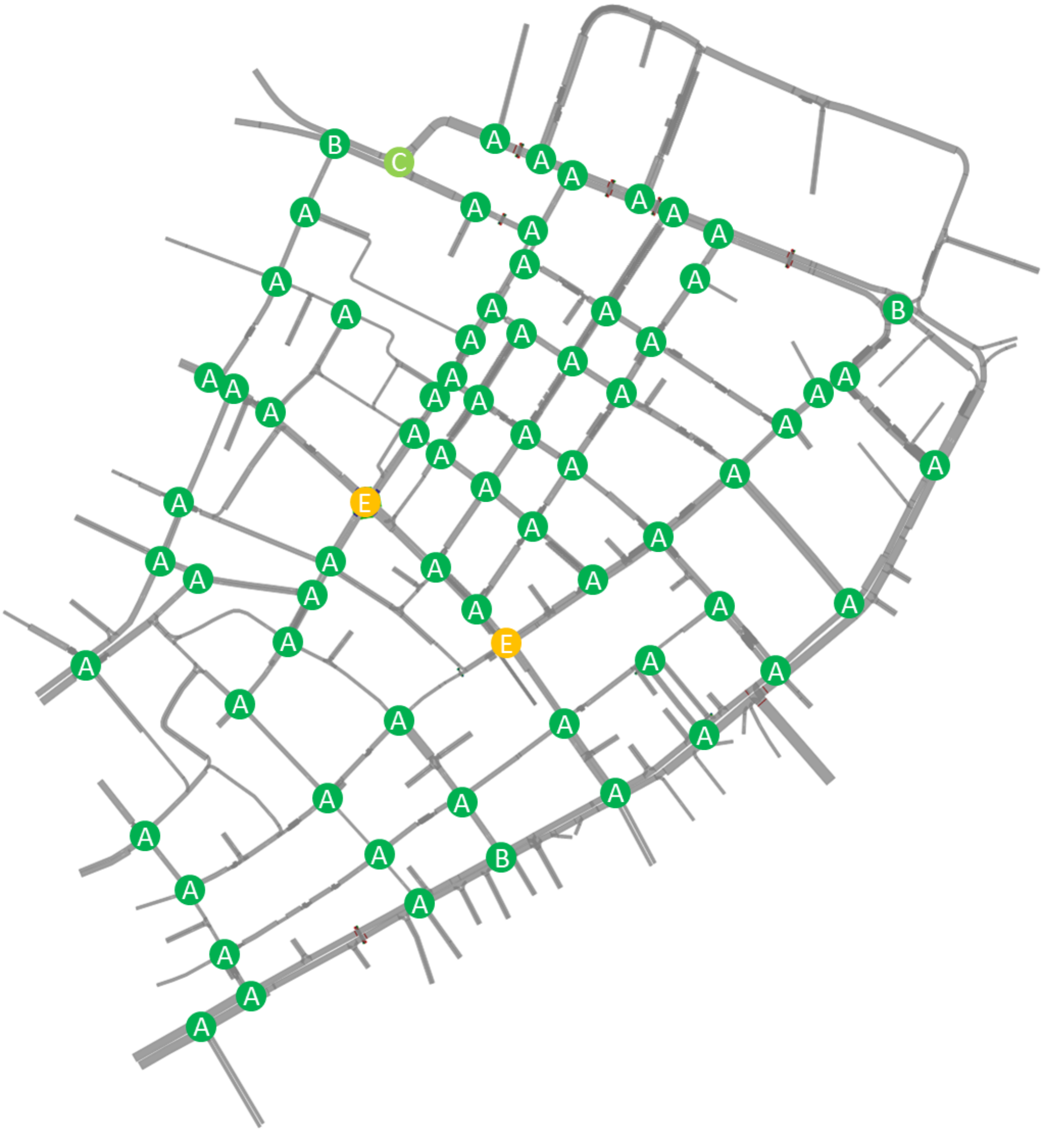


Figure 5-71 Level of Service-Scenario4 – PM Peak

From the above images following observation can be done:

- All the junctions in scenario-4 are performing with LOS A expect J23 which is performing at LOS E and J34 which is performing at LOS D in AM peak;
- In PM peak, J23 and J34 is operating at LOS E and J63 is operating at LOS C. Remaining junctions are all operating with LOS A or LOS B.

Delay experienced on trial area road network in scenario-4 is displayed in below graphs.

Figure 5-72 Delay-Scenario4 – AM Peak

Figure 5-73 Delay-Scenario4 – PM peak

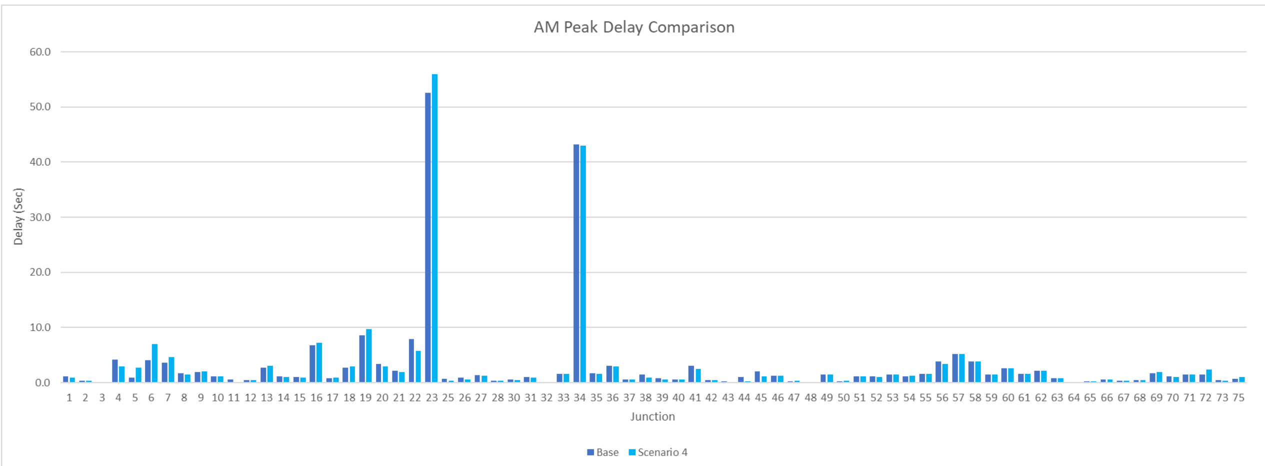


Figure 5-74 Scenario 4 - Delay Comparison -AM peak

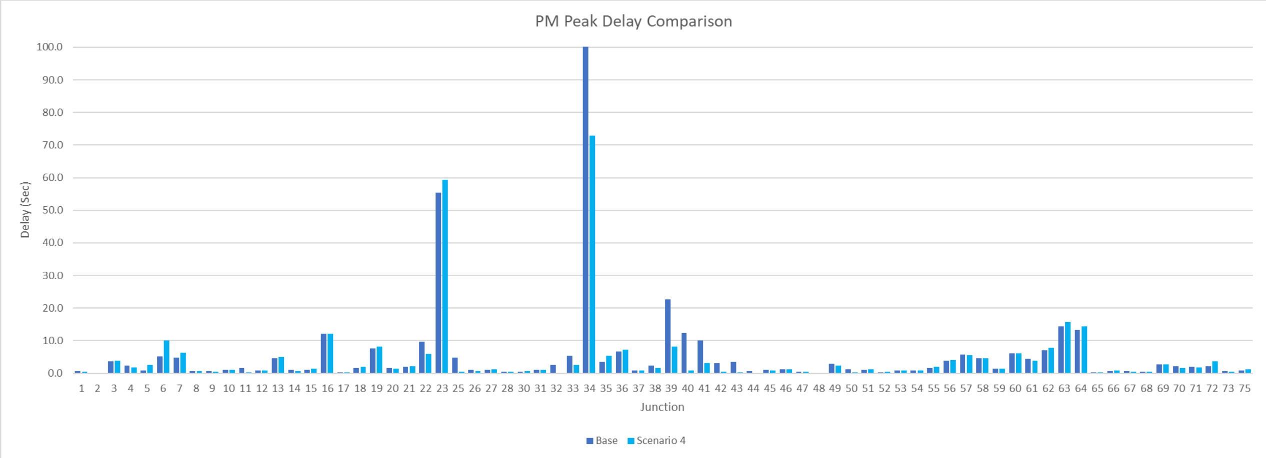


Figure 5-75 Scenario 4 - Delay Comparison - PM peak

Following observation can be made from above delay graphs and plots:

- For all the junctions expect J5, J6, J7, J23, J34, J39, J40, J41, J42 and J43, average delay is more or less same as of base scenario;
- Average Delay for J5, J6 and J7 increased in scenario-4 in both AM and PM peak because of the implementation of the traffic signal;
- Average Delay for J23 increased in scenario-4;
- Average Delay for J34, J39, J40, J41, J41, J42 and J43 are reduced in scenario-4 especially in PM peak;
- Overall average delay increased in scenario-4 by 0.5% in AM peak.
- Overall average delay reduced in scenario-4 by 9% in PM peak.

5.14.2 Vehicular Measurement: Density

Density of the road network in scenario-4 is shown in below images.

Figure 5-76 Density- Scenario 4-AM Peak

Figure 5-77 Density - Scenario 4-PM Peak

Minor increase in density is observed on Pengkalan Weld at J5, J6 and J7 due to implementing traffic signal in both AM and PM peak.

5.14.3 Vehicular Measurement: Speed

Average speed on road network in scenario-4 is demonstrated in below images.

Figure 5-78 Speed - Scenario 4-AM Peak

Figure 5-79 Speed - Scenario 4-PM Peak

From above graphs it can be observed that average speed on Pengkalan Weld at J5, J6 and J7 in both AM and PM peak dropped to 10kmph to 20kmph compared to base scenario.

5.14.4 Proposed Signalized Junctions

Junction performance of the newly proposed signalized J5, J6 and J7 is compared in the tables below.

Table 5-17 AM Peak Junction Comparison

Junction/ Scenario	Movement	Avg Modelled Queue (m)	Volume	Delay	LOS	Junction/ Scenario	Movement	Avg Modelled Queue (m)	Volume	Delay	LOS
Junction 5 Base Scenario	J5-W-Left	0	407	1	A	Junction 5 Scenario 4	J5-W-Left	4	405	3	A
	J5-W-Through	0	1654	1	A		J5-W-Through	4	1648	3	A
	J5-N-Left	1	134	10	B		J5-N-Left	0	134	5	A
	J5-E-Through	0	856	0	A		J5-E-Through	1	855	2	A
	J5-S-Left	0	28	1	A		J5-S-Left	0	28	1	A
	Total		**3079**	**1**	**A**		**Total**		**3070**	**3**	**A**
Junction 6 Base Scenario	J6-W-Left	3	164	2	A	Junction 6 Scenario 4	J6-W-Left	8	164	3	A
	J6-W-Through	3	2260	4	A		J6-W-Through	8	2253	6	A
	J6-W-Right	3	0	0	A		J6-W-Right	8	0	0	A
	J6-E-Left	0	0	0	A		J6-E-Left	5	0	0	A
	J6-E-Through	0	873	3	A		J6-E-Through	5	855	7	A
	J6-E-Right	0	46	31	D		J6-E-Right	5	43	45	D
	J6-S-Left	0	0	0	A		J6-S-Left	0	0	0	A
	J6-S-Through	3	164	2	A		J6-S-Through	8	164	3	A
	J6-S-Right	0	0	0	A		J6-S-Right	0	0	0	A
	Total		**3507**	**4**	**A**		**Total**		**3479**	**7**	**A**
Junction 7 Base Scenario	J7-W-Through	3	2288	2	A	Junction 7 Scenario 4	J7-W-Through	2	2286	1	A
	J7-N-Left	7	137	13	B		J7-N-Left	13	136	10	A
	J7-N-Right	8	155	33	D		J7-N-Right	13	155	65	E
	J7-E-Through	0	872	0	A		J7-E-Through	1	855	1	A
	Total		**3452**	**4**	**A**		**Total**		**3432**	**5**	**A**

Table 5-18 PM Peak Junction Comparison

Junction/ Scenario	Movement	Avg Modelled Queue (m)	Volume	Delay	LOS	Junction/ Scenario	Movement	Avg Modelled Queue (m)	Volume	Delay	LOS
Junction 5 Base Scenario	J5-W-Left	0	324	0	A	Junction 5 Scenario 4	J5-W-Left	2	321	3	A
	J5-W-Through	0	867	0	A		J5-W-Through	2	861	2	A
	J5-N-Left	0	234	3	A		J5-N-Left	0	233	3	A
	J5-E-Through	1	2159	1	A		J5-E-Through	3	2119	2	A
	J5-S-Left	0	57	6	A		J5-S-Left	0	57	4	A
	Total		3641	1	A		**Total**		3591	2	A
Junction 6 Base Scenario	J6-W-Left	0	178	1	A	Junction 6 Scenario 4	J6-W-Left	2	177	1	A
	J6-W-Through	0	1272	3	A		J6-W-Through	2	1270	7	A
	J6-W-Right	0	0	0	A		J6-W-Right	2	0	0	A
	J6-E-Left	12	0	0	A		J6-E-Left	43	0	0	A
	J6-E-Through	12	2342	6	A		J6-E-Through	43	2271	12	B
	J6-E-Right	12	136	9	A		J6-E-Right	43	131	22	B
	J6-S-Left	0	0	0	A		J6-S-Left	0	0	0	A
	J6-S-Through	0	178	1	A		J6-S-Through	2	177	1	A
	J6-S-Right	0	0	0	A		J6-S-Right	0	0	0	A
	Total		4106	5	A		**Total**		**4026**	**10**	**B**
Junction 7 Base Scenario	J7-W-Through	3	1292	3	A	Junction 7 Scenario 4	J7-W-Through	1	1289	1	A
	J7-N-Left	17	159	24	C		J7-N-Left	21	159	6	A
	J7-N-Right	18	247	41	E		J7-N-Right	21	251	71	E

Junction/ Scenario	Movement	Avg Modelled Queue (m)	Volume	Delay	LOS	Junction/ Scenario	Movement	Avg Modelled Queue (m)	Volume	Delay	LOS
	J7-E-Through	0	2340	1	A		J7-E-Through	2	2266	2	A
	Total		4038	5	A		**Total**		**3965**	**6**	**A**

Following observation can be made from above junction performance summary:

- Average Delay for J5 increase in scenario-4 due to the new proposed traffic signal but can operate in LOS A in both AM and PM Peak;
- Average Delay for J6 increased in scenario-4 due to the new proposed traffic signal. LOS decreased from LOS A to LOS B in PM Peak;
- Average Delay for J7 increased in scenario-4 due to the new proposed traffic signal. LOS for north approach decreased since vehicles now have dedicated green phase to come out of Gat Lebuh Acheh.

5.15 Comparison and findings

5.15.1 Vehicular Measurement: Delay

Comparison of overall road network performance of the trial study area for all the scenarios considered in terms of delay is presented in figures below.

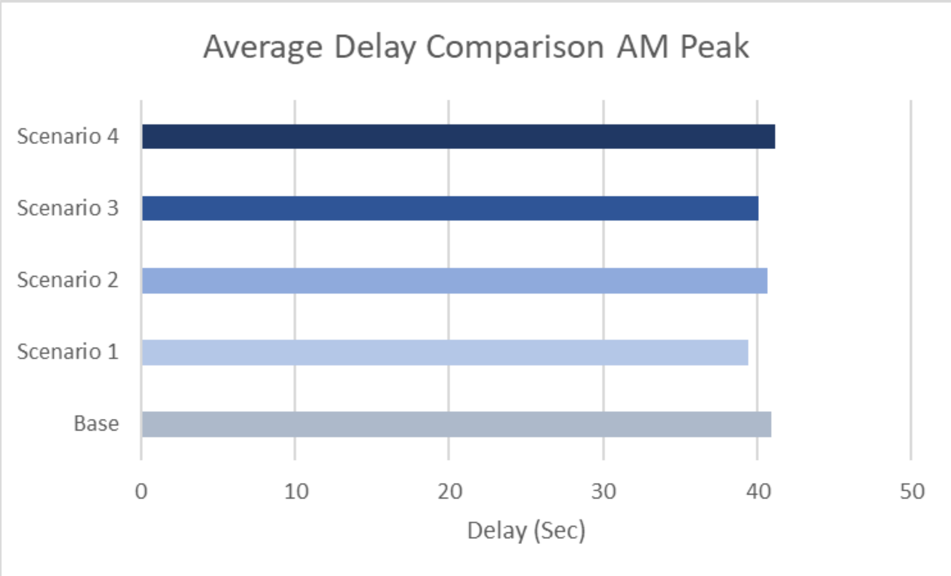


Figure 5-80 Average delay comparison – AM Peak

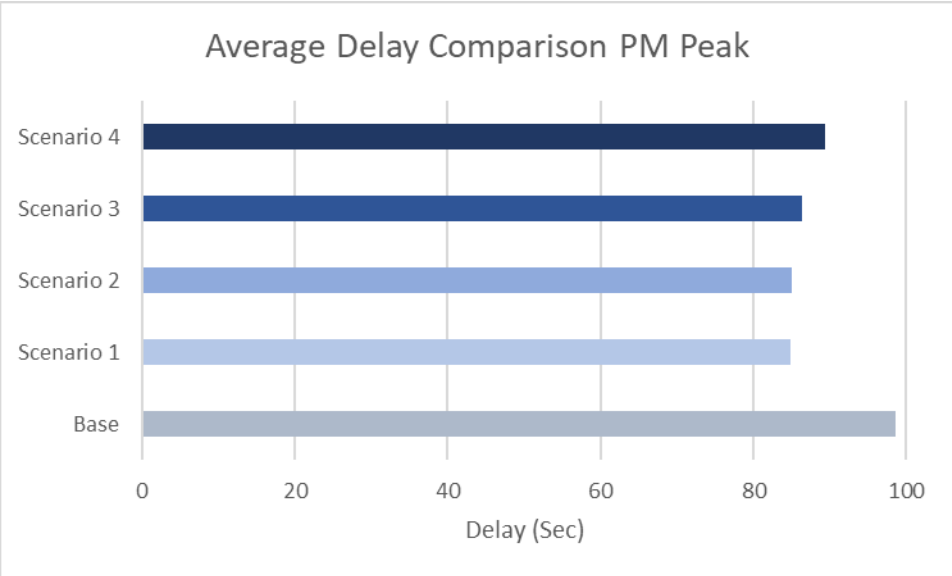


Figure 5-81 Average delay comparison – PM Peak

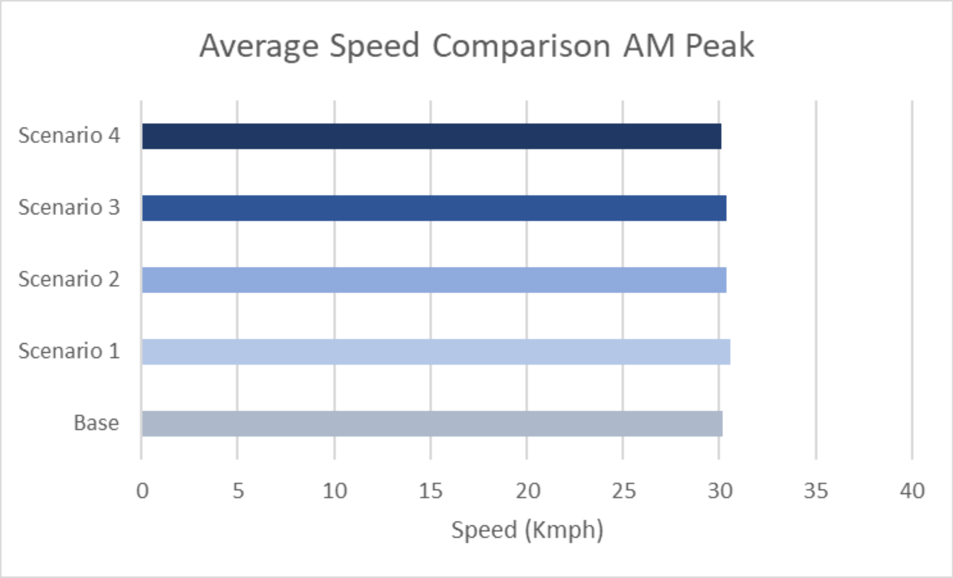
From above table, following points can be incurred when scenarios are compared with base scenario:

- Scenario 1: The introduction PT lanes in Scenario 1 does not change the network delay too much. Overall average delay decreased from 41 sec to 39 sec which is around 4% decrease in AM Peak. In PM peak overall average delay is decreased from 99 sec to 85 sec in PM peak which is 14% decrease.

- Scenario 2: Pedestrian and cyclist infrastructure improvements in study area is done in Scenario 2. Overall average delay decreased from 40.9 sec to 40.7 sec which is around 1% decrease in AM Peak. In PM peak overall average delay is decreased from 99 sec to 85 sec in PM peak which is 14% decrease.
- Scenario 3: In Scenario 3, on-street parking at certain locations of the study area is removed. Due to this improvement, capacity road is expected to increase as there are more road space provided. Overall average delay decreased from 41 sec to 40 sec which is around 2% decrease in AM Peak. In PM peak overall average delay is decreased from 99 sec to 86 sec in PM peak which is 12% decrease.
- Scenario 4: New development is proposed in the study area, which is expected cause slight increase in delay in the study area. Overall average delay increased from 40.9 sec to 41.1 sec which is around 0.5% increase in AM Peak. In PM peak overall average delay is decreased from 99 sec to 89 sec in PM peak which is 9% decrease.

5.15.2 Vehicular Measurement: Speed

Comparison of overall road network performance for all the scenarios in terms of speed is done and presented in figures below.



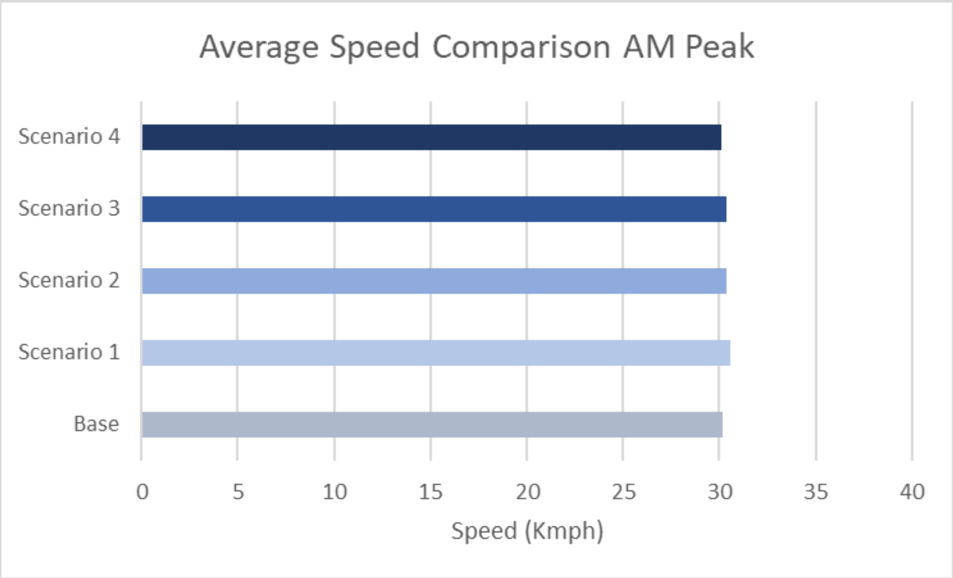


Figure 5-82 Average speed comparison – AM Peak

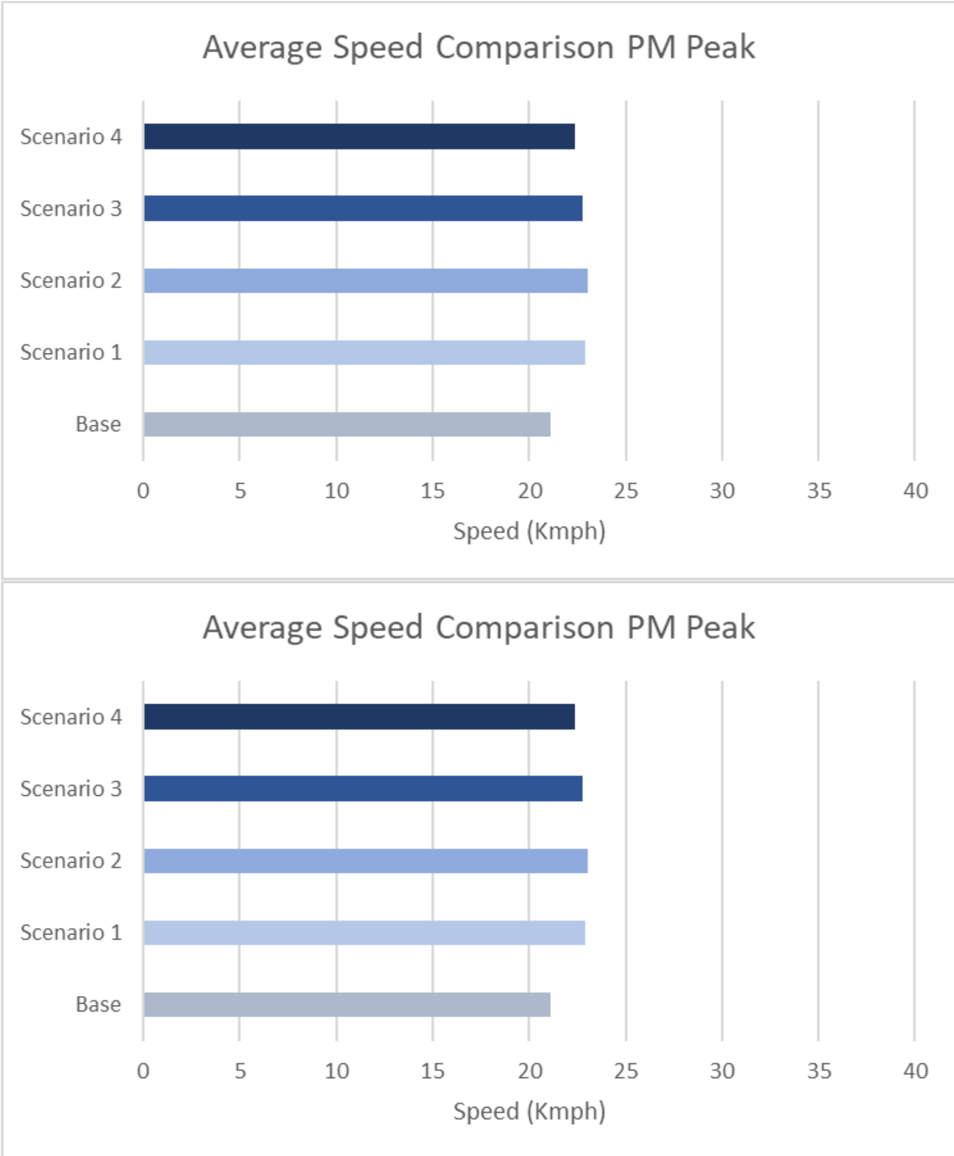


Figure 5-83 Average speed comparison – PM Peak

Following observation can be done from above speed images:

- Average speed of the network is around 30 kmph for all the scenarios in AM peak and 22 in PM Peak;
- Average speed doesn't change too much in AM peak in each scenario compared to base scenario with the difference smaller than 2%;
- Average speed increased in PM peak in each scenario compared to base scenario with the 6% to 9% increment.

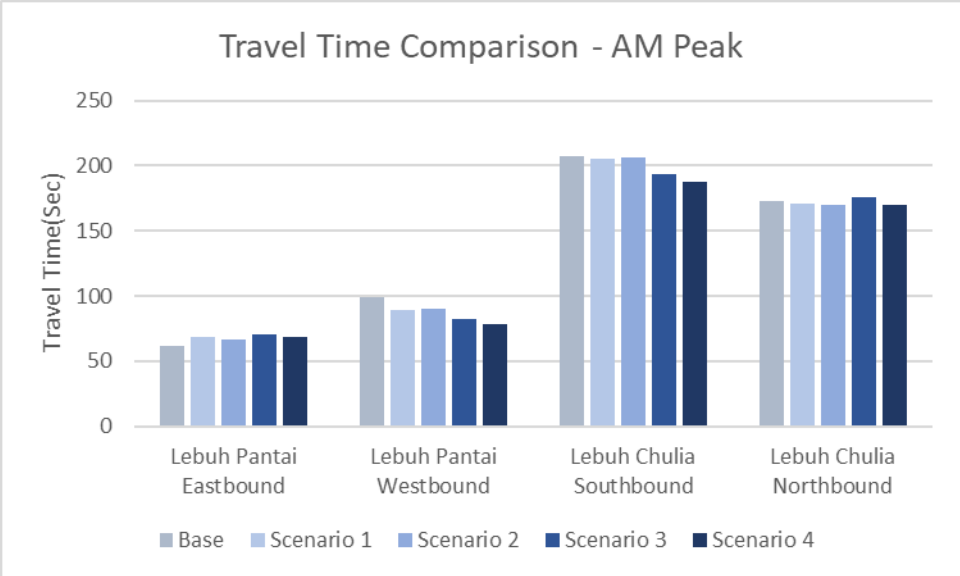
5.15.3 Travel time

Certain sections of road are randomly selected, and travel time measurements are done to understand the impact of improvements carried out in all the scenarios.

Below image shows the section considered for travel time measurements.

Figure 5-84 Travel Time Measured Road Sections

Figures below show the travel times on sections considered for all the scenarios:



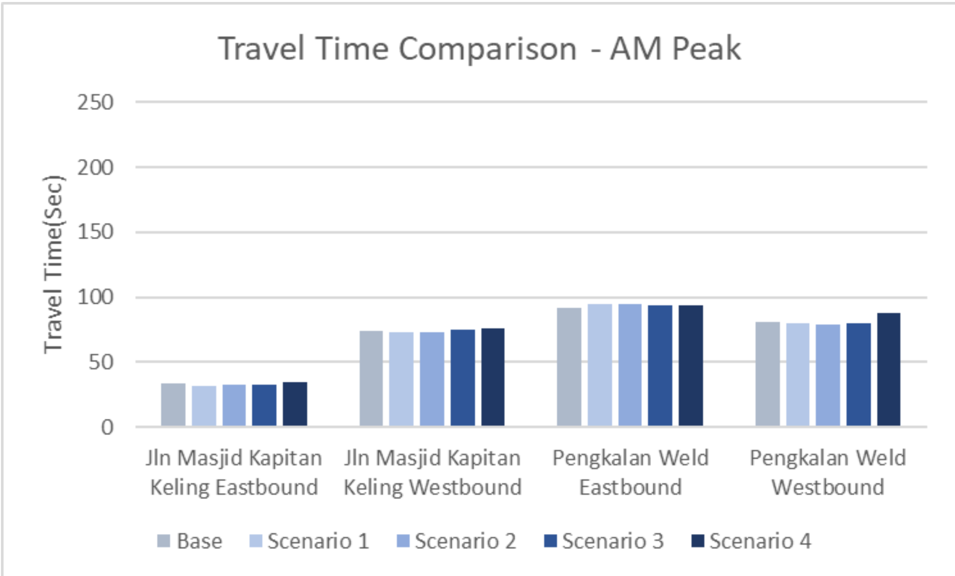
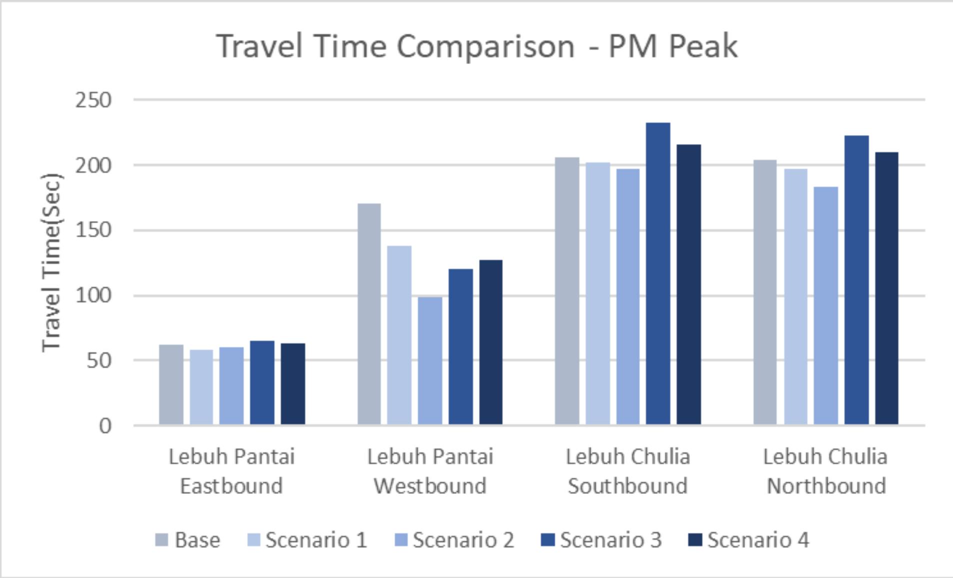


Figure 5-85 Travel Time – AM Peak



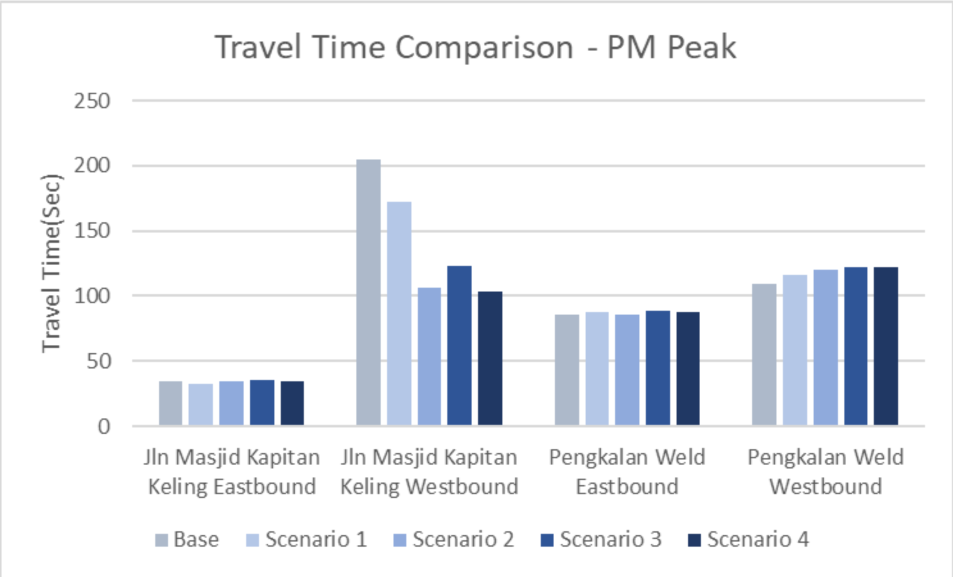


Figure 5-86 Travel Time – PM Peak

From above table, following points can be incurred:

- Lehuh Pantai East Bound: Travel time is 11%, 15% and 12% higher in AM peak in scenario-1, scenario-3 and scenario-4 when compared with base scenario. Lebuh Pantai east bound is having more or less same travel time in all scenarios in PM peak;
- Lehuh Pantai West Bound: Travel time is 18% and 21% lower in AM peak in scenario-3 and scenario-4 when compared with base scenario. Travel time is 42% and 30% lower in PM peak in scenario-3 and scenario-4 when compared with base scenario;
- Lehuh Chulia South Bound: Travel time is 10% lower in AM peak in scenario-4 when compared with base scenario. Travel time is 13% higher in PM peak in scenario-3 when compared with base scenario;
- Lehuh Chulia North Bound: Lehuh Chulia north bound is having more or less same travel time in all scenarios in AM peak. Travel time is 10% lower in PM peak in scenario-2 when compared with base scenario;

- Jalan Masjid Kapitan Keling East Bound: Jalan Masjid Kapitan Keling east bound is having more or less same travel time in all scenarios in both AM and PM peak;
- Jalan Masjid Kapitan Keling West Bound: Jalan Masjid Kapitan Keling west bound is having more or less same travel time in all scenarios in both AM peak. Travel time is 48%, 40% and 50% lower in PM peak in scenario-2, scenario-3 and scenario-4 when compared with base scenario;
- Pengkalan Weld East Bound: Pengkalan Weld east bound is having more or less same travel time in all scenarios in both AM and PM peak;
- Pengkalan Weld West Bound: Pengkalan Weld west bound is having more or less same travel time in all scenarios in both AM peak. Travel time is 11% and 12% higher in PM peak in scenario-3 and scenario-4 when compared with base scenario.

6. PLANNING AND POLICY RECOMMENDATIONS

This chapter outlines the microsimulation modelling use cases in an urban context and its specific use on traffic impact assessment process. The software outputs form an integral part of traffic impact assessment submission reports in various countries.

6.1 Micro-Simulation Modelling and Use Cases

The following sections document the process of the demonstration model.

VISSIM is a microscopic, multi-modal traffic flow simulation software package developed by PTV Group. It's widely used for traffic engineering studies, transportation planning, and designing road networks. Here's a typical use case scenario for VISSIM:

Traffic Impact Analysis: City planners, engineers, and developers often use VISSIM to simulate the impact of new developments or infrastructure changes on traffic flow. For example, if a new shopping mall is being built, planners can simulate how the additional traffic generated will affect nearby intersections, roadways, and overall traffic patterns.

Intersection Design and Optimization: VISSIM can be used to design and optimize intersections to improve traffic flow and safety. Engineers can simulate different intersection configurations, signal timings, and lane layouts to identify the most efficient design before implementation in the real world. This helps in reducing congestion and improving the overall traffic efficiency.

Public Transport Planning: VISSIM can simulate not only vehicular traffic but also public transportation systems like buses and trams. Planners can use VISSIM to design and optimize bus routes, transit schedules, and station locations to improve accessibility and efficiency for public transport users.

Traffic Management and Control: VISSIM can simulate various traffic management and control strategies such as traffic signal coordination, dynamic lane assignment, and ramp metering. By simulating these strategies, traffic engineers can identify the most effective ways to alleviate congestion and improve traffic flow on road networks.

Safety Analysis: VISSIM can also be used for safety analysis by simulating different traffic scenarios and identifying potential safety hazards such as high crash-prone areas, conflicts between different modes of transportation, and pedestrian safety concerns. This information can then be used to implement safety measures and design safer road networks.

Environmental Impact Assessment: VISSIM can help in assessing the environmental impact of transportation projects by simulating traffic emissions, energy consumption, and noise levels. Planners can use this information to make informed decisions about transportation projects that minimize environmental impact.

Overall, VISSIM is a powerful tool for simulating and analyzing various aspects of traffic flow and transportation systems, helping planners and engineers make data-driven decisions to improve urban mobility, safety, and sustainability.

6.2 Simulation and Traffic Impact Assessment

Simulation is a valuable tool in traffic impact assessment (TIA) because it allows transportation planners and engineers to predict and evaluate the effects of proposed developments or infrastructure projects on the surrounding road network. Here's how simulation is used in traffic impact assessment:

1. **Modeling Existing Conditions:** Before assessing the impact of a proposed development, planners use simulation software like VISSIM to model existing traffic conditions in the study area. This involves inputting data such as traffic volumes, road geometry, signal timings, and other relevant parameters to create an accurate representation of the current traffic flow.

2. **Trip Generation and Distribution:** Planners estimate the number of trips generated by the proposed development based on factors such as land use, size, and type of development (e.g., residential, commercial, industrial). Simulation software helps in distributing these trips to the surrounding road network based on travel patterns and available transportation infrastructure.

3. **Impact Analysis:** Once the trips generated by the proposed development are distributed to the road network, simulation software is used to analyze the impact on traffic flow, congestion, travel times, and other performance measures. Planners can assess how the additional traffic affects intersections, road segments, and other key points in the network.

4. **Intersection Analysis:** Simulation allows for detailed analysis of intersections affected by the proposed development. Planners can evaluate intersection capacity, queue lengths, delays, and level of service under existing and future conditions. This information helps in identifying potential congestion hotspots and determining the need for intersection improvements.

5. **Network-Wide Effects:** Simulation enables planners to assess the network-wide effects of the proposed development by considering interactions between different roads, intersections, and traffic flow patterns. This holistic approach helps in understanding how changes at one location can propagate throughout the entire network.

6. **Evaluation of Mitigation Measures:** Planners can use simulation to evaluate the effectiveness of mitigation measures aimed at alleviating traffic impacts. This could include strategies such as signal timing adjustments, road widening, adding turn lanes, implementing traffic calming measures, or improving public transit options. Simulation allows planners to assess the potential effectiveness of these measures before implementation.

7. **Sensitivity Analysis:** Simulation facilitates sensitivity analysis to understand how changes in key parameters (e.g., trip generation rates, development design, transportation network configurations) impact traffic outcomes. Planners can explore various scenarios to identify the most effective strategies for mitigating traffic impacts while considering different uncertainties and factors.

8. **Documentation and Reporting:** Simulation results are used to document the findings of the traffic impact assessment. Planners prepare reports and presentations summarizing the predicted impacts of the proposed development, the effectiveness of mitigation measures, and any recommendations for transportation improvements or changes in land use planning.

Overall, simulation plays a crucial role in traffic impact assessment by providing planners and decision-makers with valuable insights into the potential effects of proposed developments on the transportation network and guiding the development of strategies to mitigate negative impacts and improve overall traffic performance.

6.3 Traffic Impact Assessment Guidelines

The following section provides the sample impact assessment guidelines generally adopted for any new development or infrastructure changes that impact the existing network and has proposals of change in road configuration that might change and network traffic results of the future.

The TIA guidelines document is attached as an Appendix 6.

7. GENDER EQUALITY, DISABILITY AND SOCIAL INCLUSION

The AASCTF has three crosscutting themes which guide the program's approach: Gender Equality, Disability, and Social Inclusion (GEDSI); climate change/resilience; and private sector engagement. On GEDSI, the AASCTF's GEDSI Strategy outlines a twin track approach to GEDSI in interventions – GEDSI mainstreaming and targeted GEDSI interventions where specific needs and opportunities are identified.

The focus of this task order is to model micro-simulation interventions in the heritage area. While GEDSI mainstreaming has been implemented where appropriate and possible, the potential to meaningfully address GEDSI has been limited by the narrow scope of the intervention. GEDSI may, however, be further and more tangibly considered and addressed in the application of the model and interaction of the model with city planning. Thus, the following sections undertakes to address aspects important for inclusive planning of transport infrastructure facilities in Penang, with a specific focus on accessibility of transport infrastructure for persons with disabilities.

"Building on the UN Secretary-General's statement on disability inclusion, we need everyone, including persons with disabilities, on board to achieve the Sustainable Development Goals. Both the Convention on the Rights of Persons with Disabilities (CRPD) and the 2030 Agenda call for placing persons with disabilities at the center of all our efforts, as agents of planning and implementation. According to UN data, of the one billion people with disabilities around the world, 80 percent live in developing countries. The COVID-19 pandemic has deepened pre-existing social and economic inequalities associated with disabilities and threatens to exacerbate them further.

We also need to revisit the way we plan our cities as it has become clear that following standards and adhering to best practices can make human settlements more resilient. Ensuring inclusivity is at the heart of managing cities. Public spaces designed for sustainable mobility and transportation are a great way to rethink our cities." [8]

7.1 Persons with Disabilities

Disability is an evolving concept that results from the interaction between persons with impairments and attitudinal and environmental barriers that hinders their full and effective participation in society on an equal basis with others.[9] Disabilities can be obvious or invisible, and they can appear at any age, including birth, childhood, adolescence, adulthood, and older persons. People with disabilities are diverse and complex; nonetheless, stereotyped perceptions of impairments focus on wheelchair users and people with visual and hearing impairments (Park, Curtice, Thomson, Phillips, & Johnson, 2011). The table below shows the official definition of persons with disabilities contained within the Persons with Disabilities Act 2008, Malaysia.

8 Under-Secretary General & Executive Director, United Nations Human Settlements Programme (UN-Habitat), Access and Persons with Disabilities in Urban Areas

[9] UN Convention on the Rights of Persons with Disabilities, 2007, preamble (e).

Table 7-1 PWD Definition

Code	Definition
The Persons with Disabilities Act 2008, Malaysia	Persons with Disabilities are those who have long term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder their full and effective participation in society

Source: ACCESSIBILITY FOR PERSONS WITH DISABILITIES IN BUILT ENVIRONMENT OF URBAN AREA: CASE STUDY OF GEORGE TOWN, PENANG, Journal of Malaysian Institute of Planners

Table 7-2 Categories of PWD by the Department of Social Welfare Malaysia

Category	Definition
Hearing	Unable to hear clearly in both ears without using a hearing aid or incapable of hearing even when using a hearing aid.
Vision	Blinds in either eyes or blind in one eye, or vision impaired in either eyes or any other permanent visual impairment.
Speed	An inability to speak impairs proper communication and is impossible to understand to those who interact with the individual. It is a permanent or incurable condition. For children, it must be based on an evaluation at five years of age and above. An Otorhinolaryngology Expert shall be consulted in case of doubt.
Physical	The permanent impairment of parts of the body, whether caused by damage or absence or the failure of any part of the body to perform its essential functions thoroughly, results from injury (trauma) or disease.
Learning Difficulties	Intellectual capacity which does not conform to biological age. Late Global Development, Down Syndrome and Intellectual Disabilities are the ones that fall within this category.
Mental Disability	Refers to a condition of severe mental illness that causes an inability to function in person, in whole or in part, in matters relating to him/herself or his / her relationship within the community.
Multiple Disabilities	Having more than one type of disability and usually not being categorized in categories 1 to 7 is not common

Source: ACCESSIBILITY FOR PERSONS WITH DISABILITIES IN BUILT ENVIRONMENT OF URBAN AREA: CASE STUDY OF GEORGE TOWN, PENANG, Journal of Malaysian Institute of Planners

7.2 Legislation, Statutory and Guideline for Persons with Disabilities

Malaysia's government has made a concerted effort to recognize and promote the rights of persons with disabilities by enacting legislation and providing guidelines. Accessibility to a location, public circulation, where it can be pursued by all people, equipment, or the use of every member of society, priority security, and the duty of each responsible party are all highlighted in the legislation. The table below summarizes Malaysia's legislation aimed at maintaining and improving the living standards of persons with disabilities.

Table 7-3 Regulation Employed by Malaysia to Protect Right of PWD

Policy / Act / Legislative	Definition
Uniform Building By-Laws: UBBL (34A)	The Uniform Building By-Laws 1984 was amended in 1990 to supplement the provisions of by-law 34A. 34A requires improvements to buildings for public use to enable Persons with Disabilities to get into, out of and within. (Legal Research Board Malaysia, 1984).
Malaysian Standard (MS)	Malaysian Standard 1183:1990 - Code of Practice for Means of Escape for Disabled Persons - This MS is used as an instruction to design and modify new buildings. In the sense of fire safety, it provides the planning, intervention, and obligation to be extended to building for people with disabilities (Department of Standards Malaysia, 1990). Malaysian Standard 1184:2002 - Code of Practice for Access for Disabled Persons to Public Buildings - This MS-specific the basic requirements for elements of a building and related facilities to permit access by Persons with Disabilities Department of Standards Malaysia, 2002). Malaysian Standard 1131:2003 - Code of Practice for Access for Disabled Persons Outside Buildings - Specifies the basic requirements for providing and designing outdoor facilities so that disabled persons can access facilities and make them usable (Department of Standards Malaysia, 2003).
Persons with Disabilities Act 2008	The Person with Disabilities Act (2008) encourages the development and improvement of the quality of life and well-being of disabled persons. It has given a new breath to disabled people in Malaysia, especially about the protection, development and welfare of Persons with Disabilities, registration, rehabilitation, and the establishment of a national council to protect the rights of Persons with Disabilities. with disabilities (International Labour Organization, 2008).

Source: ACCESSIBILITY FOR PERSONS WITH DISABILITIES IN BUILT ENVIRONMENT OF URBAN AREA: CASE STUDY OF GEORGE TOWN, PENANG, Journal of Malaysian Institute of Planners

7.3 Summary of Case Study of Georgetown, Penang – Accessibility for Persons with Disability in Built Urban Area, 2021[10]

Persons with Disabilities confront several challenges that hinder them from fully exercising their rights and participating in social, professional, and cultural activities when it comes to accessing built environment. This report explores some of the accessibility challenges that persons with disabilities face in George Town, Penang through summarizing the key findings from a case study on this topic published in the Journal of the Malaysian Institute of Planners. The questionnaire survey techniques employed was to obtain data from persons with disabilities, including from wheelchair users, the walking impaired, the visually impaired, and the hearing impaired in George Town areas.

In the George Town case study, a total of 329 respondents took the survey. Most walking impaired people face three main issues: obstruction on sidewalks such as vehicles, garbage, signage, utility poles, and other objects (68.2 per cent of total respondents), narrow sidewalks (67.4 per cent), and inconsistent sidewalk surface quality and conditions (67.4 per cent) (50.4 per cent). Obstruction on sidewalks such as vehicles, rubbish, signage, utility poles, and other obstructions are the top two difficulties for visually

[10] Journal of the Malaysian Institute of Planners VOLUME 19 ISSUE 5 (2021), Page 53 – 65

impaired people, according to 68.8% of respondents, followed by inconsistent sidewalk surface quality and conditions (50.0 per cent). In terms of hearing-impaired people, there are two major issues that respondents face: which are obstruction on sidewalks such as vehicles, garbage, signage, and utility poles, which was experienced by 81.8 per cent of the total respondents, and inconsistent sidewalk surface quality and conditions, that was experienced by the remaining respondents (54.5 per cent). Finally, wheelchair users face obstacles such as vehicles, garbage, signage, utility poles, and other objects on sidewalks (79.3%), dangerous drop curb conditions (75.9%), lack of proper sidewalks (75.0%), inconsistent sidewalk surface quality and conditions (74.1%), narrow sidewalks (69.8%) and a lack of shelter and covered areas (55.2 per cent).

Some of the other challenges experienced by persons with disabilities in navigating the built environment are noted to include uneven sidewalk surface, incorrect placement of street furniture, wrongly placed textured pavement blocks, hostile pedestrian crossing for disabled individuals, a lack of or dangerous design of a drop curb, and inability to see the signboards.

George Town is no exception. As the areas are well connected, vehicle mobility in Georgetown (Penang Island) is unaffected by obstructions or challenges. On the other hand, it is the opposite for pedestrian movements, particularly those involving persons with disabilities. Because of the ways in which the built environment is organized to prioritize vehicles, access to George Town is either difficult or impossible for persons with disabilities without assistance. This is evidenced by the shared experience of a wheelchair user travelling in George Town, who mentioned low quality, steepness and lack of curb ramps that prohibit the confidence among those with impairments and wheelchair users from leaving the footpaths or crossing the road. Besides that, non-level access and gaps between infrastructure platforms have been listed as frequent problems while travelling around the city.

7.3.1 Recommendations from the Study

The study recommends that future planning to develop and expand the built environment infrastructure is required, which can be done in phases. As Malaysia moves toward becoming a more developed nation, ongoing legislation and reviews are crucial for the future well-being of persons with disabilities. Aside from that, the study notes that future project consultations, task force consultants, and organizing seminars on universal interior and exterior design are all examples of ways to recognize the basic needs of persons with disabilities. Professional involvement, government involvement, and critically, the involvement of persons with disabilities themselves as reference sources can help solve difficulties in this local context. Finally, Malaysians is recommended to study countries that have effectively implemented Universal Design principles and those that have struggled to do so in order to avoid making the same mistakes.

7.4 Recommendations from Penang Green Transport Master Plan

The ADB (Asian Development Bank) and IMT-GT (Indonesia-Malaysia-Thailand Growth Triangle) jointly supported the development of Green Transportation Plans that was completed in 2019. AASCTF recommends that Penang implements the recommendations made in the Green Transport Master Plan. A brief summary of the challenges faced by differently abled people on the existing infrastructure facilities in Penang is provided, based on the Green Transportation Plan work.

7.4.1 Inconsistent Sidewalks

The Green Transport Master Plan lays stress on the inconsistent sidewalks that causes difficulty in accessibility. Some of the observations made in Green Transport Master Plan are provided below:

It often has different elevations from building to building which impose great barrier for senior citizen, people with disability and/or wheelchair users. The 5-foot design is also not wide enough to be able to serve high volume of pedestrian.

For a World Heritage Site Area, cycling should get priority over cars. Streets inside the focus area mostly serve on-street parking while bike lanes are often shared with the drive lane or shared on the sidewalk.

Figure 7-1 Inconsistent Sidewalks in Penang

7.4.2 Provision of Facility at Bus Stops

The Green Transport Master Plan stresses on provision of efficient bus stop accommodating the need for Non-Motorized Transport as well as differently abled requirements. The Plan recommends installation of access facilities at other bus stops very similar to facilities provided at Jalan Penang and Lebuh Light.

Figure 7-2 Bus Stop at Jalan Penang

Figure 7-3 Bus Stop at Lebuh Light

7.4.3 Boarding and Crossing Facilities for Persons with Disability

Green Transport Master Plan stresses on the need to augment transport infrastructure facilitates as it observes a slow boarding process at terminals and bus stops mainly caused by the gap or distance between curb and bus door. It has been recommended to bridge the gap between the bus floor height and the footpath surface to provide seamless boarding and alighting. The challenge of difference in height is presented in image below.

It is also specifically mentioned in Green Transport Master Plan that many of the bus stops are also located far from safe and universal crossings. “Even though pedestrian bridge is available near Jetty Terminal, almost nobody use the facility since they have to walk 5 meters up the bridge through stairs, and would then take much longer time than crossing at-grade, albeit unsafe and without any proper crossing facility.”

The Green Transport Master Plan recommends to provide seamless transfer facilities for differently abled to make public transport user friendly.

Figure 7-4 Inconvenient Boarding Alighting at Bus Stops and Terminals

7.4.4 Parking Facility for Differently Abled

Parking for the differently abled in not chargeable. Persons that are entitled to park free because they are disabled, must have obtained a disabled card, which is issued by the Local Council on the basis of a doctor's attest. On street there are no specific places for handicapped with a size that would enable a person in a wheelchair to properly get in and out of his or her car using the wheelchair. Also, the city does not have a minimum standard for a share of disabled parking places its parking provisions for new building (often 2% is used).

The Green Transport Master Plan Local recommends improvement in regulations regarding the provision of parking space for persons that are differently abled.

Figure 7-5 Differently Abled Parking Sticker

7.5 Adoption of Walking & Cycling Plan – Singapore Case

The adoption of walking and cycling plan is an important consideration in countries like Singapore and Land Transport Authority provides approval to any infrastructure development. Streamlining Traffic Impact Assessment and creating a Walking and Cycling Plan will help enable provision of sustainable infrastructure for the future years. Singapore case is referred as Malaysia is more culturally and regionally inclined to Singapore.

A brief of some aspects of the design are presented below but it is recommended to refer to the walking and cycling plan attached as an Appendix.

Roadside elements refer to those within the roadside table, which facilitate the movement of people along the road. They form the key urban design elements to make the public streetscape friendly, vibrant and attractive. They are typically located within the road reserve that indicates the extent of the existing or future road and its related facilities such as footpaths, cycling paths, bus bays, covered linkways and other commuter facilities.

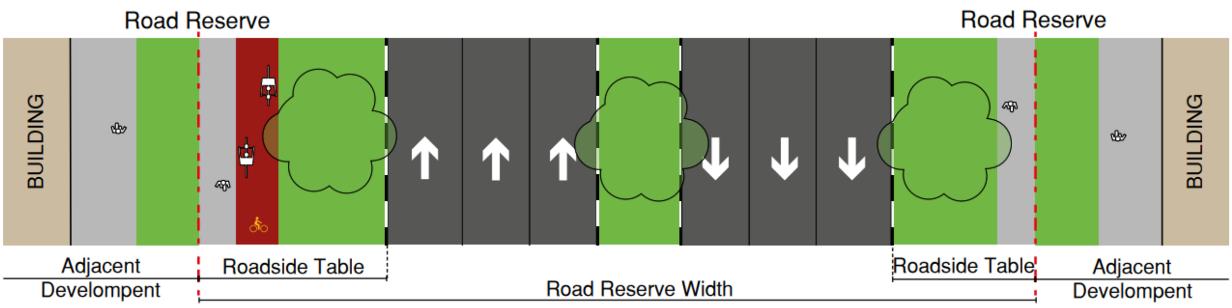


Figure 7-6 Right of Way Considerations

Footpath is a vital roadside element as it facilitates pedestrian movement and enhances overall connectivity. Accessible, safe, comfortable, and well-maintained footpaths enhance walking experience and promote walking as a mode of transport for short-distance commuting.

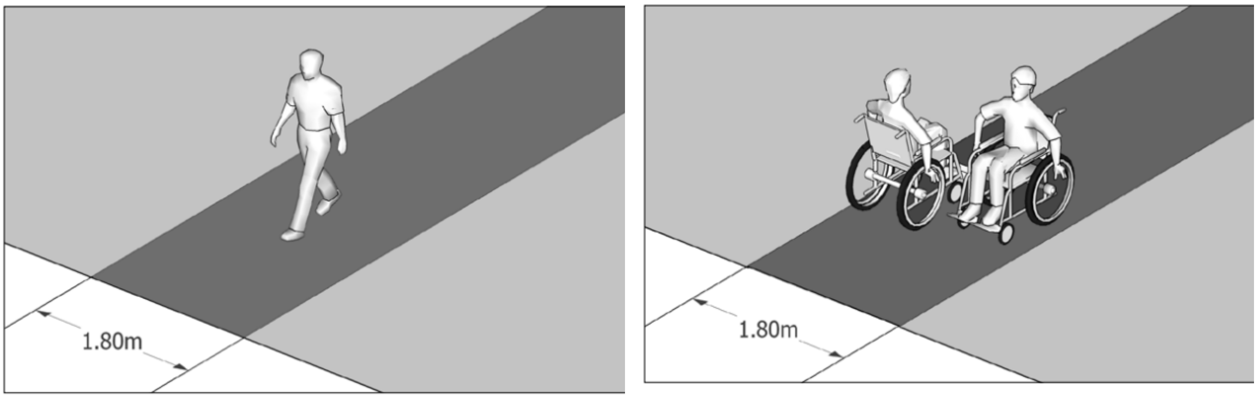
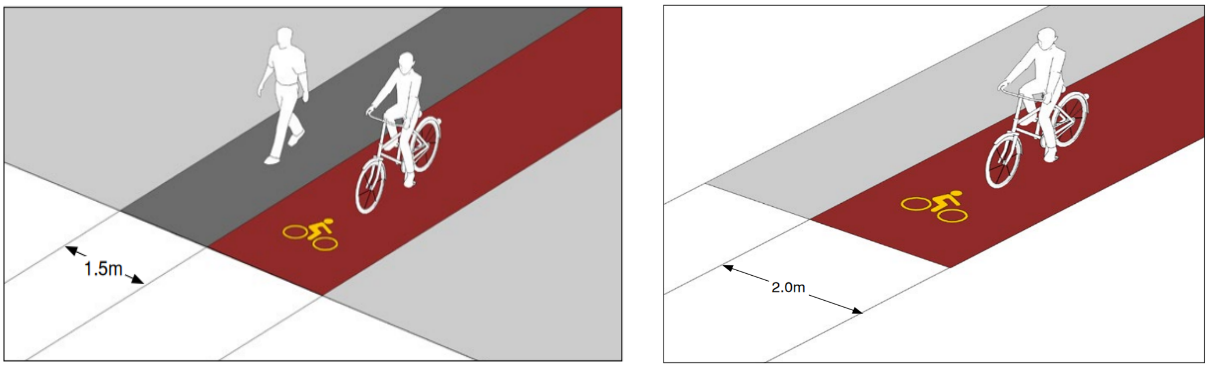


Figure 7-7 Width of Footpath

With Singapore's reference, the use of Personal Mobility Aids (PMAs), (e.g. wheelchairs, mobility scooters, etc.) is becoming more prevalent. New footpaths have been increased from 1.5m to 1.8m, which is the adequate width for two typical wheelchairs to pass each another, where there are observed or projected high pedestrian volume, footpath widths of more than 1.8m would be considered.

Cycling paths adjacent to footpaths may be used to negotiate maneuvering space required by pedestrians, including wheelchair users. Under such circumstances, 1.5m is adopted as the dedicated pedestrian width. Intra-town cycling paths facilitate short utilitarian distance trips within the town, and connect cyclists to the major public transport nodes (e.g. MRT, bus interchange). To improve the first- and last-mile connectivity, commuters are encouraged to cycle as a commute option to save time.



ABOVE: Dimension of footpath is 1.5m when sited next to a cycling path

ABOVE: Intra-town cycling path requires minimally 2m width for bi-directional movements.

Figure 7-8 Width of Bicycle Tracks

Tactile tiles and kerb ramps are provided at areas near crossings to remind pedestrians, especially pedestrians with vision impairment, to be vigilant while crossing the road.

Figure 7-9 Tactile Tiles for Differently Abled

The planning should cover the following pedestrian groups:

- (i) infants and children
- (ii) expectant mothers
- (iii) older persons
- (iv) wheelchair users
- (v) the ambulant disabled
- (vi) persons with visual impairment
- (vii) persons with hearing impairment

The bus bays must be planned with adequate access space without hindering access facilities for pedestrians and cyclists. It is recommended to refer to the detailed Walking & Cycling Plan of Singapore.[11]

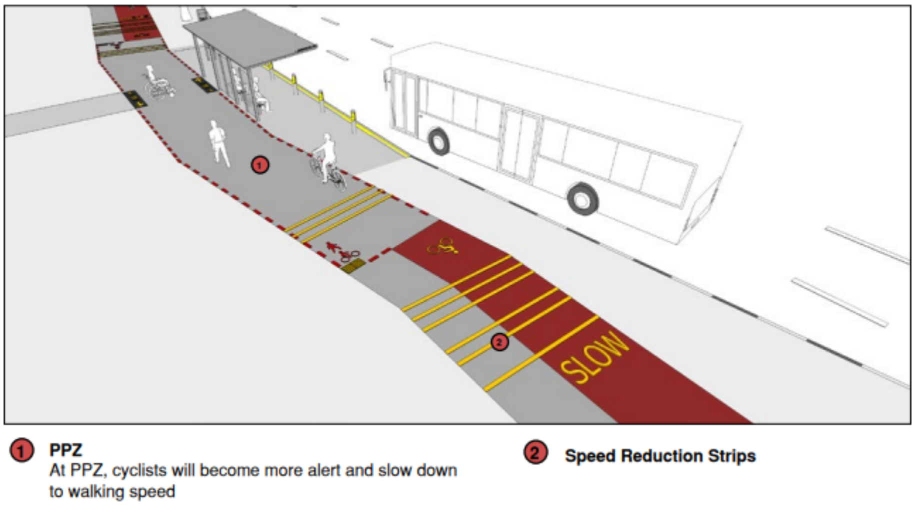


Figure 7-10 Typical Bus Bays

7.6 Recommendations

AASCTF recommends that the local government, builds on the findings, learnings, and recommendations from documented in the above case studies towards the implementation of sustainable and accessible

[11] https://www.lta.gov.sg/content/ltagov/en/industry_innovations/industry_matters/development_construction_resources/walking_cycling_plan.html.

transport infrastructure. To ensure that the micro-simulation model developed by the AASCTF is able to meaningfully inform and enable the City to address GEDSI needs and opportunities, the following specific actions are recommended as a primary focus, and which tie into the reasonable extrapolation of the model.

1. Ramboll can test specific interventions like introduction of a signalized crossing at an intersection with specific modelling of a zebra crossing that can help the differently abled.
2. Specific wait times at bus stops for considering the access time of differently abled can be modelled for an identified bus route.

But to make the efforts more streamlined to actionable points from Green Transport Master plan, it is recommended to the City authorities to suggest specific proposals that are expected to be implemented as per the Green Transport Master plan.

8. VISSIM TRAINING

This chapter summarizes the details on micro-simulation modelling.

8.1 Training Scope

The scope of micro-simulation modelling covers the aspect of dynamic assignment with which the AM and PM models are created. The VISSIM training will be carried out in the last week of February 2024 in Penang.

The use of Dynamic Traffic Assignment (DTA) in transportation modeling is an emerging analysis approach around the world. The benefits of applying DTA in transportation analysis increase with network size and level of congestion. The major benefit of using DTA is the capability of the modeling method to take into account the spatial and temporal effects of congestion in determining route choice, time of departure choice, and mode choice. DTA is suitable for analyses involving incidents, construction zones, Active Transportation and Demand Management (ATDM) strategies, Integrated Corridor Management (ICM) strategies, Intelligent Transportation Systems (ITS), and other operational strategies, as well as capacity increasing strategies.

The training will cover the following major components:

- Discuss the principles of DTA's abstract network
- Explore the principles of Vissim's destination and route choice methods
- Insert travel demand elements; zones, matrices, zone connectors, nodes
- Apply DTA calibration techniques
- Discuss and apply assignment convergence techniques

Table 8-1 VISSIM Training Participants List

No.	Name	Organization	Email
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8.2 Model Handover

The Stage 2 model also covering Stage 1 scope VISSIM model developed by Ramboll will be handed over to MBPP for further usage.

This training will demonstrate how to successfully apply DTA models. These methods include recommended approaches to model building, calibration, and alternatives analysis. The intended audiences for this guidebook include the following:

- Practitioners: Applying DTA requires skills and knowledge in many types of transportation modeling. An understanding of travel demand models and meso- and microsimulation is required in addition to an understanding of DTA. This guidebook assumes that practitioners have some background in these areas.

- Program Managers: The intent of this guidebook is to provide direction on how to apply DTA. Research on the level of effort to apply DTA was not part of this effort; however, a program manager reading this document may gain a better appreciation for the effort that goes into DTA modeling, the types and amount of data that should be collected, and the types of modeling software tools that should be used.

9. SUMMARY

This report comprises a compilation of all activities during the Penang Micro-Simulation Task Order. Throughout the process the AASCTF team has worked with Majlis Bandaraya Pulau Pinang (MBPP) and Digital Penang to show the process and benefits of Micro-simulation modelling to advance transportation planning, evaluation and decision making. The use cases in this report present only a small subset of all possible applications of Micro-Simulation for Penang. With this training and investment the AASCTF team hope to see a continued us of Micro-simulation in Penang to enable sustainable and informed transport planning decisions that improve the mobility environment for all residents and visitors to Georgetown.

Microsimulation Modelling for Penang has aimed to encourage sustainable and equitable improvement to the transportation environment by testing scenarios where congestion could be reduced, safety could be improved, public transport usage would increase, as well as scenarios that would overall be better for pedestrians and cyclists in Georgetown.

Key to the ongoing sustainment and use of micro-simulation modelling in Penang is the integration of its use in business-as-usual practices for the evaluation of transportation planning options as well as impact assessments and approvals. This report has outlined some options for how this could be included. We encourage the MBPP team who now possess the skills to develop and evaluate micro-simulation models use this tool to test improvements to the network, to engage with stakeholders using the visualization outputs and ultimately to then implement well informed proposals on the network that have garnered the approval of stakeholders well before physical infrastructure is developed.

Scenario Testing Outcomes:

The Final Report here has described all the scenarios tested as part of Stage 1 Study Area as well as the Stage 2 extended study area covering UNESCO World heritage Area. It is important to note that bus priority measures can be implemented as tested on specific stretches. It works well with other measures being implemented simultaneously. For example, removal of on street parking as indicated by Green Transport Master Plan, Penang will go a long way addressing any congested environment along the road networks.

In addition to bus priority and parking reduction, Non-Motorized Transport scenario also works as suggested in Penang Green Transport Master Plan like modifying Lorong Love to pedestrian street and Armenian Street. Existing road traffic patterns of one-way streets helps establish rerouting origin destination points.

Acknowledgments:

The successful completion of project would not have been possible without the collective efforts, dedication, and contributions of stakeholders. We would like to acknowledge the involvement of MBPP, MBSP and Digital Penang throughout this study.

ABOUT THE ASEAN AUSTRALIA SMART CITIES TRUST FUND

The ASEAN Australia Smart Cities Trust Fund (AASCTF) assists ASEAN cities in enhancing their planning systems, service delivery, and financial management by developing and testing appropriate digital urban solutions and systems. By working with cities, AASCTF facilitates their transformation to become more livable, resilient, and inclusive, while in the process identifying scalable best and next practices to be replicated across cities in Asia and the Pacific. The Trust Fund is supported by the Government of Australia through the Department of Foreign Affairs and Trade, managed by the Asian Development Bank, and implemented by Ramboll.

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